Olfactory Measurement Method at Health checkup with Olfactory Display using Pulse Ejection

Aya Fukasawa†, and Ken-ichi Okada‡

†Graduate School of Science and Technology, Keio University, Kanagawa, Japan
‡Faculty of Science and Technology, Keio University, Yokohama, Japan
{fukasawa, okada}@mos.ics.keio.ac.jp

Abstract - A decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. Thus, from a medical point of view, understanding the condition of the olfactory system is important. However, unlike sight and hearing, olfaction is not examined at a regular health checkup. Because scents linger in the air and measurements require a great deal of care and time. In this study, we construct olfactory measurement method for health checkups. We use inkjet olfactory display. Thus, pulse ejection for scent presentation is able to minimize odor elimination. Measurement algorithm uses binary search. Therefore, we can measure the detection threshold at 192 levels in total by changing the number of stimultaneous ejections and ejection time. For measurement result, we can quantify the detection threshold. Furthermore, only 5 min is needed to measure the detection thresholds. From this knowledge, measurement time, burdens on the patient and operator and problem such as odor elimination were cleared up so that olfactory measurement in health checkups is expected to work out in the future.

Keywords: olfactory display, olfactory characteristics, pulse ejection, interface application, medical check

1 INTRODUCTION

Olfaction is used to detect dangers such as rotten food and gas leaks. Moreover, a decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. If we detect it, the possibility of the recovery is increased. Thus, from a medical point of view, understanding the condition of the olfactory system is important. The predominant measurement method for olfaction is Toyota and Takagi (T&T) olfactometry and venous olfactory test. However, unlike sight and hearing, olfaction is not examined at a regular health checkup. Because these methods have some problems.

The health checkup is the health care service that local government and health insurance union provides publicly. It is mainly carried out by schools, and having a health checkup is needed once a year. In health checkup, various measurements including body measurement, eye exams are performed in a mass. Moreover, the measurement is carried out for hundreds of people per day. However, in current olfactory checks, it takes a great deal of care and time. On the other hand, health checkup is carried out in a gymnasium and classrooms as schools, so same people have to be measured at a time in the place where there is not enou-gh ventilation. In olfactory check, it is necessary to pay adequate attention not to fill a room with scent. However, if olfactory measurement is carried out, scented paper and bags filled with scents are used in each olfactory check, and a considerable amount of waste which is scented is generated. So, scent is scattered in the room. From the viewpoint of these, existing olfactory examinations are difficult to carry out at health checkup. Hence olfactory examinations are not standard in health checkups today.

In this study, we construct olfactory measurement method using olfactory display which can control scents precisely enough to be used in olfactory measurement. For the measurement, we use olfactory display by using a technique based on an inkjet printer mechanism. It uses pulse ejection for scent presentation so that we can measure without diffusion of scent. However, human olfactory characteristics to pulse ejection are unknown. So, in this study, we measure it as a trial.

2 MEDICAL KNOWLEDGE

2.1 Disease about Olfaction

Alzheimer's and Parkinson's disease occupy approximately 60% of dementia in Japan and are generally well known[1]. Alzheimer is easy to be mistaken for forgetfulness, and the early detection is difficult. However, here is the risk becoming too late if discovery becomes late. Patients with these disease have risk that olfactory impairment is caused[2]. About lower respiratory infection and inflammatory disease in stage of old age, etiology is discussed in relation to rhinosinusitis. Checking the condition of the olfactory system leads to early detection of disease such as Alzheimer[3].

2.2 Existing Olfactory Examinations

To discover whether any olfactory impairment has occurred, a suitable assessment technique is required. In Japanese, T&T olfactometry is usually employed to take such measurements. T&T olfactometry measures a patient's olfactory thresholds by presenting, in front of the nose, paper scented with a basic odorant[4]. Tests thus use five smells. Each test begins at the lowest scent concentration, which is then increased until the examinee detects the odor. This value is set as the detection threshold. Next, the concentration is further increased until the examinee recognizes the scent. At this point, the examiner displays a choice of words to express the quality of the smell. If the correct answer is selected, the corresponding concentration is set as the recognition threshold. Each basic smell

is given a score at one of eight levels from -2 to 5, where 0 corresponds with the mean Japanese detection threshold. The result is finally plotted in an olfactogram on graph paper[5].

Intravenous test is also employed to determine the level of olfactory impairment. In this test, Alinamin injection with a strong garlic odor is injected via the cubital vein, and the interval between the start and end of the reported smell perception is timed. In normal participants, the start time for perception is around 5–10 s and the end time is 60–90 s. Although this test is a limited method, which is done in a general clinic, implementing this test could be important in determining the prognosis of olfaction impairment and deciding upon a treatment regimen. Except for respiratory dysosmia, this test is helpful for olfactory anesthesia. If a long time elapses without recovery of olfaction, the patient will have only a small chance of recovery. Therefore, this test is crucial for early diagnosis and treatment of olfaction impairment[6]. However, a disadvantage of the test is that in one-third of cases, participants experience pain near the injection site from elbow to shoulder[7].

2.3 Olfactory Threshold

Olfactory thresholds are values used to express the intensity of a scent. Typically, four types of olfactory thresholds are used: detection, recognition, differential and identification [8].

- Detection threshold: the minimum concentration at which a scent can be detected when the patient does not need to recognize the type of smell.
- Recognition threshold: the minimum concentration at which the type of scent can be recognized. Its value reflects the ability of the patient to express the quality and characteristics of the scent.
- Differential threshold: the minimum concentration at which a patient can distinguish the strength of a scent. Its value reflects the patient's ability to detect changes in the stimulus and to quantify the change.
- Identification threshold: the minimum concentration at which a patient can identify a scent presented beforehand.

In a general olfactory examination, acuity is measured by using these thresholds. For example, T&T olfactometer measures detection threshold. In this study, we measure the detection thresholds. Measuring detection threshold can help to find an early symptom of diseases.

3 OLFACTOORY MEASUREMENT METHOD FOR HEALTH CHECKUP

Olfactory examinations are not carried out at health checkups on grounds that scent scatter in the air, waste such as scented paper and bags filled with scents is generated, measurements require a great deal of care and time and so on. Through the solution of the issue, olfactory examination can be utilized in health checkup. To this end, we work out olfactory measurement method aiming to use at health checkup. This method makes it possible to measure detection threshold. By using this measurement method, we can easily carry out the olfactory measurement at the place such as a classroom and a gymnasium. Detection threshold is simple examination that people can understand scented or odorless. Thus, we adopted detection threshold from olfactory threshold because it takes shorter time than other olfactory threshold. As for measurement method, we discussed with ear, nose, and throat doctor, and made many improvements. Hence it is more practical measurement method. We measure the detection threshold with this method as a trial.

The issue such as diffusion of scents, waste and a great deal of care to measure is cleared up by olfactory display we developed, using a technique based on an inkjet printer mechanism. This olfactory display can use a scent presentation technique to emit scent at the picoliter level for a short duration that we call " pulse ejection " . It has use of the wind and carries scent to user's nose directly, so that user can feel it. Pulse ejection emits aroma chemical minutely small doses, so that user can feel little scent when user departs from the device. Thus, it isn't necessary to worry about scent diffusion. This device uses wind to carry scent and has ink tank filled with aroma chemical in place of ink. Once scent is restocked with tank, more than ten thousand times of ejection is possible. Hence waste isn't generated at measurement. Scent intensity is controlled with the number of simultaneous ejections (NSE) and ejection time. The device is controlled with PC and can change NSE and ejection time freely. Thus, care to measure is alleviated because we can emit scent just to operate a PC. Although detection threshold can be measured at 192 levels in this measurement method by using the olfactory display, measurement can be finished in a short amount of time. By measuring olfactory threshold with this olfactory display, like sight and hearing, it is possible to quantify the human olfactory characteristics. For example, the scent intensity of T&T olfactometry is eight levels. However, by using this device, we can measure more finely and quantify it more precisely. Moreover, if the human olfactory characteristics can be quantified, we can apply it to the field of multimedia. And, if the scent intensity is decreased, problems such as lingering scent may be diminished.

In this study, measurement algorithm is specific one using binary search to combine with these parameters. Value of these parameters is changed in order to take dynamic range widely. Hence a lot of people who have from good sense of smell to a little good sense of smell can be measured. This measurement method is aimed at the utilization of screening in the future. It is also aimed at finding fear of olfactory impairment. If the fear is found at this measurement, the patient shall go to hospital and measure precisely by existing olfactory examinations. Existing olfactory examinations can measure precisely but isn't suitable for measurement with many people at a time in the place such as a gymnasium and classrooms as schools. Hence we worked out olfactory measurement method aiming at health checkup. This time we examined olfactory characteristics by using it at the beginning.

Then, we could quantify the human olfactory characteristics.

4 OLFACTORY MEASUREMENT METHOD

4.1 Olfactory Display

Figure 1: Olfactory Display

We developed an olfactory display shown in Fig. 1. This display uses the technique used in ink-jet printer in order to produce a jet which is broken into droplets from the small hole in the ink tank. The device can change the ejection time at 667 μs intervals so that measurement can be controlled precisely.

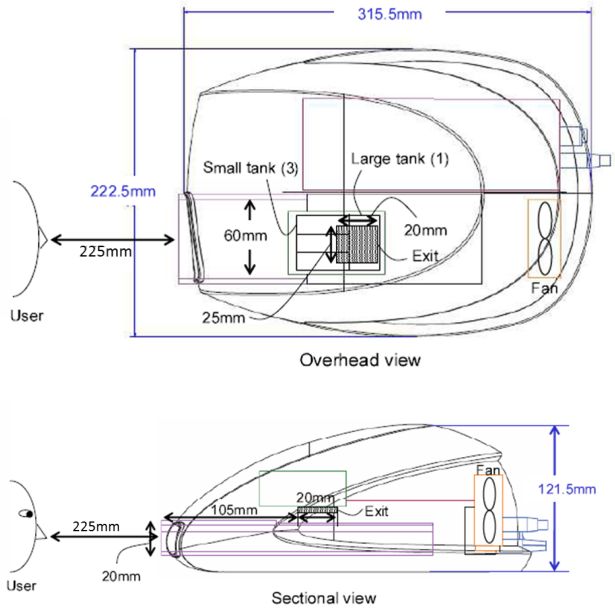

Figure 2: Plane and side view of the olfactory display

Figure 2 shows internal design of the olfactory display. The display can set up an ejection head. This head can store three small tanks and one large tank, thus this display can contain 4 kinds of scents maximum. In this study, we used large tank. The display is equipped with a fan and there are 10 phases of wind velocity control in the range of 0.8 m/sec-1.8 m/sec. The scent presentation hole is a rectangle of 2 cm length and 6 cm width.

It is possible to change the ejection quantity and the kinds on 100msec rate at this display. The ejection quantity (EQ) is calculated as follows.

$$EQ(pL) = UAEQ(pL/time) \times NSE \times V(times) \quad (1)$$

Here, UAEQ is the unit average ejection quantity (the average ejection quantity from each minute hole in the head), NSE is the number of simultaneous ejections (the number of minute holes in the head that emit at one time), and V is the volume (explained below). There are 127 minute holes in the head connected to the small tank and 255 minute holes in the head connected to the large tank. Moreover, the display can emit scent from multiple holes at the same time, so NSE is adaptable to 0-127 (small tank), 0-255 (large tank). In addition, the user can set the number of ejection times 1-150 in 100 msec from one hole, which we denote the " volume ". By setting the volume, ejection control of 667 μs for a unit is possible. The concept of volume is shown in Fig. 3. Volume is converted at time and expressed in " ejection time " in the measurement.

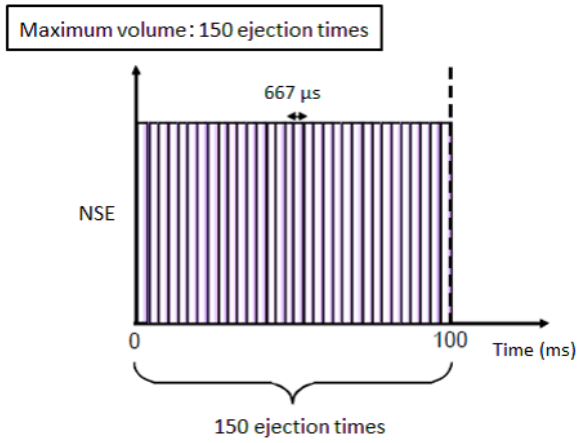

Figure 3: Concept of Volume

UAEQ from one minute hole on large tank is 7.3 pl. It was confirmed to be approximately constant without depending on the residual quantity of ink on examination. In this study, we adjust EQ by changing NSE. We put the change of EQ into " scent intensity " and denote as follows. And scent is diluted by 5% with ethanol and water. So scent quantity is practically calculated as follows.

$$Scent\ Intensity = UAEQ(pL/time) \times NSE \quad (2)$$

$$Scent\ Quantity = EQ \times 0.05 \quad (3)$$

4.2 Measurement Algorithm using binary search

In this study, we use NSE from 0 to 255 and ejection time 8 ms and 4 ms. We previously measured olfactory character-

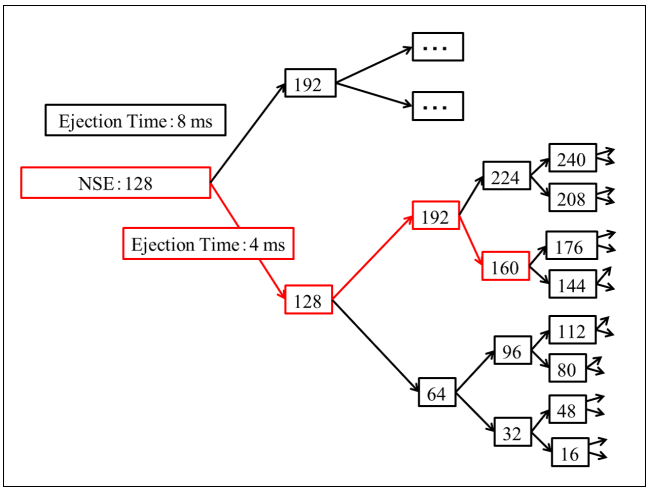

Figure 4: Measurement Algorithm for Detection

istics by using 100 ms and 13.3 ms ejection time. However, average of detection threshold was low, and hence people who have a good sense of smell were found little difference[9]. We repeat preliminary experiment and adjust value to measure people who have a good sense of smell. Thus, we adopted 8 ms and 4 ms.

We use the algorithm shown in Fig. 4. This algorithm is binary search algorithm NSE with ejection time. NSE is decreased if the answer is correct and increased if the answer is incorrect. We begin with 128 NSE and an ejection time of 8 ms. NSE is changed from 0 to 255 in the measurement, and hence we start measurement from median NSE. For the first measurement, the ejection time changes to 4 ms if the participant's answer is correct and stays at 8 ms if the answer is incorrect. We give an example and explain the way of value change. First, we begin with 128 NSE and an ejection time of 8 ms. For the first measurement, the ejection time changes to 4 ms if the participant's answer is correct. Second, NSE changes to 192 which is the value added 64 that is half 128 value to 128 if the participant's answer is incorrect. Next, NSE changes to 160 which is the value subtracted 32 that is half 64 value from 192 if the participant's answer is correct. Similarly, we measure until a change level becomes 2.

5 EXPERIMENTAL OUTLINE

The screening value which can determine the possibility of olfactory disturbance in a short time is needed. However, olfactory measurement by using olfactory display with pulse ejection is not worked out. So the human olfactory characteristics are numerically unknown. Then, we measure it precisely as a trial. We also timed the measurement and use it as a reference for future measurement method.

5.1 Experimental Environment

In the experiment, the olfactory display connects with a personal computer. The measurer controls the personal computer. The measurer and participant sit face to face, so participant can't see the measurement display. Each participant was required to sit in front of the olfactory display and place their

Figure 5: State of the experiment

chin on the chin rest such that the distance from the olfactory ejection point to the nose was fixed at 22.5 cm as shown in Fig. 5. The patient experiences a feeling of oppression if he gets too close the device and he can't feel scent if too far from one. For this reason, this is the value we adjusted to meet conditions. The fan of the display was switched on during experiments to stop participants being able to tell when the scents were delivered to them. A previous experiment found that a scent will not linger in the air if the wind speed is higher than 1.2 m/s[10], and so the wind speed in the current experiment was set to 1.8 m/s.

5.2 Experimental Method

By following olfactory measurement method shown in Section 3, we conducted olfaction examinations on 44 participants, measuring their detection threshold. A description of the participants is given in Table 1. Participants were 33 men and 11 women in their 20s to 40s. There were many participants in their 20s and all participants had perfect olfactory function.

Table 1: Description of Participant(people)

	Male	Female	Sum
20s	26	9	35
30s	6	2	8
40s	1	0	1
All	33	11	44

To determine the detection threshold, we use isoamyl acetate, which smells like banana. This scent is simple chemical substance, and hence it does not come under an influence by a production area and the preservation organization unlike natural fragrance and there is an advantage to be superior in reproduction. We use this scent in the measurement because scent of banana is relatively easy to detect. We use the triangle test to judge the detection threshold in the measurement. In the triangle test, three stimuli are presented at random, where one of them is scented and the other two are odorless. The participant then answers when the scented odor was presented in the

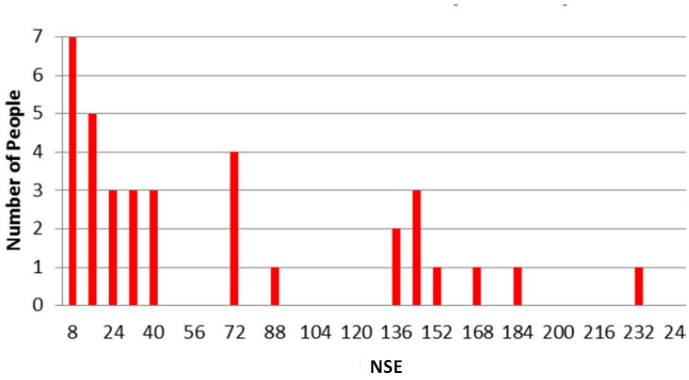

Figure 6: Detection threshold in 4ms

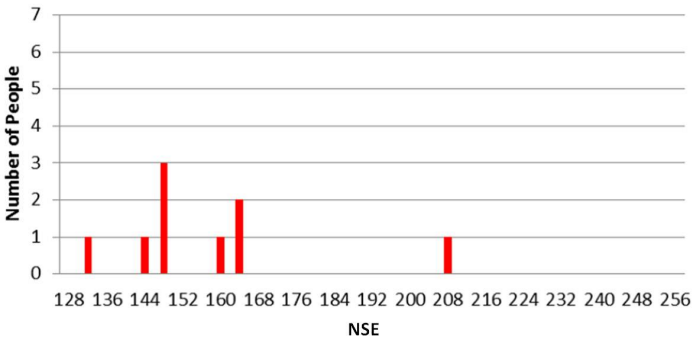

Figure 7: Detection threshold in 8ms

three times. In the experiment, Measurer uses the application for olfactory measurement. The measurer clicks the ejection button on the computer to present the scent. When the scent is ejected, the countdown starts with the auditory cue. Scent emission then commences 0.5 s after giving the cue "Go" according to previous study[11]. After the participant answer, measurer chooses from options and input the participant's answer. This operation is assumed once, and repeated seven or eight times. When the measurement is finished, the participant's detection threshold is recorded on the computer. Then, at the same time to find a value of the detection threshold, we timed measurement from beginning to finishing.

6 RESULTS

6.1 Measurement Result of Detection Threshold

The results of detection threshold measurements for the 44 participants are listed in Table 2, which shows average, standard deviation, max and min on the 4 ms and 8 ms results. Depending on measurement algorithm, NSE is from 2 to 255 when ejection time is 4 ms, and from 128 to 255 when ejection time is 8 ms. Here, the standard deviations are large. Thus, a definite expression of a person's olfactory ability can be obtained. Minimum value participants can detect is 2 in 4 ms, and it fits in minimum value in measurement algorithm. Hence, measurement for person who has a good sense of smell was possible in this measurement. Moreover, Maximum value participants can detect is 206 in 8 ms. It was found that the detection threshold for participants who have perfect olfactory function depended on personal olfactory ability in this measurement method.

Figures 6 and 7 show distribution of measurement result. In fact, we measure detection threshold at 192 levels. However, we show the measurement result at 48 levels in Fig. 6 and 7, so that distribution of the number of people can be easy to understand. Abscissa axis shows NSE, which is detection threshold of each person. Vertical axis shows a number of people and expresses it how many participants who became each detective threshold there is. From the result, participants who have good sense of smell can detect subtle scent. On the other hand, participants who have not so good sence of smell

Table 2: Result for detection threshold

	4 ms (35 people)	8 ms (9 people)
Average	60.06	155.78
Standard Deviation	62.64	21.39
Max	228	206
Min	2	130

can't detect stronger scent than the scent person who have good sense can detect. When the scent is presented with multimedia such as TV, the scent intensity fall inside this range. This result can be applied to the field of multimedia. However, we didn't measure the people who have olfactory disturbance this time. When we measure them, the much stronger scent is needed.

We measured the detection threshold precisely in this study, and hence a measurement finishes has been completed up to eight times. It cannot take time for the per person measurement at health checkup. Because the screening of olfactory impairment is a purpose at health checkup, it is thought that such delicate measurement is not necessary. We measure detection threshold at 192 levels, however, we show the measurement result at 48 levels in Fig. 6 and 7. Through this, it is revealed that personal ability to smell is seen even if the number of the measurement is reduced to some extent. So we also need to examine how much has to quantify it finely.

6.2 Measurement Time

The average measurement time was 4 minutes 21 seconds and the standard deviation was 37.1 seconds. Thus, measurement could be finished within 5 minutes regardless of participants. Measurement time for per person has to be kept to the minimum at health checkup. According to ear, nose, and throat doctor, olfactory measurement has to be finished within 5 minutes at least. As consider it as a guide, this measurement method has possibility to carry out at health checkup.

In this measurement, participants had no experience in olfactory check, so they got bewildered and got thoughtful, and hence there were many persons who took time more than rad-

ical measurement time. It is thought to shave off time if olfactory check is carried out at health checkup and persons are used to measure. In fact, measurement of us who are used to measure olfactory check was finished in 3 minutes 40 seconds. Moreover, we measured finely, so it took much time. As cited in chapter 6.1, it was found that personal ability to smell is seen even if the number of the measurement is reduced to some extent. Thus, a number of levels are decrease so that measurement time can reduce more than result in this time. To carry out at health checkup, it is needed to determine the screening value for measuring olfactory threshold. By using this result, we perform further experiments to examine the screening value. If we determine it, the measurement time is more short and the possibility to carry out the olfactory measurement at health checkup is increased.

7 CONCLUSION

A decline in olfaction is reported to be an early symptom of diseases such as Alzheimer's and Parkinson's disease. However, olfaction is not examined at a regular health checkup on grounds that scent scatter in the air, waste such as scented paper and bags filled with scents is generated, measurements require a great deal of care and time and so on.

In this study, we worked out olfactory measurement method aiming to use at health checkup. We used inkjet olfactory display which can use pulse ejection for scent presentation to minimize odor elimination. Measurement algorithm uses binary search. Therefore, we could measure the detection threshold at 192 levels in total by shift in the number of simultaneous ejections. By using this measurement method, we think the problems of predominant olfactory measurement are cleared up. However, the human olfactory characteristics to pulse ejection are unknown. So we tried to measure it. For measurement result, only 5 min was needed to measure the detection thresholds.

On the other hand, the olfactory threshold is quantified with computing control. The device could measure it finely and clear up the problems. This time, we examined it on a trial basis. However, to carry out at health checkup, we will examine the screening value for olfactory measurement based on this result. And we try to measure in more short amount of time. We hope that this study is useful in the future.

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Aya Fukasawa B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2012. She is currently working toward an M.S. degree in Open and Environment Systems at Keio University. She received the best presentation award from IWIN'12. Her research interests include fragrance information processing work.

Kenichi Okada received his B.S., M.S. and Ph.D. in instrumentation engineering from Keio University, in 1973, 1975, and 1982, respectively. He is currently a chief professor in the Department of Information and Computer Science at Keio University. His research interests include CSCW, groupware, human computer interaction, and ubiquitous computing. He has published 140 journal papers, 170 international conference papers, and 18 books entitled "Collaboration and Communication", "Designing Communication and Collaboration Sup-

port Systems", "Introduction to Groupware" and so on. He is a member of IEEE, ACM, IEICE and IPSJ. He was a chair of SIGGW, a chief editor of IPSJ Magazine, and a chief editor of IPSJ Journal. Dr. Okada received the IPSJ Best Paper Award in 1995, 2000, and 2008, the IPSJ 40th Anniversary Paper Award in 2000, IPSJ Fellow in 2002 and the IEEE SAINT Best Paper Award in 2004.