# Study on Indoor Activity Monitoring by using Electric Field Sensor

Sosuke Tsukamoto, Hiroshi Hoshino, and Toshiyo Tamura, *Non-members*

***Abstract*—This paper describes the evaluation result of the practicability of an indoor activity monitoring system comprising electric field sensors. Three general-purpose sensor units were installed on a television set, electric fan heater, and microwave oven in an ordinary house. The usage statistics of these appliances were obtained for a period of eleven weeks. The experimental result showed that the on/off distinction of the power state was successful, and the usage information was accurately obtained.**

## I. Introduction

Recent studies have revealed that the physical and mental conditions of elderly people are reflected in their behavior. The behavioral patterns of elderly people change when they are in poor health. It is considered that these behavioral irregularities can be evaluated from information regarding the usage of home electric appliances, particularly television sets [1][2]. However, very little evidence is available in this regard since few experiments have been conducted to study this issue. Thus far, we have developed an easily/temporarily installable monitoring system comprising an electric field sensor [3]. The sensor unit detects the usage of home electric appliances by measuring the electric field strength surrounding them since most modern electric appliances produce an electromagnetic field when in operation. This system employs a wireless data communication device for transmitting the obtained data, enabling the sensor unit to be used by simply attaching it to an appliance. In this study, we have evaluated the practicability of the proposed system.

## II. Method

### A. Sensor Unit

Most electric appliances have a power transducer that comprises coils, and this produces an electromagnetic field having the same frequency as commercial electric power systems (50 or 60 Hz) that can be detected around the appliances. Even if the field strength is very weak, it is possible to measure it by amplification, and the strength varies depending on the power consumption of the appliance. Therefore, by measuring the electromagnetic field strength, we can estimate the usage of home electric appliances [3].

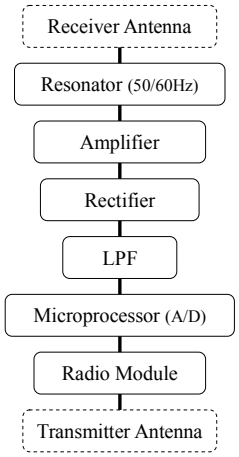



Fig. 1. Block diagram of the sensor unit.

A block diagram of the sensor unit developed in this study is shown in Fig. 1. As the first stage, the electromagnetic field of a commercial electric power system is detected by using a resonator (general-purpose sensor). The signal is then amplified, rectified, and low-pass filtered in order to determine whether the appliance is in use by means of very-low-frequency sampling. A microprocessor samples the sensor output and transmits the data through the radio module.

The sensor unit can be easily installed by end-users since it can be used by simply attaching it to an appliance. However, the unit may be inadvertently moved due to earthquakes or during cleaning, and this may change the intensity of the sensor output. Therefore, a constant threshold value cannot be used for the on/off distinction of the power state of the target appliance. Consequently, an adaptive threshold setting mechanism was employed; the threshold value $V_{th}$ for the on/off distinction was set as:

$$V_{th} = V_{low} + \frac{1}{3}(V_{high} - V_{low})$$

where $V_{low}$ and $V_{high}$ are the lowest and highest sensor outputs, respectively, of the last 10 days.

### B. Validity Study

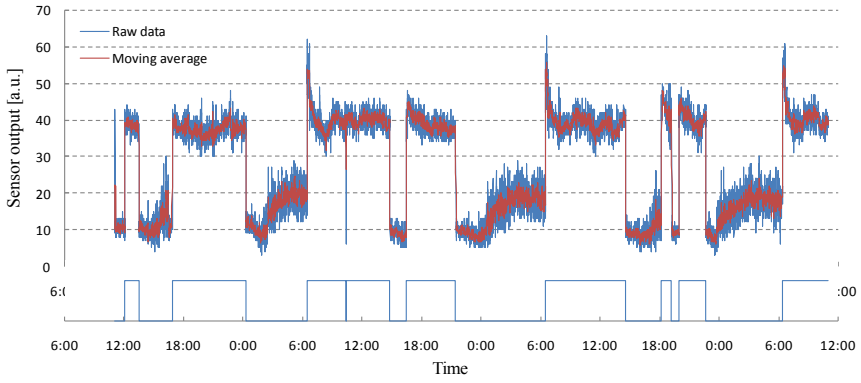
In order to confirm the validity of the proposed system, we installed it in an ordinary house. One healthy volunteer (a 56-year-old female) agreed to participate in this evaluation. Three (general-purpose) sensor units and one data logger were installed in the subject's residence. The sensor units were placed on a television set, electric fan heater, and microwave oven. The power state of the target

Manuscript received April 30, 2008. This study was supported in part by the Academic Frontier Project for Private Universities; matching fund subsidy from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan (2006–2007) (Tokyo Denki University); Grant-in-Aid for Scientific Research (16700429) from MEXT of Japan (2004–2006); Grants-in-Aid from the Ministry of Health, Labour and Welfare; the National Institute for Longevity Sciences; and the CREST project of Chiba University.

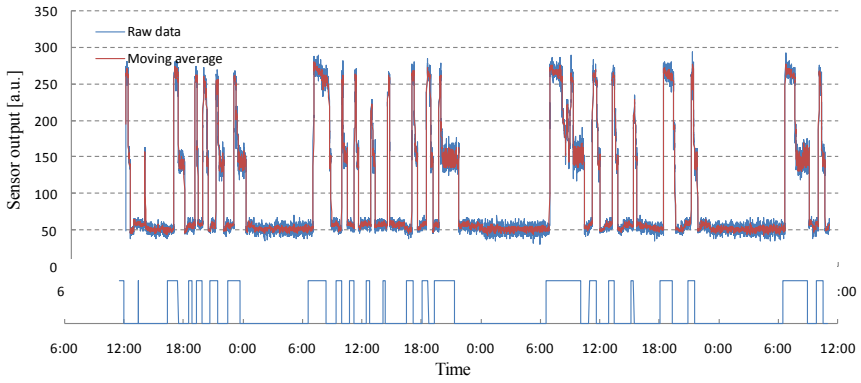
S. Tsukamoto is with the School of Science and Engineering, Tokyo Denki University, Ishizaka, Hatoyama, Hiki, Saitama 350-0394, Japan (Tel.: +81-49-296-5918, Fax: +81-49-296-6413, E-mail: tsuka@ieee.org).

H. Hoshino is with the Graduate School of Science and Engineering, Tokyo Denki University, Ishizaka, Hatoyama, Hiki, Saitama 350-0394, Japan (E-mail: hoshino@f.dendai.ac.jp).

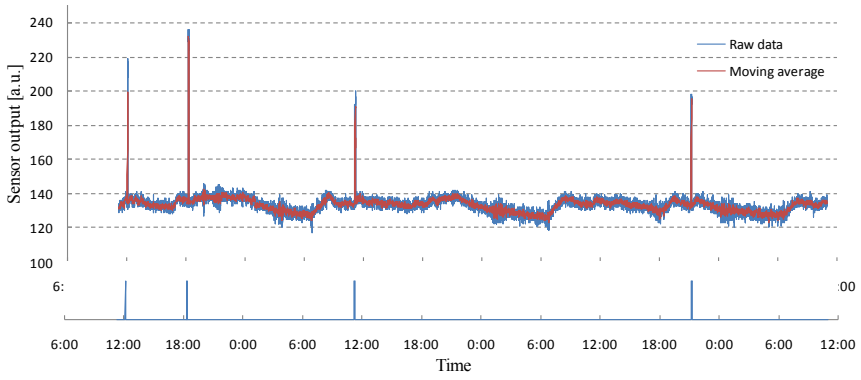
T. Tamura is with the Graduate School of Engineering, Chiba University, Yayoi 1-33, Inage, Chiba 263-8522, Japan (E-mail: tamurat@faculty.chiba-u.jp).




(a) Television set




(b) Electric fan heater




(c) Microwave oven

Fig. 2. Typical sensor outputs and the results of the power on/off distinction. The upper graph shows the obtained raw wave (blue) and the filtered data (red, five-point moving average), and the lower graph shows the result of the on/off distinction.

appliances was recorded every minute, and the usage statistics were obtained for a period of eleven weeks.

## III. Results

Figure 2 shows the typical sensor outputs obtained in this experiment and the results of the on/off distinction of the power state. In Figs. 2(a) and (c), the sensor outputs are observed to fluctuate (due to the effects of environmental noise arising from power lines laid in walls, and/or from high-tension wires near the house). Nonetheless, the on/off distinction was successful. Figure 2(b) shows two intensity levels (around 150 and 250), and the appliance appears to be powered on and off often during the day. The responses given by the subject to a questionnaire indicate that the electric fan heater was usually kept on during the day. The heater appears to be automatically and periodically powered on and off (in addition, the output power was controlled) to maintain the desired temperature. The usage duration of the microwave oven is approximately 1 to 5 min, and its usage is less than that of other appliances (Fig. 2(c)). The usage duration may vary depending on what the subject heats.

Figure 3 shows the usage history of the appliances. In a manner similar to other systems (e.g., [1][2]), a usage pattern can be clearly observed; the subject turns on the television set and the electric fan heater in the morning (at around 6 AM) and turns them off (when going to sleep) at midnight (0 AM). The usage history of the electric fan heater could not be obtained after January 15 because of a malfunction in the appliance (right-hand side of Fig. 3(b)). Unlike the usage history of the television set, the on/off switching of the electric fan heater during the day does not directly reflect the subject's indoor activities; instead, it

reflects the atmospheric temperature of the room. In addition, unlike the television set and electric fan heater, the usage ("on") timing of the microwave oven is not fixed; the oven was mainly used before noon and at around 8 PM (Fig. 3(c)).

The usage statistics of these three home electric appliances are shown in Figs. 4 and 5. From this result, we can also estimate that the subject usually wakes up at around 6 AM and then turns on the television set and the electric fan heater. This is consistent with the responses given by the subject to the questionnaire. The higher correlation (~0.87) between the usage statistics of the television set and electric fan heater also indicates that the usage of home electric appliances reflect the subject's indoor activities. The usage rate of the microwave oven is very low as compared to that of other appliances because it usually turns off automatically in a few minutes. In other words, even if the subject usually uses the microwave oven for preparing meals, unless the timing of turning on the microwave oven is the same (an accuracy of the order of minutes in this experiment), the on-timings scatter. If we include such short-time-usage appliances for the later analysis, we may have to introduce methods such as the decoding of PDM (pulse density modulation) signals.

## IV. Discussions

In this experiment, we used a general-purpose sensor for the television set, although we have developed appliance-specific (television) sensors. The obtained signal was faint relative to that in the other appliances; however, the on/off distinction was successful. In order to confirm whether we can unify the sensor with a general-purpose sensor, we must conduct more experiments in different houses.

The frequent on/off switching of the electric fan heater after around 10 AM does not reflect the subject's indoor activities (Fig. 3(b)). The heater was kept on during the day; however, it controls its own power automatically in order to maintain the temperature of the room. This phenomenon will occur in all electric/electronic appliances that control their own power (e.g., notebook computer, electric pot). However, the first "on" timing in the morning reflects the time the subject awakens.

A periodicity is also observed in the usage timing of the microwave oven (Figs. 3(c) and 4); however, the precise timing does not have any important meaning. In addition, the pattern may easily and suddenly change when traveling, entertaining guests at home, and so on. Therefore, we are now developing an algorithm that analyzes the global patterns and trends in the timings of events (e.g., waking up, sleeping, meal times, etc.) to relate them to the health of a subject.

The subject sometimes left the house on Sundays, and also left on Thursdays to buy foodstuffs at around 10 AM. However, except for the fact that the usage rate of the appliances on Sunday is relatively low, a clear weekly periodicity was not found in this experiment (Fig. 5). Long-term data acquisition is necessary to clearly identify the weekly periodicity.

Thus far, we have focused on the usage statistics of home electric appliances; a sensor that measure the power (current) consumed by a target appliance was introduced to the Welfare Techno-House Mizusawa in Japan in 1998 (e.g., [4][5]). The current detector was used as a part of the lifeline sensor system, and the sensor was installed on a television set; here, the problem faced was how to analyze the obtained data. The solution proposed by Nambu et al. [1] and that described in the literature [2] can be considered as one of the applications of the sensor with the Connected Home technology.

The information obtained by the sensor unit developed in this study is similar to that detected by the current detector;

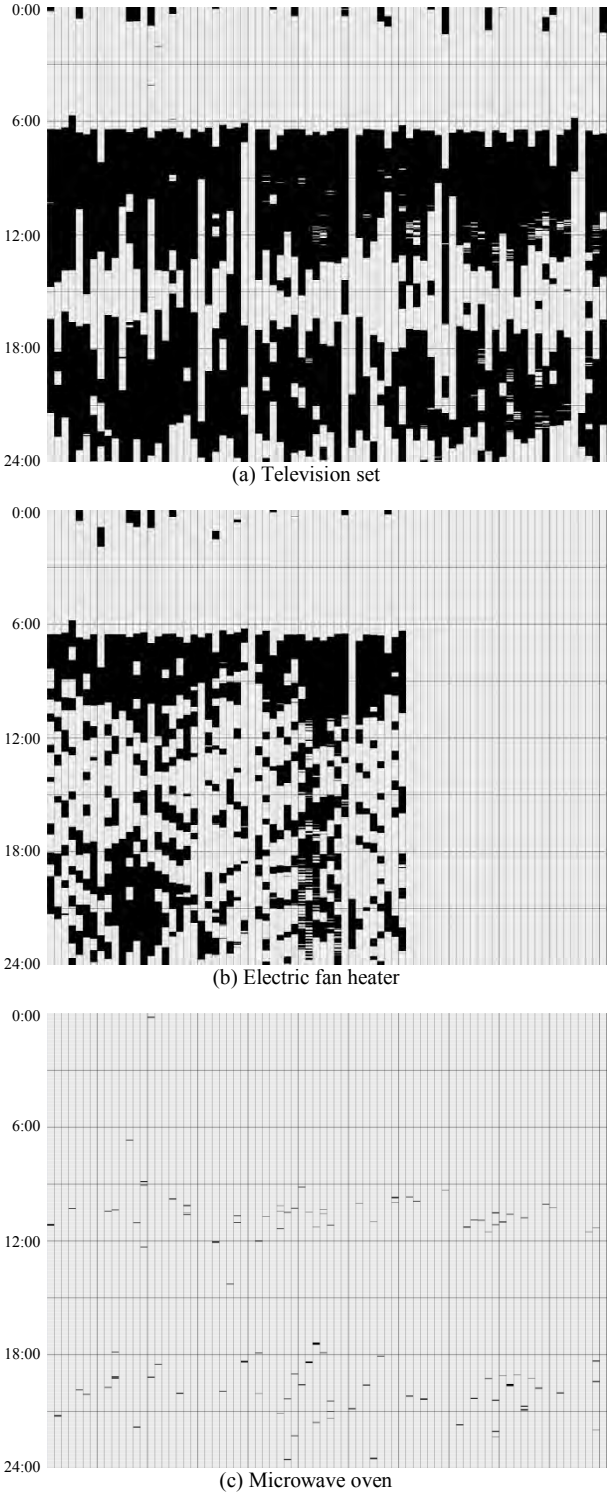



Fig. 3. Usage history of the home electric appliances. The horizontal axis represents the date (left: November 25, 2007; right: February 10, 2008). The black square implies that the appliance is in use (power on state) at the given time.

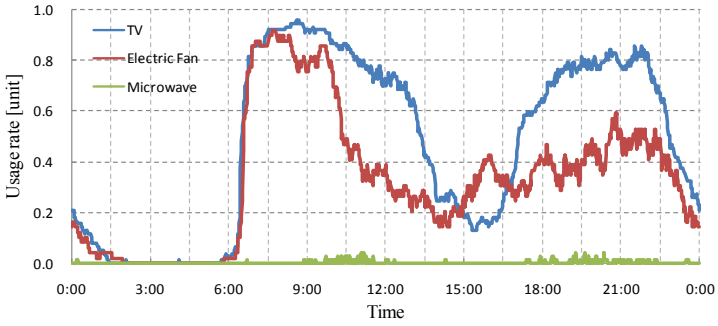
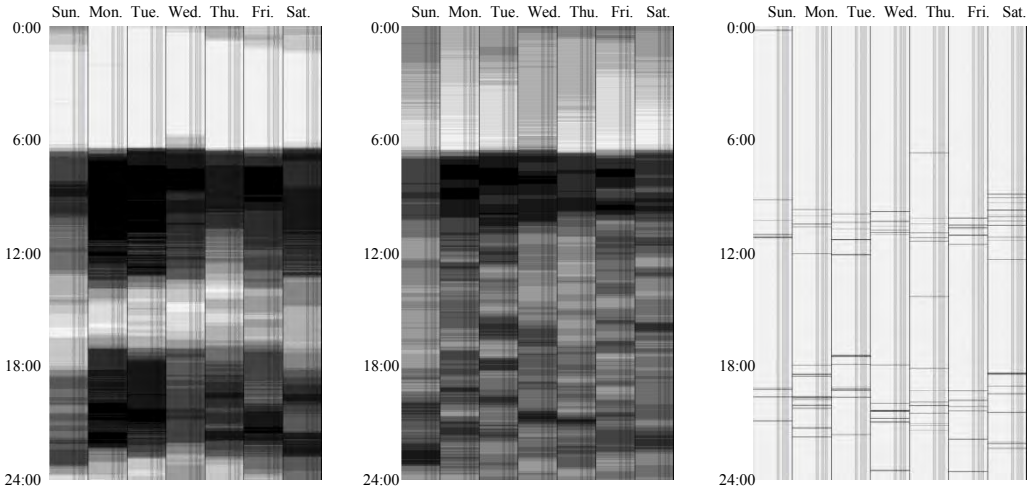



Fig. 4. Usage statistics of home electric appliances (entire period).




(a) Television set (b) Electric fan heater (c) Microwave oven

Fig. 5. Weekly usage statistics of home electric appliances.

therefore, if the sensor is installed only on a television set, the system becomes the same as that described in literatures [1][2], and the analysis method used in both literatures may be applied.

The sensor unit developed in this study can be used with almost all home electric appliances [3]. A current-detector-type sensor such as a clamp meter requires access to the power cable; however, the proposed system can be used by simply attaching it to an appliance and more units can be easily added since the usage information is gathered wirelessly. If the sensor is added to a cooking appliance (e.g., microwave oven, rice cooker, electric pot, etc.), we can estimate the time when a subject has a meal.

## V. Conclusion

A behavioral monitoring system that focuses on the activity of home electric appliances by detecting the electric field strength surrounding them was evaluated in an ordinary house. The experimental results suggest that the proposed system will be useful for monitoring the usage of home electric appliances. In future studies, we will evaluate whether or not the sensor circuit can be unified with a general-purpose sensor, and develop a method for analyzing the obtained data.

## Acknowledgment

The authors are grateful to Mr. Yoshinori Akabane, Mr. Noriyuki Kameda, and Mr. Takeshi Matsumoto for their technical support.

## References

[1] M. Nambu, K. Nakajima, M. Noshiro, and T. Tamura, "An algorithm for the automatic detection of health conditions," *IEEE Eng Med Biol Mag.*, vol. 24, no. 4, pp. 38–42, 2005.

[2] K. Nakajima, A. Kamiya, H. Matsui, D. Oikawa, K. Fujita, Y. Higashi, T. Tamura, T. Fujimoto, and K. Sasaki, "Development of a television-use telemonitoring system for elderly daycare-recipients living alone," *J. Robotics and Mechatoronics*, vol. 19, no. 6, pp. 683–690, 2007.

[3] S. Tsukamoto, H. Hoshino, and T. Tamura, "Easily installable wireless behavioral monitoring system with electric field sensor for ordinary houses," *The Open Medical Informatics J.*, vol. 2, pp. 49–57, 2008.

[4] S. Otake, M. Ogawa, R. Suzuki, T. Izutsu, and T. Iwaya, "Developing of the monitoring system for single living elderly in welfare techno house Mizusawa," *Lifesupport*, vol. 13, no. 4, pp. 26–33, 2002. *(in Japanese)*

[5] M. Ogawa, R. Suzuki, S. Otake, T. Izutsu, T. Iwaya, and T. Togawa, "Long term remote behavioral monitoring of elderly by using sensors installed in ordinary houses," *Proc. of 2nd Annu. Int. IEEE-EMBS Special Topic Conf. on Microtechnologies in Med. and Biol.*, pp. 322–325, 2002.