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Abnormality Detection of Persons Living Alone Using Daily Life Patterns Obtained from Sensors

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***Abstract*—**In this research, the goal was construction of a system by which multiple sensors were used to observe the daily life behavior of persons living alone (while respecting their privacy), using this information to judge such conditions as bad physical condition or falling in the home, etc., so that these abnormal conditions can be made known to relatives and third parties. The daily life patterns of persons living alone are expressed by the number of responses of sensors each time that a set time period has elapsed. By comparing data for the prior two weeks, it was possible to judge a situation as "normal" when the person was in good physical condition or as "abnormal" when the person was in bad physical condition.

***Keywords*—** Sensors, Elderly living alone, Abnormality detection, Lifestyle habit.

I. INTRODUCTION

IN Japan, which is increasingly faced with an aging society, survey reports showed that 23% of the total population was age 65 or over as of 2010, with about 24% of that number living alone in one-person households [1]. In such a situation, about 76% of persons aged 65 or over living alone in Tokyo die in their homes [2], so that unattended deaths have become a social issue [3].This is a problem common to all nations and has led to investigations on measurement of sounds conducted by the body and physical condition [4], [5], communication via TV with persons living alone [6], [7], medical care service support [8], [9], etc.

In consideration of this situation, this research involved construction of a system by which multiple sensors were used to observe the daily life behavior of persons living alone (while respecting their privacy), using this information to judge such conditions as bad physical condition or falling in the home, etc., so that these abnormal conditions can be made known to relatives and third parties [10]. As their method, the authors proposed focusing on differences in the daily life patterns of persons living alone to obtain daily life patterns in a normal condition and compare those patterns to judge abnormal conditions. The daily life patterns in a healthy condition were compiled by obtaining the number of responses per set time period for the past two weeks from the obtained sensor responses. This data was compared with present data to carry out investigations on how to judge abnormal conditions.

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II. SUMMARY OF EXPERIMENT

The experiment was conducted in the room of a person living alone. Fig. 1 shows an overview of the room where the experiment was conducted and the positions of the sensors. The installed sensors included: IR sensors (body detectors) in entrance and living room, lighting sensor, door opening/closing sensor, remote control sensor and sound sensors. All sensors, with the exception of the remote control sensor, were located near the ceiling out of considerations that the sensors should not impair the daily life of the subject. The responses of the sensors were obtained at sampling times of 10 seconds.

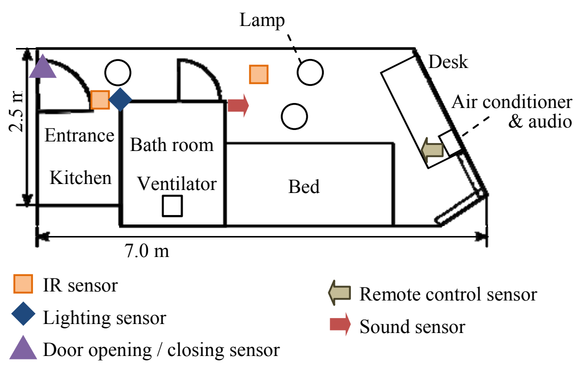


Fig. 1 The room layout and installation location of the sensors

The body detectors are pyroelectric infrared sensors. The sensitivity wavelength is 1μ-20μm. The lighting sensor is a Si photo-diode with a sensitivity wavelength of 480n-660nm and a peak sensitivity wavelength of 550nm. The door opening /closing detection sensor is a combination of lead switch and a permanent magnet. The remote control sensor is a PIN photodiode with a peak sensitivity wavelength of 940nm and a demodulation frequency of 38 kHz. The sound is an electret condenser microphone with frequency characteristics of 70-15 kHz and a sensitivity of -32.5dBV. Under these conditions, data was obtained when the subject was in good physical condition and when the person was resting in bad physical condition after catching a cold.

III. OBTAINING DAILY LIFE PATTERNS

Fig. 2 shows the responses of the individual sensors. Part (a) is data for when the subject was in good physical condition, and part (b) is data for when the subject was in bad physical condition. The outputs are expressed by the body detector in the living room, the body detector in the entrance, lighting, whether the person was in a room or not, remote control operation and acoustic signals. Whether the person was in a room or not was judged by means of a combination of the body detector in the entrance and the door opening/closing sensor. During the time the subject was in good physical condition in (a), the person was in bed from 12 midnight to 7:20 AM and from 10:30 PM to 12 midnight. The body detector in the living room sensed and reacted when the subject turned over in bed. However, there was no sensor reaction from the body detector in the entrance, the lighting sensor, the remote control sensor or the sound sensor. In the period from 7:20 AM to 8:50 AM the person had already gotten up from bed. Together with the body detector in the living room, there was a response from the remote control sensor. Because the subject went to the entrance at 8:50 AM to leave the house, there was a response from the body detectors in the living room and entrance. The subject was away from home from 8:50 AM to 7:10 PM, so that there was no response from any of the sensors.

After the subject returned home at 7:10 PM, all of the sensors responded. Because the subject went to bed at 10:30 PM, there was detection of when the person turned over in bed. Otherwise there was no response from the sensors. Meanwhile, when the person was in bad physical condition as shown in part (b), the person was in bed from 1:30 PM to 9:30 PM and from 11 PM to midnight. Although there was a response from the body detector in the living room, there was no response from any of other sensors. When the subject was in good physical condition, on the other hand, during the period from 9 AM from 7 PM, when the person was often away from home, responses from the sensors could be seen because the person had refrained from leaving the apartment. Nevertheless, during the period from 2 PM to 2:30 PM, because the person had left the apartment to go shopping, there was no response from any of the sensors. In the period starting at 2:30 PM, immediately after returning home, up to 11:10 PM, the subject repeated irregular behavior that included daily actions as well as lying down in bed, so that there were responses from all the sensors.

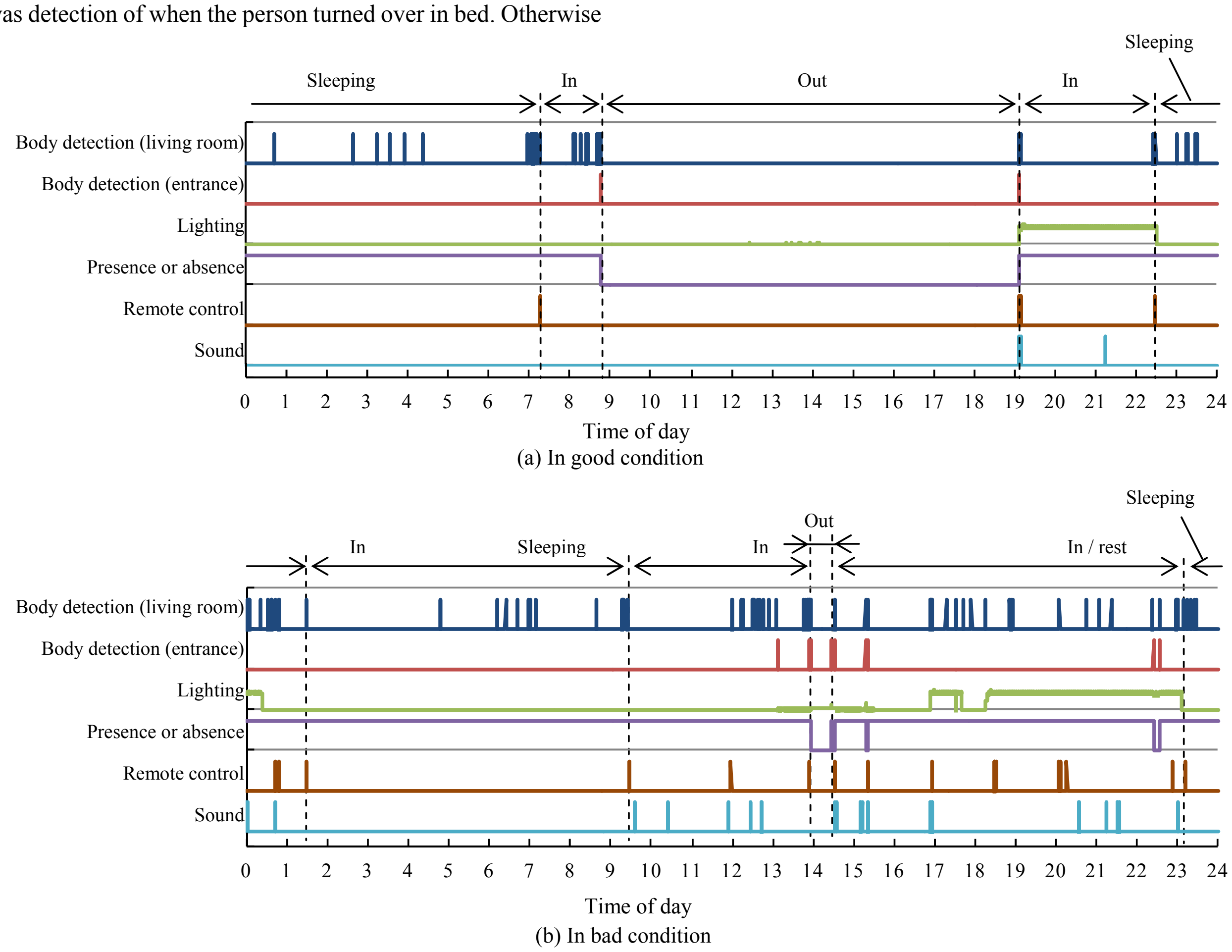


Fig. 2 Output response of each sensor

IV. Analysis Methods

The daily life patterns in a normal condition of the subject (person living alone) were compiled by referring to the data for the past two weeks prior to the date of carrying out judgment.

Judgment on whether the subject was in a normal or abnormal condition was carried out by comparing data for one day each of when the person was in good condition and in bad condition. When the person was in bad condition, the bad physical condition was sensed by the person in the period from 2 PM to midnight. The daily life patterns when the person was in normal condition were compiled by obtaining the average values for number of responses every ten minutes for data that was obtained at the same time for the preceding two-week period. This was used as basic data. The data for when the person was in bad physical condition was compiled by obtaining the number of responses every ten minutes using data for the same time as when the basic data was compiled. Judgment of abnormality was carried out by obtaining the extent of difference with the basic data. By means of this method, since it differs from the standard value by which a difference value became large, it was considered “abnormal.” Conversely, the smaller difference value, the more the condition was considered “normal.”

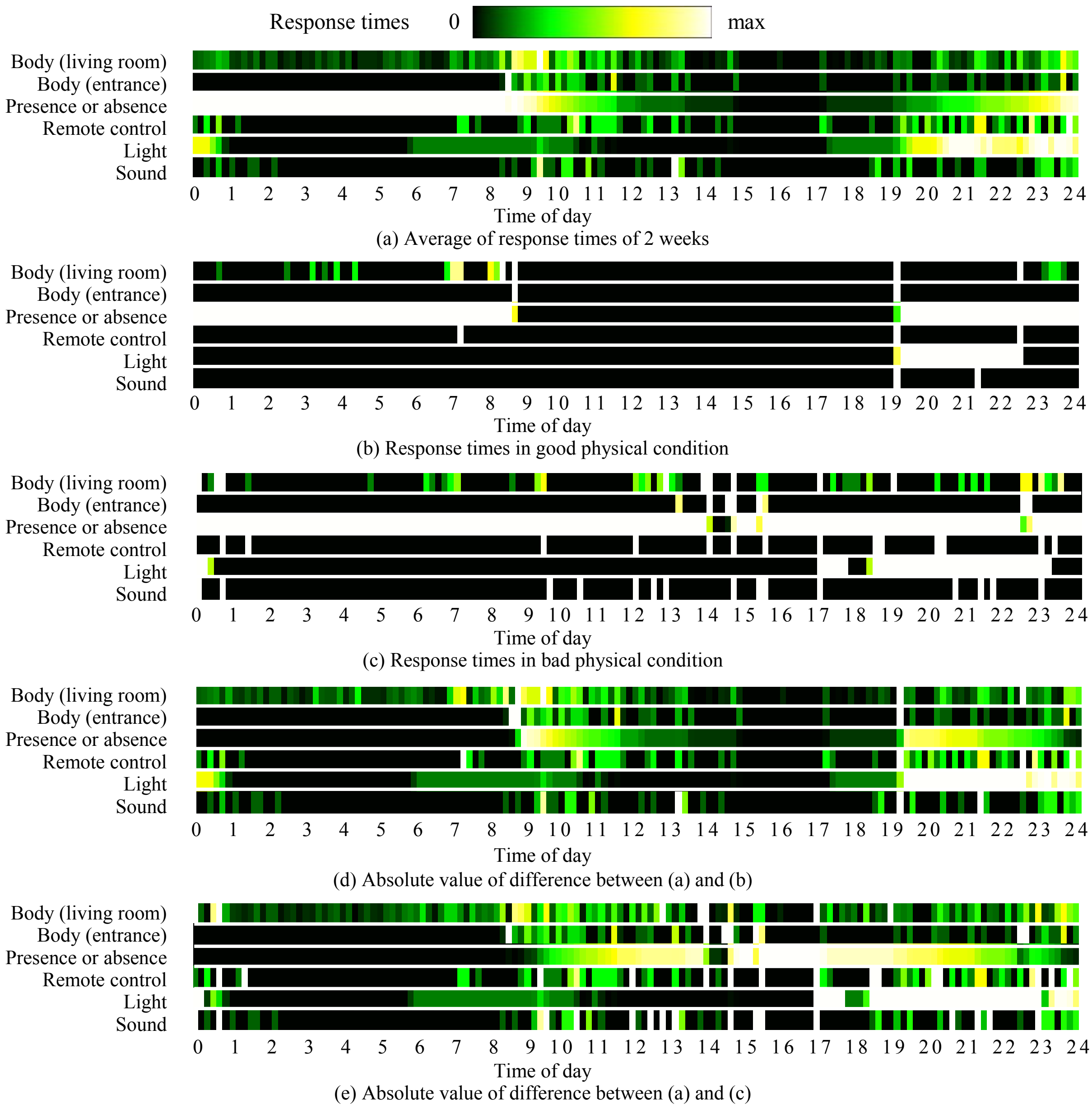
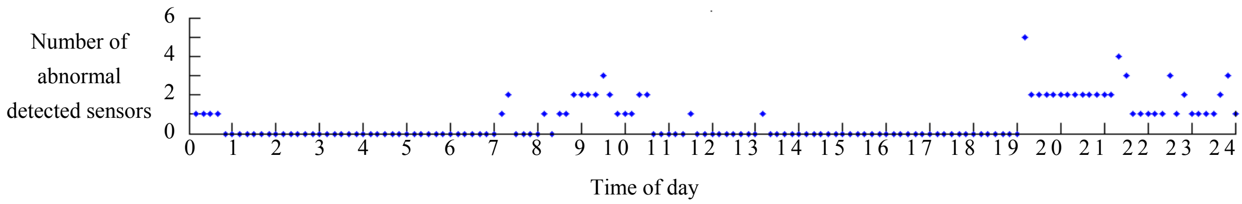


Fig. 3 Response times

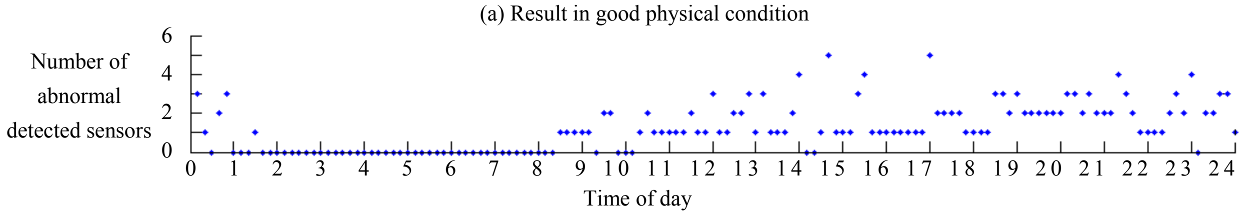
V. Results Of Experiment and Analysis

Fig. 3 lists the number of responses for the various data with different colors. Black indicates when there was no response. White indicates when there were many responses. Fig. 3 (a) is the average value of the number of responses for the two-week period, which is considered the basic data. Fig. 3 (b) shows the number of responses for when the subject was in good physical condition. Fig. 3 (c) shows the number of responses for when the person was in bad physical condition. Fig. 3 (d) is the absolute value of Figs. 3 (a), (b). Fig. 3 (e) is the absolute value of Figs. 3 (a), (c). These are the respective number of responses for the body detector in the living room, the body detector in the entrance, detection of whether the person was in the room or not, detection of remote control operation, detection of lighting on/off, and sound detection. The dark and light areas have been normalized as based on the average value for the number of responses during a two-week period for the various sensors. As for Fig. 3 (d), which is the period when the subject was in good physical condition, because the average value for the two-week period and the daily life pattern are similar, the values for the differences are on the whole small. However, in the case of Fig. 3 (e), which is the period when the subject was in bad physical condition, because the daily life pattern differs from the average values for the two-week period, we can see that there are places for which the difference value is large. This being the case, the cases where the difference value exceeded 0.5 were considered as being "different from normal." Fig. 4 shows the values of the sensors for times that are judged normal. For Fig. 3 (a), which is the period when the subject was in good physical condition, the number of sensors for which it was judged differing from the norm for periods other than between 8 and 11 AM or 7 to 9 PM, was 2 or less. For Fig. 3 (b), which is the period when the subject was in bad physical condition, the number of sensors for which there was a judgment of differing from the norm in the long periods from midnight to 1 AM and 9 AM to midnight, was 2 or more. Particularly in the case of when the subject, in differing from the norm, refrained from going outside and rested in the apartment, we can see that a large number of sensors judged a situation differing from the norm in that period from 2 PM to 6 PM.

However, because differences are obtained in a simple manner with the above methods, there were many cases where, even when the subject was in good physical condition, it was judged as differing from the norm, which means there were large discrepancies. The reason why it was judged as differing from the norm even when the person was in good physical condition could be that the time at which the person returned home was irregular regarding the period from 8 to 11 AM, when the person was away from home, and the period from 7 PM to 9 PM. For this reason, judgment of an abnormal condition was done by considering the time factor. In Figs. 3 (a) and (b), the irregular time period for a condition of being at home regarding the times when the person was out and when the person had returned was a maximum of 150 minutes. As for the number of responses for when the person was in good physical condition or in bad physical condition (Figs. 3 (b) and (c)), this was determined by obtaining the average value for the past 150 minutes. Fig. 5 shows the number of sensors that judged "differing from the norm" when the average values for the past 150 minutes were obtained. When the person was in good physical condition, the number of sensors that judged "differing from the norm" only for the time 10:50 PM were two or more. For other times, the figure was one or less. On the other hand, when the person was in bad physical condition, the number of sensors judging as "differing from the norm" were two or more for the periods from 1 AM to 2 AM and from 1 PM to midnight. Particularly in the period from 2 PM to 10 PM, when the bad physical condition was felt by the subject, there were a large number of sensors judging as "differing from the norm." For this reason, a case in which two or more sensors judged a situation as "differing from the norm" was judged to be "abnormal." Fig. 6 shows the results of those investigations. When the person was in good physical condition, there was only one case of a judgment of abnormal only at 10.50 PM. Other than that, it was judged as "normal," which means that a normal daily life could be carried out. When the person was in bad physical condition, the time period in which the subject personally felt that the condition was bad was judged continuously as "abnormal," so that this can be considered the result of bad physical condition.

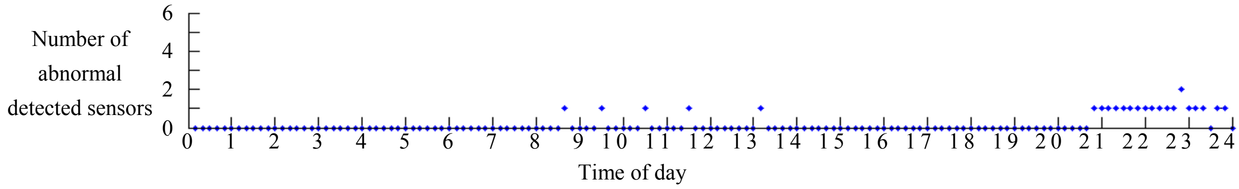


(a) Result in good physical condition

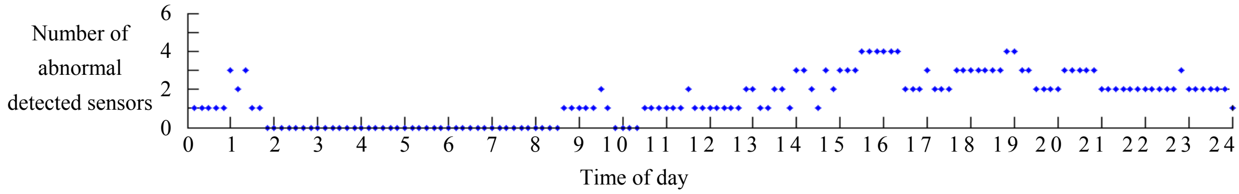


(b) Result in bad physical condition

Fig. 4 Number of abnormal detected sensors

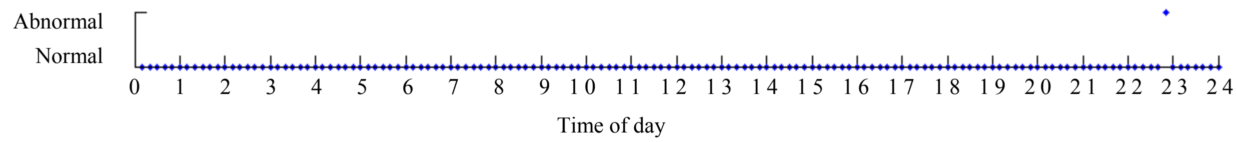


(a) Result in good physical condition

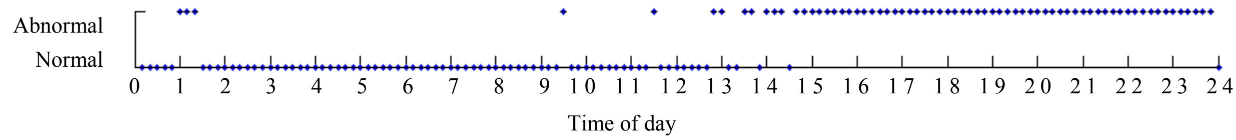


(b) Result in bad physical condition

Fig. 5 Number of abnormal detected sensors with moving average



(a) Result in good physical condition



(b) Result in bad physical condition

Fig. 6 Detection of normal or abnormal

VI. Conclusion

To distinguish abnormal states of persons living alone, attention was focused on living habits to carry out investigations that involved obtaining daily life patterns from multiple sensor responses. The normal daily life pattern was expressed in terms of the number of sensor responses for set times in data for the past two weeks. These patterns were compared for the times when the person was in good physical condition and the times when the person was in bad physical condition and in bed after catching a cold. Results show that the time when the person was in good physical condition was judged as “normal” and the time when the person was in bad physical condition was judged as “abnormal.” Because this was in agreement with the time period in which the bad physical condition was felt by the subject, it was possible to confirm the effectiveness of the proposed method.

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