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Odor Sensing Characteristics in Residential Space Using Metal-Oxide Sensors

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Various odors are generated in an indoor environment. It is necessary to know the kinds and grades of odors in order to recognize patterns of behavior in the daily life of a resident. In this study, four kinds of odor sensors are adopted, all of which are the metal oxide type. The daily behavior of the resident is recognized and understood using sensor-output characteristics. A sensor unit, which consists of four odor sensors, is installed in the residence. Twelve sensor units are set up at various points. Opening and shutting a door, taking a meal and sleeping can be identified as behavior based on the sensor characteristics. A running spectrum-method, which is a kind of frequency analysis, is used to identify the operation of an air-conditioner. The spectrum has a high frequency component at meal times. The aim of this system is to construct a surveying system for the aged individual living alone as a part of a welfare system.

1. Introduction

The aged population is rapidly increasing in Japan. It is estimated that the number of people over 65 years old will constitute 27% of the population in the year 2020. This phenomenon is remarkably noticable in rural districts and secluded places in the mountains. The fees for medical treatment and nursing care for the aged are also increasing, and a self-governing body may experience severe financial difficulties under the heavy burden of the costs of services. It is important to solve these problems using new social systems and to improve social security. It is also necessary to decrease the number of people requiring care and nursing by using an engineering system, and to derive a new social system and economical system from interdisciplinary research.

An experimental residence for the aged is built as a model and various daily periodical patterns in their behavior are examined to identify whether these patterns are typical or not. It is possible to know a person's pattern of living using an odor sensing system.[1] The number of times the toilet is used, eating breakfast, lunch and supper, and taking a bath and so on are examined to survey daily life of the aged .[2] The purpose of this study is to understand the aged person's lifestyle using odor sensors and to construct an odor sensor system for the healthcare system. Human beings generate various odors as vital signs and various air polluting gases,[3] for instance, while preparing a meal, eating the meal and heating a room. Odor sensors have a high reliability and stability, and are adopted in gas leakage detectors installed in residences.[4] Odor is a gas. The kinds and the concentrations of the generated odors depend on the resident's behavior. Namely, the sensor is able to identify the behaviors of the aged using an odor sensing system. The system can also diminish the infringement of privacy of the resident more than systems using infrared detectors or microphones.

In this study, sensor units composed of four types of odor sensors are installed at twelve points in a residence. The output characteristics of the sensors are analyzed by frequency analysis to recognize when the resident eats breakfast, lunch and supper.

2. System

A monitoring residence was constructed to aid in the experimental development of medical and welfare instruments and techniques for the aged. The house is subsidized by the Ministry of International Trade and Industry (MITI) of Japan. This institution is also used to create a comfortable residential environment for the aged. Another purpose is to combine various techniques for both medical-welfare treatments and care equipment. There are six working groups (WG) attached to this experimental residence. They are as follows;

(1) hardware
(2) software
(3) examining living activity
(4) equipment for health and welfare
(5) residential environment for the aged
(6) developing support instruments for the life of aged people.

This study belongs to the (2) WG, and one of the purposes of this group is to develop an odor monitoring system for recognizing living patterns of the aged resident. The outside and inside views of the house are shown in Fig. 1. The first floor is a centralized data processing room in which there are many computers and work-stations. The second floor is the residential area for the aged.

Tin oxide and zinc oxide odor sensors are employed in the system. There are four odor sensors in a sensor unit (SU). The materials and gases or odors to which each sensor has

(a)

(b)

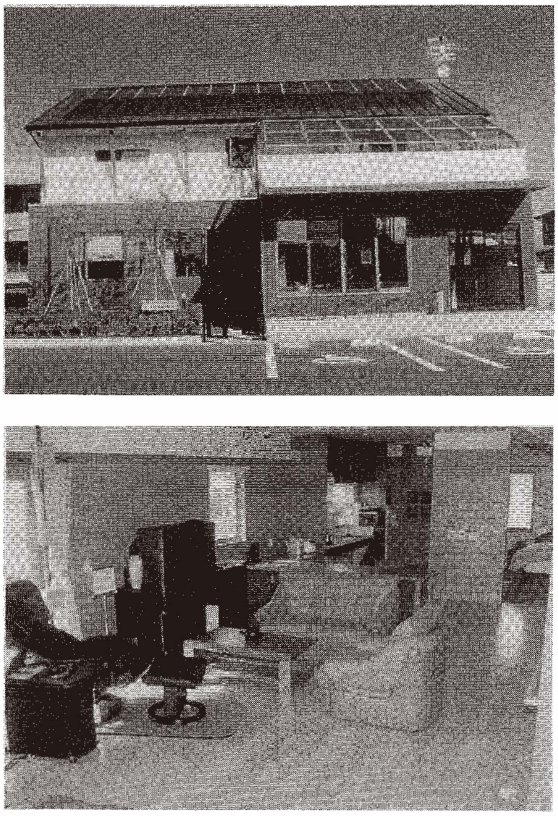


Fig. 1. Welfare-oriented experimental residence. (a) Exterior of the residence and (b) interior of the residence.

Table 1 Employed odor sensors which are fabricated by New COSMOS Inc. of Japan.

Type	Material	High sensitivity gases and odors
CH-E2	SnO_2	VOC, CH_3CHO, CH_4, alcohol
CH-E3	SnO_2	high sensitivity type for CH-E2
CH-N	SnO_2	NH_3, C_2H_5OH, CH_3OH
AET-S	ZnO_2	H_2S, CH_3SH, CH_3SCH_3, CH_3 $SSCH_3$

high sensitivity are listed in Table 1. These sensors are adopted in odor detecting apparatuses, which are manufactured by New COSMOS Inc. of Japan and are commercially available. The output of these sensors is somewhat influenced by changes in temperature. The system can, however, isolate human behavior characteristics from the sensor outputs. Humidity does not have any influence on the sensor output in the residential environment. The sensors can be used for over 5 years in an indoor environment. Many kinds of odors and gases are generated in an indoor environment. Some of them are generated from building materials, for example VOC (volatile organic compounds). Body odor also occurs in an indoor environment. The odors are due to NH_3, H_2S and CH_3SH. Therefore, four types of odor sensors are employed. There are twelve SUs in the second floor of the house, with a total of forty-eight sensors. All sensor signals are entered into a computer through a data converter and a data logger as shown in Fig. 2. The second floor plan is shown in Fig. 3. Installation points of SUs are also indicated in the figure. Each sensor signal can be sampled every 2 s, but for this study, is usually sampled once a minute. The signals are memorized on a PC card memory (PCCM) and a hard disk, and the data can be viewed over the Internet.

3. Experimental

3.1 *Odor sensor characteristics in daily life*

Odor sensors, which are made of metal oxide, do not have a high gas selectivity. The sensors are sensitive to many reducing gases and odors, and catalysts are added into the material to produce some selectivity.

Aged people prefer a barrier-free house, and most of them live in a one room residence. The scope of their activity is centered in the dining room. Therefore, the odor sensor signals in the room are influenced by their daily activities. The sensor output characteristics in the dining room of the experimental house are shown in Fig. 4(a). A door to a roof terrace was opened to the outside at 21:48 and 6:53, and all sensor outputs decreased at that time. The concentrations of the gases and odors in the indoor environ-

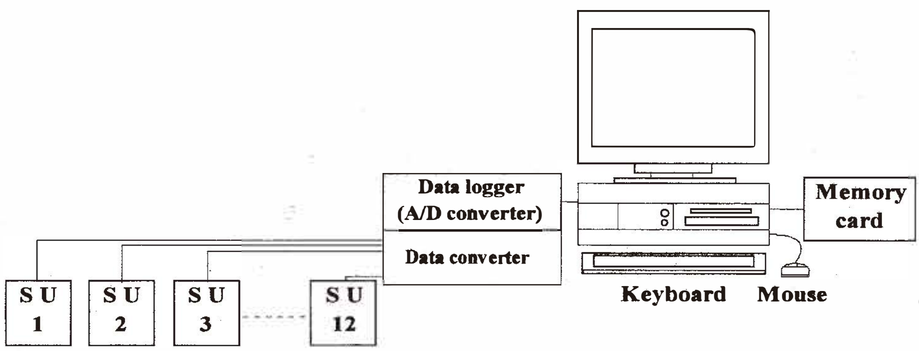


Fig. 2. Data accumulation system for odors.

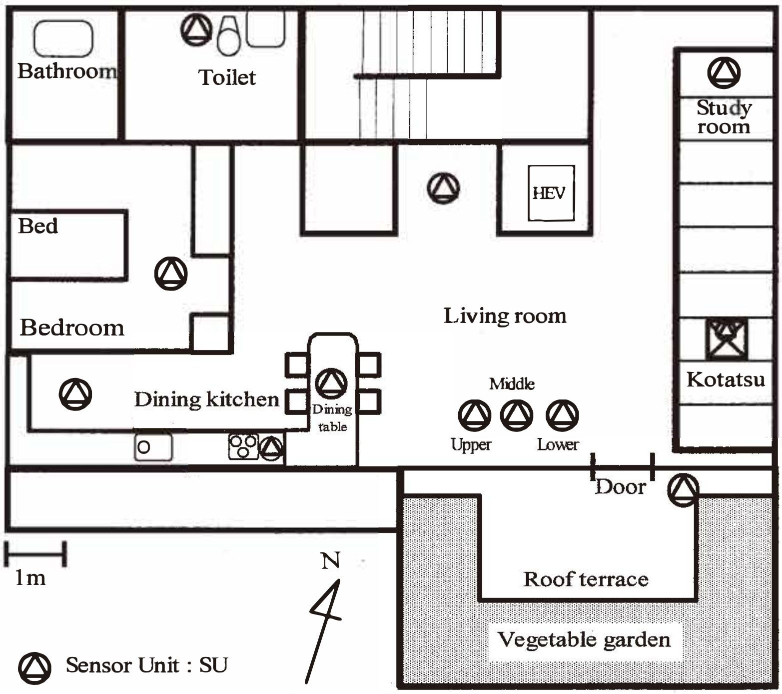


Fig. 3. Floor plan of welfare oriented residence and points of installation of SUs.

ment decrease when the door is opened. They return to their original levels when the door is closed. The behavior of the sensor outputs on the roof terrace is shown in Fig. 4(b). The sensor output characteristics increase when the door is opened. If the characteristics inside decrease and those outside increase, the door has been open. The subject ate supper at about 20:00 and afterwards washed the dishes. The characteristics fluctuate sharply when the table is prepared, a meal is eaten and the table is cleaned. These sensor output characteristics contain high frequency components. Fuel gas is not used when preparing the meal; an electromagnetic cooking apparatus is used. The air polluting gases generated with combustion do not appear. The subject awoke twice to use the restroom at 3:03 and 4:53. The sensor output characteristics barely vary at these times. The main behavior of the subject is as follows:

20:02 eats a meal, drinks tea, clears the table
21:43 opens door after clearing the table
22:21 closes the door
0:23 switches air-conditioner off (it had been operating all the time)
6:53 rises and opens the door
7:53 closes the door
8:03 breakfast (without cooking)

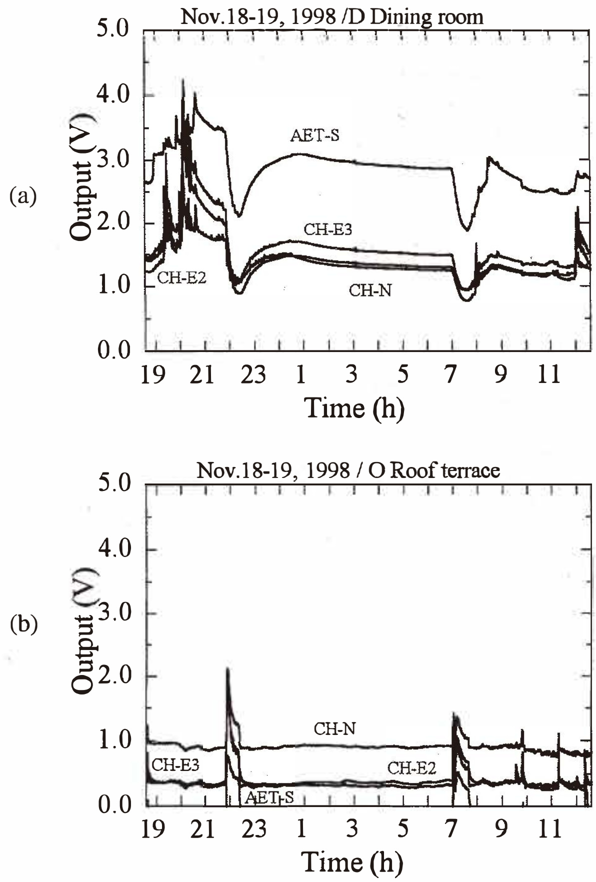
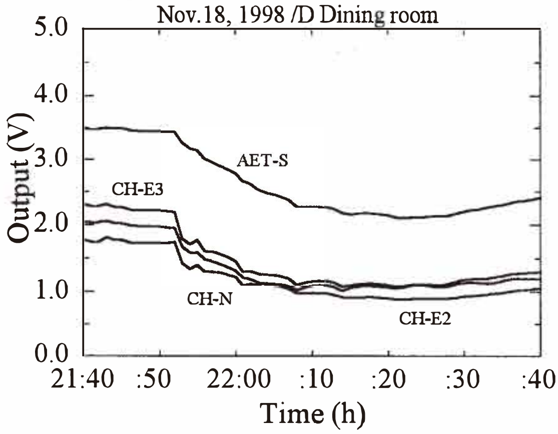


Fig. 4 Sensor output characteristics in the dining room and roof terrace. (a) In the dining room and (b) on the roof terrace.

8:53 clears the table
12:05 cooks and eats lunch
12:25 clears the table

A time lag occurs in Figs. 4(a) and 4(b) when the door is opened, namely, the decrease in Fig. 4(a) and the increase in Fig. 4(b) have a discrepancy of three min. This phenomenon is also shown in Figs. 5(a) and 5(b). The sensor unit in the roof terrace is installed near the door and is 5.6 m away from the sensor unit in the ceiling of the dining room. A three-min discrepancy over that distance (5.6 m) must be considered when human behaviors are interpreted. It is difficult to identify an action that is completed within only three min, because an odor molecule takes about three min to travel 5.6 m.

(a)



(b)

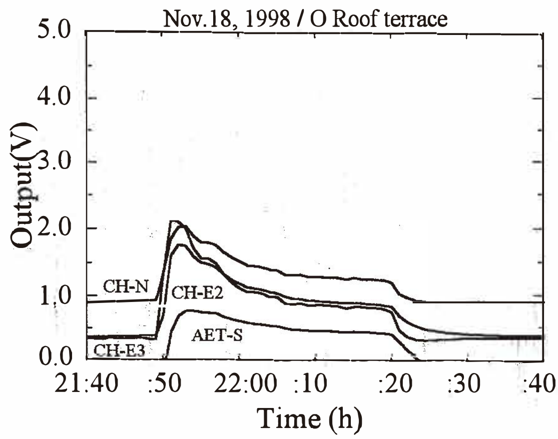


Fig. 5. Output characteristics in which the time axis of Fig. 4 is expanded. (a) In the dining room and (b) on the roof terrace.

3.2 *Frequency analysis*

The characteristics of the CH-N odor sensor in Fig. 4(a) are analyzed using the "Running Spectrum" method which is also called "Sonic Analysis."[5] The results are shown in Fig. 6. Figure 6(a) shows the original data. The horizontal axis corresponds to the passage of time. The dc component is removed in the figure. In this method, the data are divided into short periods, which are called "windows," and the analysis is applied to each window. The sampling time is 60 s and the width of the window is 64 min. Changes in frequency components are emphasised by this method. The result is indicated in Fig. 6(b). The data in Fig. 6(a) fluctuate sharply at about 20:00. The subject eats supper at that

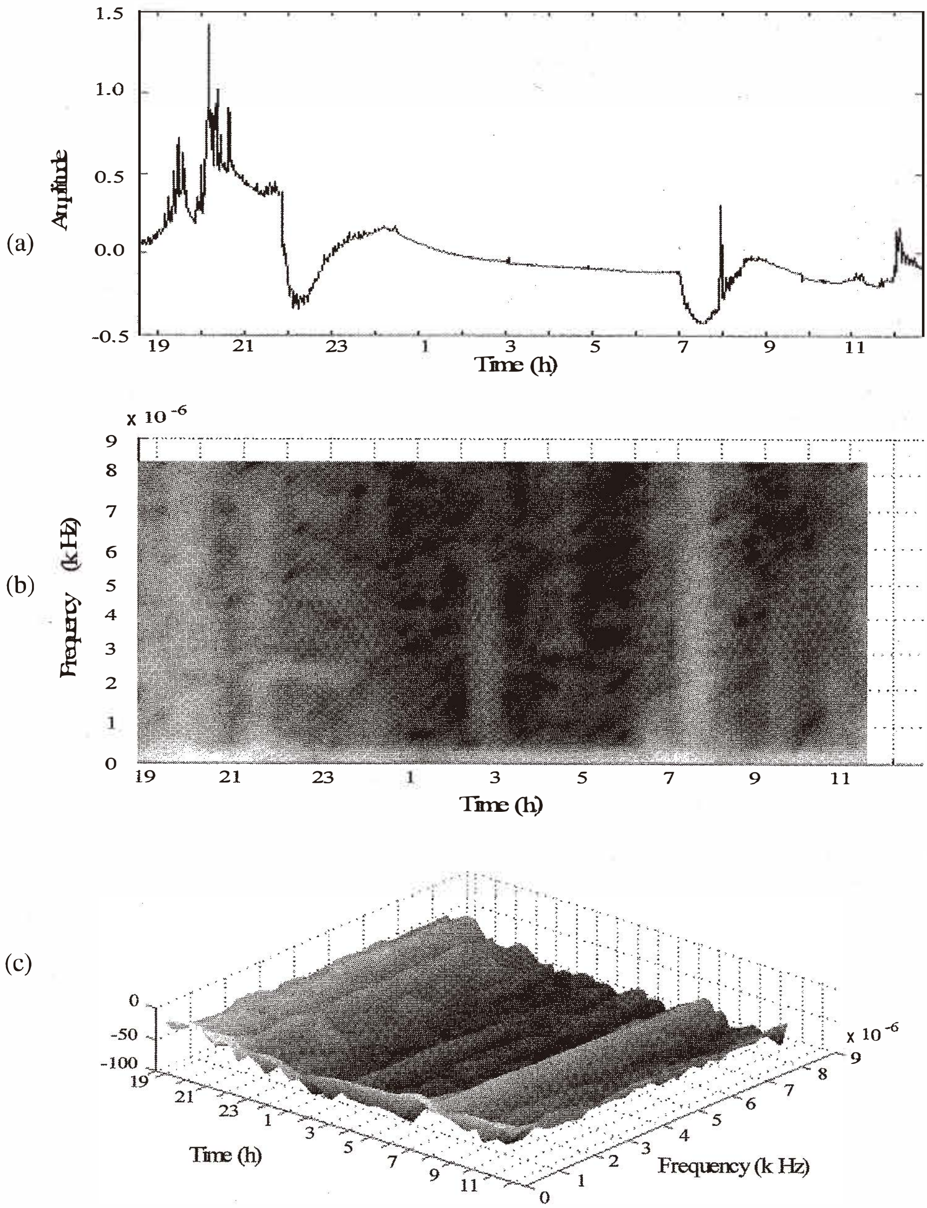


Fig. 6. Result of running spectrum analysis. (a) Output of odor sensor CH-N, (b) running spectrum in two dimensions and (c) spectrum of (b) in three dimensions.

time. The data also fluctuate at about 8:00. These phenomena are indicated by the striped patterns of light and shade in Fig. 6(b). Light patterns indicate the high frequency components. The operation of the air-conditioner is noted until 0:23, and the spectrum of the operation appears as lateral stripes. A three-dimensional graph is shown in Fig. 6(c). The vertical axis is [20*log V] and the units are decibels [dB]. The term [V] is the grade of the signal in units of volts. The top view of Fig. 6(c) is shown in Fig. 6(b). The frequency-component variation and signal amplitude as a function of time are understood from this figure.

Results of frequency analysis for outputs of four odor sensors in Fig. 4(a) are shown in Fig. 7. Figure 7(a) indicates high frequency components which exceed a period of 35 min. Figure 7(b) indicates the low frequency components below that period. The CH-E2 and

(a)

(b)

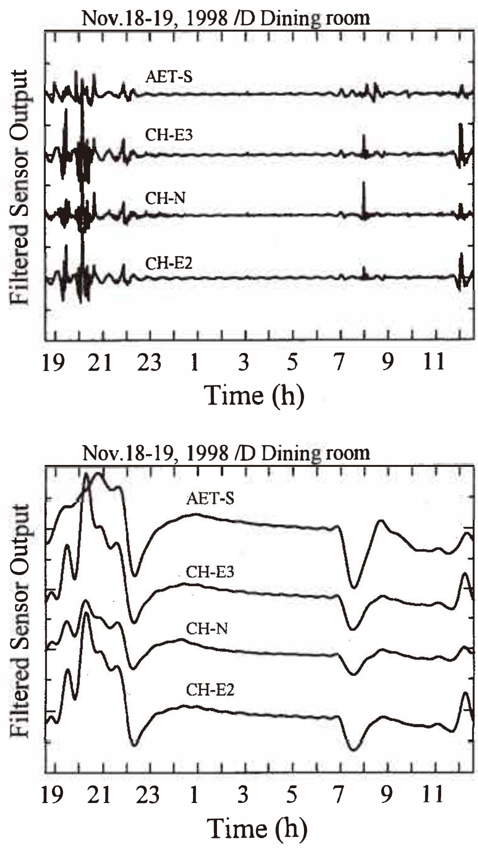


Fig. 7. Results of frequency analysis. (a) High frequency components of various sensor outputs and (b) low frequency components of various sensor outputs.

CH-E3 sensors are of the same type. Therefore, the frequency characteristics of these sensors closely resemble each other; the data from the CH-N sensor are also quite similar. All sensors are of the tin oxide type. Preparing and eating a meal as a specific behavior can be identified by observing Fig. 7(a); the impulses indicate this behavior. The impulse response includes various frequency components. A behaviour lasting for a long period, for example opening and then shutting a door after several ten minute intervals have elapsed, can be identified in Fig. 7(b). The time of eating a meal is also detectable in the figure. Of course, the dc components are removed from the figure. In Fig. 7, the four odor sensors appear to exhibit similar characteristics, but these characteristics differ subtly. In this study, we could not determine which sensor was best suited to recognize daily human behavior; hence four types of odor sensors are adopted.

3.3 *Data fusion in a three-dimensional graph*

The outputs of each CH-N odor sensor in the different locations are fused into a 3D graph. It is thought that the sensor output expresses the minute variations in human behavior. Opening and closing the door, the extent of cooking (snack, light meal or usual meal) and so on as specific behaviors can be recognised in the form of a graph. The 3D graphs are shown in Fig. 8(a) and 8(b). In Fig. 8(a), the z-axis indicates the CH-N sensor output on the roof terrace. The y-axis indicates the output in the dining room and the x-axis indicates the lapse of time. If the output on the roof terrace increases and the output in the dining room decreases, this means that the door is open. In the opposite case, it means that the door is closed. The preparation of a meal is identified when the output in the dining room exceeds a threshold value. In Fig. 8(b), the z-axis indicates the sensor output in the bedroom and the y-axis indicates the output in the dining room. The characteristics do not fluctuate in either figure while the person is asleep. It is useful to combine plural sensor outputs to identify various behaviors. Human behavior can be identified using various types of sensor-characteristic graphs. If the kind of the odor generated by a specific human behavior is known, the number of sensors can be reduced.

4. Conclusions

Four odor sensors are used to identify the daily life behaviors of an elderly person living alone. The resident generates various odors, depending on his behavior. Each behavior can be recognized by analyzing the odor sensor patterns in a residential environment, because the patterns indicate a resident's behavior. It is useful to be able to isolate various vital actions from raw odor sensor data; it is important to know whether the resident of the house is living as usual or not. Frequency analysis is effective in identifying the resident's daily behavior and the condition of the indoor environment. In this paper, the daily behavior and the data from the results are matched. Information on the daily patterns of a resident can be obtained using this odor sensor system.

More specific information to understand the patterns of human life will be obtained by adopting a filtering process, and the reliability of the recognition of various behavior will increase. This system is effective in the field of care and nursing for the aged.

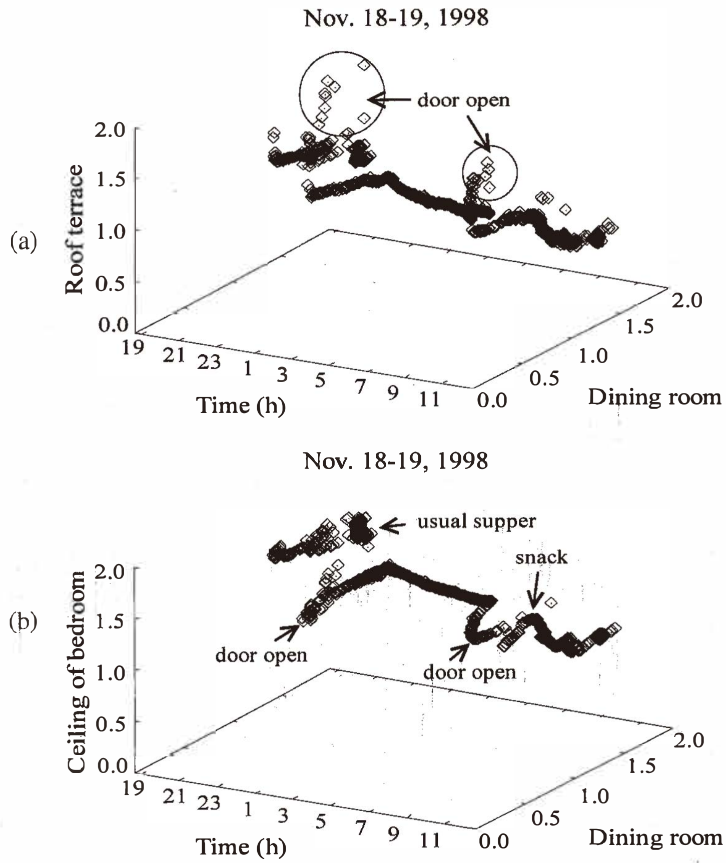


Fig. 8. The correlation between the sensor outputs in two different locations as a function of time. (a) Relationship of sensor outputs in dining room and roof terrace and (b) relationship of sensor outputs in dining room and ceiling of the bedroom.

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