Paper

Identification of Meal-degree for Aged Living in Solitude using Odor Sensors

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Gas and odor sensors have been used in various fields, for example detection of environmental pollution, safety and quality controls in the food industry and identification of various human behaviors in a residence. Many kinds of odors occur according to human behavior. The analysis of odor characteristics has been carried out. The main odors which occur in a residence are as follows: namely odors of meal preparation, excretion, perfume and body odors. Life patterns of an elderly person in solitude can be grasped roughly by analyzing the odor sensor characteristics. Taking meals and excretion are important vital actions to human beings. The actions can be known by identifying the odors.

This study attempts to identify a meal-degree, which means the kinds of meals taken, for example a light meal, a fried meal or a meal cooked by oneself. Various kinds of odor molecules occur at every meal and the sensor patterns vary. Meal-degree can be, therefore, understood by odor sensor patterns and it is also able to give the aged some suggestions about his health care according to long-term characteristics of plural odor sensors. As for the results, the number of responded sensors are few in a light meal and the sensor-grade is also small. In contrast with this matter, all of the installed sensors respond to fried or cooked meals, and the response grade is higher than a light meal.

Keywords: Odor sensor, Sensory system, Pattern recognition, Principal component analysis, Meal odor

1. Introduction

In Japan, the number of people over 65 years old has reached the population of 16.2% in 1998. Japan is faced with an aging society. The rate of elderly persons in solitude is about 12.3% of the aged. And about 80% of the solitude aged are women. This rate is fairly higher than the men's rate. This means that women have a longer life. Generally, the aged women are used to preparing meals in their houses. It is useful to identify a meal-degree (light, medium, heavy) and to know whether the elderly occupant has a meal as usual, and how it is graded. Namely, it is necessary to construct a surveying system which judges how the occupant prepares meals and lives. In the early stage, the authors had studied about extraction of drive signal for the apparatus[(1)~(3)] and indoor-air pollutants in the residential space[(4)]. This study was done to identify human behavior using odor sensors in the view of indoor-environment[(5),(6)] and to constract a part of a recognition system for the patterns of human life for the aged who live in solitude.

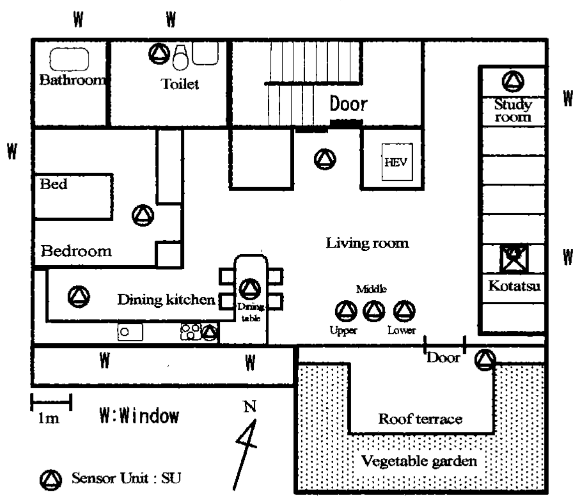

Fig.1 Floor plan of welfare oriented residence and installation points of SUs.

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 of CH-E2
CH-N	SnO_2	NH_3, C_2H_5OH, CH_3OH
AET-S	ZnO	H_2S, CH_3SH, CH_3SCH_3, CH_3SSCH_3

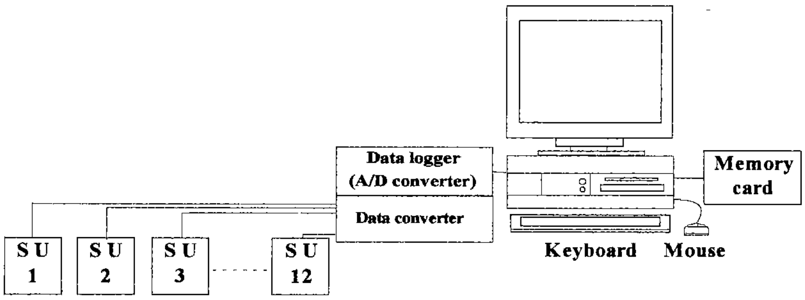

Fig.2 Data accumulating system for odors.

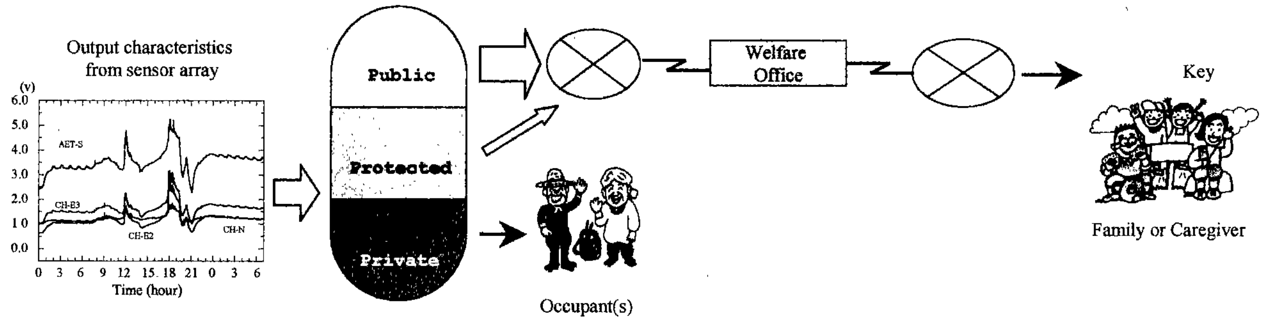

Fig.3 Recognition system of human behaviors which are grouped into three classes.

2. System and grouping for human behaviors

2.1 System

Monitoring was done in a house which was subsidized by the Ministry of International Trade and Industry (MITI) of Japan[5]. The floor plan is shown in Fig.1. A sensor unit (SU) consists of four odor sensors[6]. Twelve SUs were installed at various points in the house. The materials and gases or odors to which each sensor has high sensitivity are listed in Table 1. The system consists of a data converter for odor sensors, a data logger for converting A/D signals from the data converter and software for collecting the data. The data accumulating system is shown in Fig.2. Each sensor signal can be sampled every two seconds, but for this study, it is usually sampled once a minute. These signals are recorded onto a hard disk and a PC card memory (PCCM) for safety and for ease of hand-carrying the data.

2.2 Grouping for human behaviors

Individuals have various behaviors in their daily life. Typical patterns are recognized in normal life, but there are differences among the occupants. If these behaviors are watched every moment, most the aged will refuse the system. This system proposes to group human behaviors into three classes. Namely, "private" are the behaviors only the person himself wants to grasp, "protected" behaviors are the data offered to family or caregivers, "public" behaviors are the data opened to a person in charge of a general welfare office. Using this network, it is possible to survey the houses for the solitude efficiently and consider the resident's privacy.

An outline of the system is shown in Fig.3. The behavior is decided by opinions of the person himself, the caregiver and the family, and whether it can be open or not. In this study, human behaviors are classified into three classes. An example of the

Table 2 An example of grouping for human behaviors.

Public	Protected	Private
･Bedtime and awakening	･Number of trips to lavatory	･Characteristics of lavatory use
･Number of meals and menu	･Feces or Urine	
･Sleeping characteristics		
･Presence or absence of excretion		
･Opened or closed window		

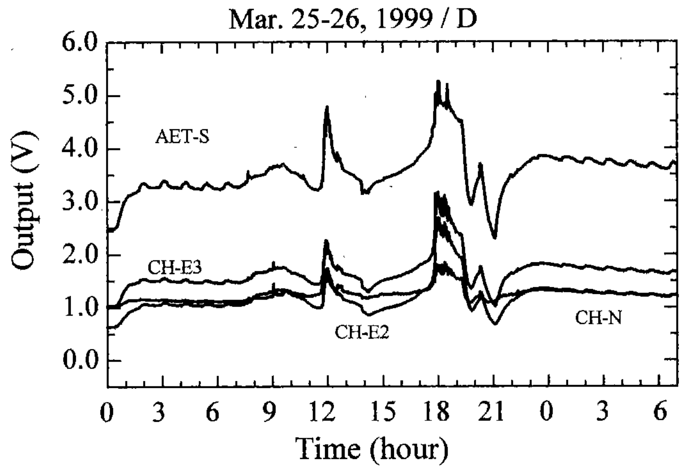

Fig.4 Sensor output characteristics in the dining room.

grouping is shown in Table 2. The information is collected by a welfare office using a telecommunication line. It is possible to view the processed information through the Internet.

3. Odor sensor pattern

3.1 Sensor output pattern

Cooking meals and eating them at home is referred as "*Uchishoku*". Eating something like rice-balls which are purchased at convenience stores is called "*Nakashoku*". Taking a meal outside is called "*Sotoshoku*". Many kinds of odors occur according to the food cooked. In this study, we try to identify whether a meal which is prepared at home is light work, medium or heavy such as fried cooking. Odor sensor patterns were measured in three different seasons: November 1998, March 1999 and July 1999. The subject had breakfast, lunch and supper in each experiment. The sensor output characteristics in the ceiling of the dining room are shown in Fig.4. From these characteristics, the grade of sensor response during each meal is evaluated as follows. The range of individual fluctuation (F_r) of sensor outputs during meal-time is derived by the following equation.

Range of individual fluctuation (F_r) = Maximum output (o_{max}) – Minimum output (o_{min}) (1)

Meal-time means the interval during the meal preparation to clean the table. The range for all fluctuation (F_{all}) of each sensor for 9 meals in November, March and July is derived by the following equation.

Range for all fluctuation (F_{all}) = Maximum value of F_r ($F_{r\text{-}max}$) – Minimum value of F_r ($F_{r\text{-}min}$) (2)

The range for all fluctuation (F_{all}) is divided into three equal parts. The part in which each F_r belongs is examined. If the value of F_r belongs to the lower part, the point is 1. In the case of middle part, the point is 2. The point becomes 3 in the higher part. This result is shown in Table 3. The result of CH-E3 is the same as CH-E2, because CH-E3 is a high sensitivity type for CH-E2. Therefore, the analysis for CH-E2 is omitted. The points are symbolized (△:1,○:2,◎:3) for ease of understanding in Table 3. The number of the point column is summed up the point of CH-E3, CH-N and AET-S for each meal. Therefore, the value of the points are from 3 to 9. The meal which obtains 3 or 4 points is a light meal, like a rice-ball or bread which are looked upon as "*Nakashoku*". The subject cooked curry and rice for supper in July, and the meal-degree is indicated at a somewhat low point because the window beside the dining table had been slightly opened. Both curry and rice for lunch in March and ham and eggs for breakfast

Table3 Odor sensor sensitivities for every meal.

		CH-E3	CH-N	AET-S	Points	Notes
Nov. 18-19	breakfast	△	△	○	4	rice-balls
	lunch	○	△	△	4	curry noodle
	supper	◎	◎	◎	9	pork soup, omelet, wine
Mar. 25-26	breakfast	△	△	△	3	pastries, green tea
	lunch	△	○	◎	6	curry and rice
	supper	○	○	◎	7	pot stickers, omelet, miso soup
Jul. 9-11	breakfast	○	◎	△	6	ham and eggs, miso soup, rice
	lunch	△	△	△	3	rice-balls, miso soup
	supper	△	△	○	4	curry and rice
△ : 1 ○ : 2 ◎ : 3						

in July have 6 points and they are medium meals. Supper in March consisted of pot stickers ("*gyoza*") and omelets, which were cooked using oil, so the point indicates somewhat of a heavy-meal. The values of all sensor-fluctuations (F_r) are large for supper in November. This indicates quite a heavy meal.

3.2 Principal component analysis

It is thought that the odor generated from meals in residential space effects on not only the dining room and kitchen but also other rooms. It is considered that the living room is especially effected, because there is no partition between the dining room and the living room. A stand is set up in the living room in which three SUs are installed at lower, middle and upper positions. The sensor output characteristics at the lower position which is 70 cm from the floor are shown in Fig.5. The range of fluctuation is smaller than the dining room, however it exhibits similar characteristics.

CH-E3 sensor signals were mainly analyzed. The results which are plotted with the sensor characteristics in the dining room and the living room are shown in Fig.6. CH-E3 sensor outputs for each meal in March are plotted. The vertical axis means in the dining room and the horizontal axis means in the living room. The arrows represent time passage. The sensor outputs at breakfast do not fluctuate largely. The characteristics in the dining room at lunch fluctuate fairly, however the living room is effected hardly. The sensor outputs in the dining room at supper increase at the start of taking meal, and then those of the living room fluctuates. It can be understood how the odor molecules diffuse in the dining room and the living room. It seems that the moving directions and domains of the plots in Fig.6 can be a clue to identify the kind of meals. The sensor outputs in the study room where is apart from the kitchen are shown in Fig.7. The characteristics are also similar

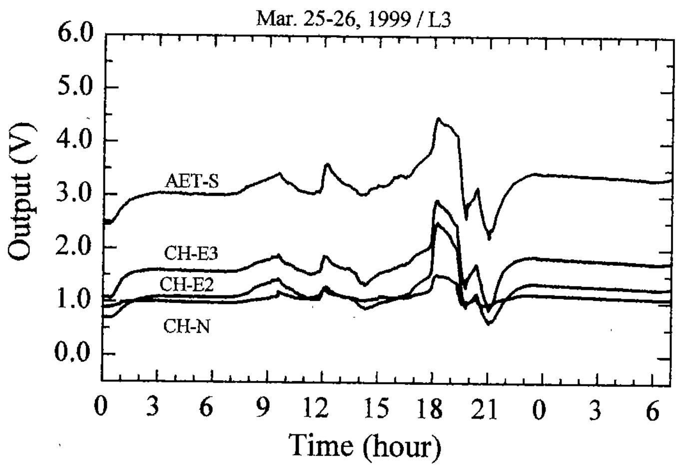

Fig.5 Sensor output characteristics at the lower position in the living room.

to the dining room. The odor diffuses in the residential space. Moreover, the sensor output in the study room delays 4 minutes than those in the dining room.

In this manner, it is useful to fuse with the sensor outputs at plural points for identification of the meal-degree. Therefore, CH-E3 sensor outputs in the dining room and the living room are analyzed by principal component analysis (PCA). The results are shown in Fig.8. The range of individual fluctuation (F_r) is calculated by equation (1) is used as the data for PCA. The contribution percentage of PC1 is 93.3%, PC2 is 6.7%. PC1 is derived by the following equation.

$$z1=0.898x1+0.439x2 \quad (3)$$

PC2 is derived by the following equation.

$$z2=-0.439x1+0.898x2 \quad (4)$$

$x1$ means F_r of the dining room. $x2$ means F_r of the living room. Therefore, the meal-degree can be decided by PC1. The light meals for breakfast in March (bread), in November (rice-balls) and lunch in July (rice-balls) are low points of less than –0.5. The meals for lunch in March and supper in July were curry and rice. PC1s for the meals are about -0.3. Lunch in November (curry noodle) also shows a same value. The results indicate that supper in March (pot stickers, omelet) and breakfast in July (ham and eggs) are quite heavy, and supper in November (pork soup, omelet, wine) is extremely heavy. These results are very similar to those of Table 3. It is thought that the result of PCA corresponds to the sense of human beings. Table 3 which is indicated by the score is, however, easier to understand.

It can be recognized that the grades of PCA in November and March had increased in following order, namely breakfast, lunch and supper. This pattern is indicated in Fig.8. This tendency represents one of the eating patterns of the occupant. The grade in July had increased in order of the kinds of meals on the axis of PC2, namely breakfast, lunch and supper. The value of PC2 is higher as the sensor outputs in the dining room becomes lower and those of the living room becomes higher. It is thought that PC2 represents an odor flow, namely from higher position in the dining room to lower position in the living room. Supper in July is

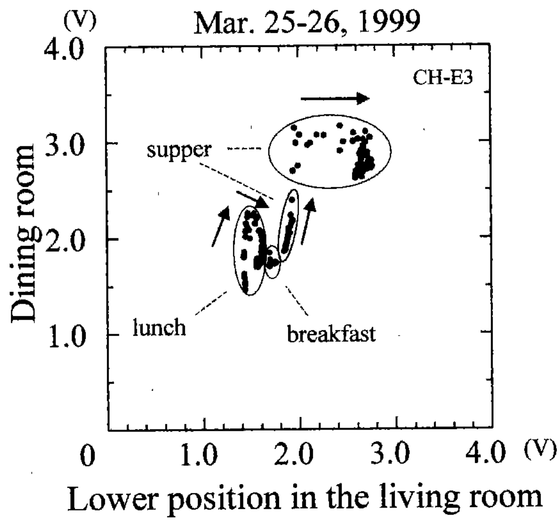

Fig.6 CH-E3 output relations between dining room and lower position in the living room for each meal.

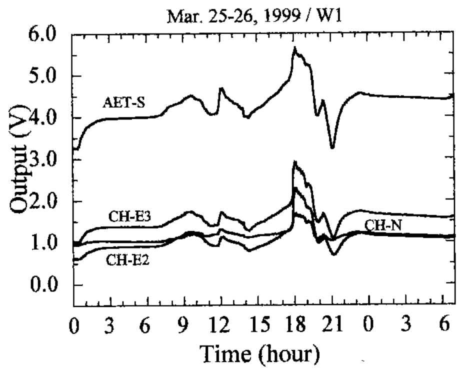

Fig.7 Sensor output characteristics in the study room.

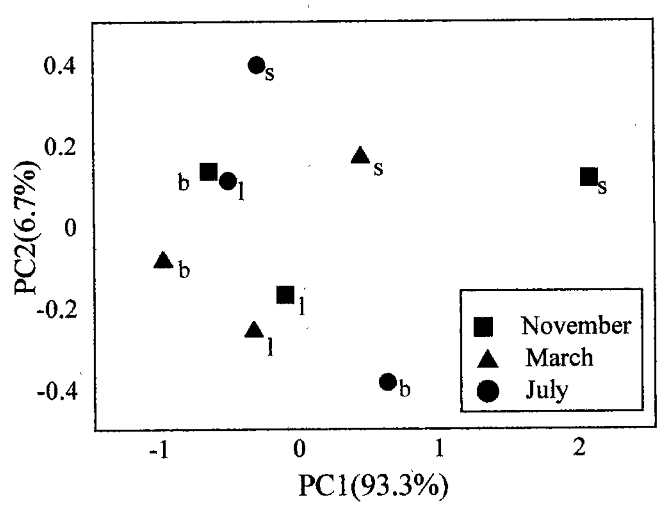

Fig.8 Principal component analysis of each meal.

plotted at higher position on PC2. An odor component flew toward the living room because the window beside the dining table had been slightly opened. It is also considered that the odor molecules did not flow toward the ceiling. It is possible to identify meal-degree by surveying the odor-sensor outputs at the plural points. PCA was done by sensor outputs at higher and lower positions in the residential space. As for the result, PCA method is useful to analyze occupant's behaviors in an indoor environment and more effective information could be obtained.

4. Conclusion

The analysis for the odor sensor outputs is done in order to identify the meal-degree in a house for the aged. The results which are similar to the sense of human beings are obtained using the scores and PCA. One of the eating patterns can be recognized using PCA. It is possible to know whether the elderly occupant lives as usual using this pattern. Namely, if it is recognized the differences among the patterns for a few days compared with usual pattern, it seems that an accident occurs in the occupant life. It is also able to give them some suggestions about their health care. The experiment and the data analysis using the outputs of plural sensors will be continued for identifying the kinds of meals in the future. The moving directions and domains can be a clue to identify the kinds of meals. Moreover, it will be necessary to analyze the meal-degree using the pattern.

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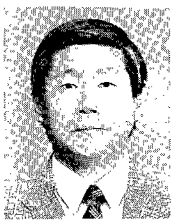

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