System of Personal Identification by Using Tactile Stimuli

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Abstract

This paper proposes a personal authentication system that uses tactile stimuli. Recently, scientists have been conducting research in biometrics using biomedical information. However, there is the problem that biomedical information is unchangeable. For example, if a thief steals another user's biomedical information, that person has no information to register. Due to the problems of sight information and unchangeable biomedical information, we propose a solution that uses the sense of tactile stimuli. Tactile information is difficult to steal and relies on human memory, which is unchangeable.

This paper proposes a system that uses a pattern formed by a tactile stimuli time series instead of a password number as the identification key. We also discuss the results of an identification experiment and a memory property experiment.

1 Introduction

Recently, passwords and password numbers have been used as non-facing personal identification. But, in systems that use passwords and password numbers, the identification key may be stolen by human sight. For example, a user's password can be stolen by cameras in the ATM system of a bank. This situation implies that general passwords and password numbers are visual information, and an identification key conveyed by sight information can be a problem.

The biometric research using individual physical information (retina, face, pattern of blood vessels, etc.) has recently been active. Biometrics has the advantage that individual information cannot be stolen easily, but it has the disadvantage that if registration information is stolen once, it cannot be used again. In other words, the biometrics system has a problem with the changeability of information [1].

The human's tactile sense can perceive information such as invisible stimulus. To develop a personal identification system based on using tactile stimulus, we can prevent the visual leakage of intelligence information and also realize the changeability of the registration information. This study proposes the development of a personal identification system using tactile stimuli as an identification key.

Table 1: Comparison of identification systems

	The system using password	The system using tactile stimuli
Identification Key	Password number	Pattern of tactile stimuli time-series
Element of Identification	Number (0～9)	Tactile stimuli (S_0～S_4)
Consist of element arrangement	4 arrangement	6 arrangement
Variation of identification key	10,000kinds	10,000kinds

2 Identification System

2.1 The pattern of a tactile stimuli time series

Table 1 shows a comparison of the system using password numbers and that using the pattern of a tactile stimuli time series. Users memorize the rhythmical sense of the tactile stimuli time series and use it as an identification key [2]. In the system using password numbers, the numbers from 0 to 9 are elements of the identification key. However, this system has the characteristic that it uses tactile stimuli. Also, a system that uses the a PIN uses four digits, but our system consists of six patterns of tactile stimuli. Because the frequency differential limen of tactile stimuli has limits

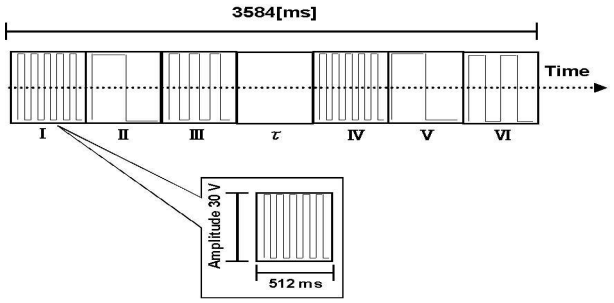

Figure 1: The pattern of the tactile stimuli time series

[3]-[5], in this research the elements of the identification key must be decided based on human frequency differential limen. According to this, we researched the human frequency differential limen in tactile stimuli through a previous experiment [6][7]. We put a mark (S_0, S_1, S_2, S_3 and S_4) on five kinds of tactile stimuli that were distinguished through the previous experiment. It is assumed that S_0 does not have any tactile stimuli condition. S_0 is usable as an element of the identification key, because it is a condition of no tactile stimuli. Six tactile stimuli are chosen from five types of tactile stimuli elements; obviously, there is some duplication. The chosen stimuli are arranged in a time series, which is named "the pattern of tactile stimuli time series" and is used as the identification key. S_0 is excluded from the start and end of the pattern in order to confirm the start and end of the pattern of the tactile stimuli. In total, $4 \times 5 \times 5 \times 5 \times 5 \times 4 = 10{,}000$ kinds of varieties can be created. This variety corresponds to that for four figures in password numbers. For convenience, we used six stimuli, labeled I'VI, in the time series. Also, the pattern of the tactile stimuli time series was separated into a first group and a last group, which was separated by a break of τ seconds. Figure 1 shows the pattern of the tactile stimuli time series. An element of the tactile stimuli is presented in 512 ms, and the all of pattern of the tactile stimuli time series is presented in 3,584 ms (This includes the break time).

2.2 The proposed system

The proposed personal identification system is shown in Figure 2. Information from a personal computer (PC) is output to the users' interface, which is composed of a monitor and a tactile stimuli vibration device. All information related to the identification key is passed through a tactile stimuli vibration device. The process of identification is as follows. Users touch a tactile stimuli vibration device with a part of their body (for example, a finger, etc). Then, each user forms his or her own "pattern of tactile stimuli time series" by controlling the PC's interface (keyboard and mouse). After that, each user registers and memorizes their chosen pattern of tactile stimuli time series, which is usable as an identification key. In a situation requiring personal identification, the users reproduce the registered pattern of the tactile stimuli time series in the same way as that used in the process of registration. At this time of identification, the system compares the registered pattern of the tactile stimuli time series with the reproduced pattern of the tactile stimuli time series. If the reproduced pattern corresponds with the registered pattern, personal identification is achieved; otherwise, identification is not achieved.

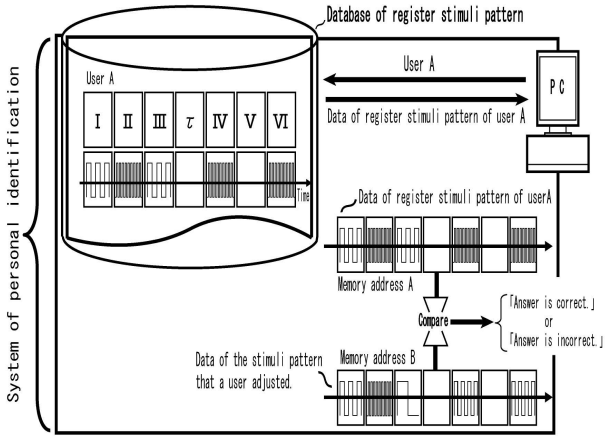

Figure 2: Components of the system

3 Experimental Methods

The experimental system is displayed in Figure 3. The tactile stimuli vibration device in this experiment is a piezoelectric transducer (PZT) vibrator (Murata Manufacturing Co., Ltd. 77B-21-19R7DM4AO), which is a circular device 20 millimeters in diameter. The waveform of the voltage is the pattern of the tactile stimuli time series that was output through a D/A transfer board (Interface Co., Ltd. CSI-340312) and operational amplifier (OP AMP). Then, this is input to the PZT vibrator.

The five kinds of tactile stimuli (S_0, S_1, S_2, S_3 and S_4) are differentiated as rectangular voltage, each of

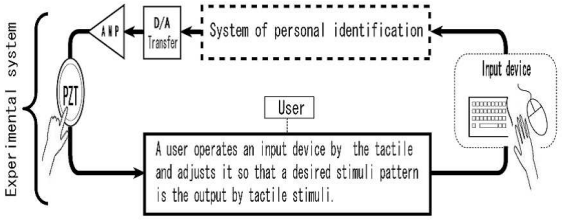

Figure 3: Experimental system

which corresponds to 0 kHz (no signal), 1/128 kHz, 1/64 kHz, 1/24 kHz, and 1/4 kHz, respectively. The voltage is input to the PZT vibrator, which generates the vibration stimuli.

Subjects wear earplugs and a headphone that eliminate the sound of extraneous vibrations during ten experiments. Subjects gently pick up the PZT vibrator by the thumb and forefinger of the left hand. Subjects operate the input device corresponding to the pattern of tactile stimuli time series output from the PZT vibrator; we refer to this as tactile feel. This practice is carried out for about an hour before the experiment, because it familiarizes subjects to the experimental method, the experimental process, and the PZT vibrator.

In the identification experiment, subjects feel tactile stimuli in a random pattern of the tactile stimuli time series. Using an input device, they adjust the pattern of the tactile stimuli time series to create their own input, and register the pattern. Hereafter, we just present a generic registered pattern instead of the user's registered pattern of tactile stimuli time series. Subjects are instructed that they are prohibited from choosing a pattern of tactile stimuli time series that can be easy memorized (for example, 1111, 2222, 3333, 4444, in password numbers). After one hour, subjects are asked to reproduce the register pattern from the random patterns of tactile stimuli time series. What is reproduced is the pattern of the tactile stimuli time series, which appears at the personal computer. Hereafter, we just use a presentation that reproduces a pattern instead of the reproduced pattern of tactile stimuli time series. We decided to use that as one trial. Ten trials were then carried out over two weeks. These trials represent the identification experiment. Then, the subjects were tested again after five months as a memory experiment. Subjects were asked to reproduce the pattern of the 10th trial as the registered pattern in the memory experiment. In this paper, we separately report the results for the identification experiment and memory experiment. Then we analyze the results of the identification by cluster analysis and correlation analysis.

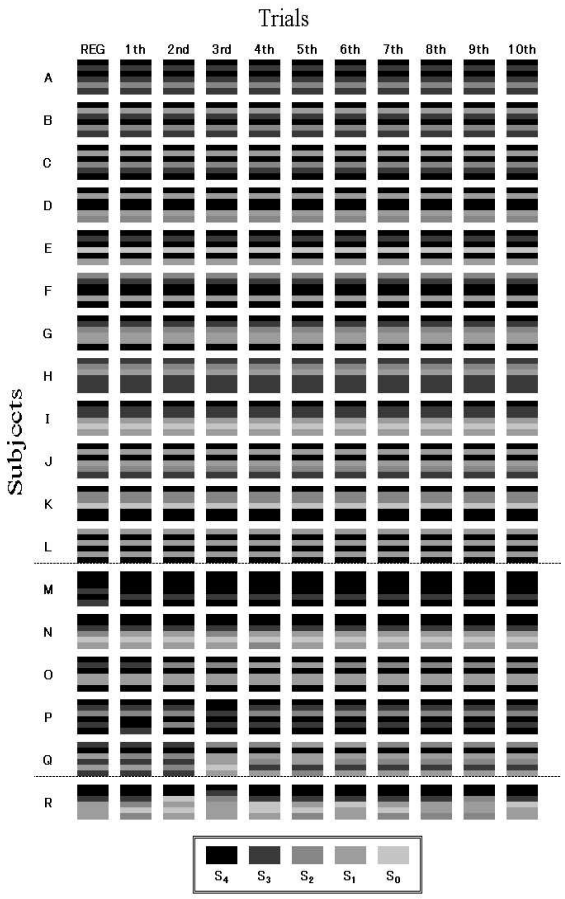

Figure 4: Result of the identification experiment

4 Experimental Results

4.1 Results of identification experiment

These experiments were carried out with 18 adults (14 males, 4 females) who were from 20 years old to 43 years old. Figure 4 shows the result of the identification experiment. This figure represents the patterns of tactile stimuli time series chosen by the subjects. The patterns are shown as color tones, and are arranged from 1 to 4 in one record. The first column represents the register pattern, the 2nd represents the reproduced pattern of the first trial, and so on. The results of the identification experiment are as follows.

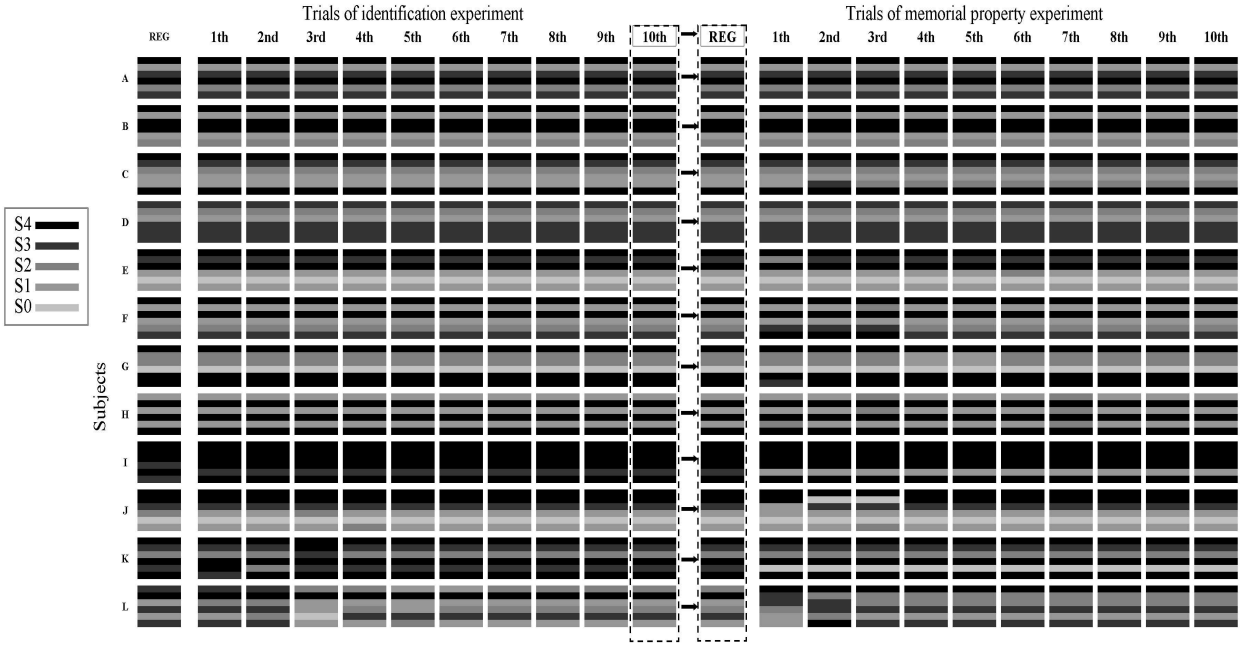

Figure 5: Results of the memory property experiment

Twelve subjects, ranging from A to L, correctly reproduced the register pattern for all ten times trials. Although five subjects (from J to L) incorrectly reproduced after ten enforcements, they began to reproduce the pattern successively after having repeated a trial after subordinate to one pattern while repeating the enforcement. There is room for improvement since this result implies that the practice beforehand was insufficient. Also, it is difficult to confirm the efficiency of the technique because there were no successes for subject R. From the above-mentioned results, it is possible to verify that twelve subjects could remember a certain pattern of tactile stimuli time series and reproduce it, even though the method should still be improved.

4.2 Result of memory property experiment

In this experiment, 12 adults (9 males, 3 females) carried out the identification experiment. Figure 5 also represents the pattern of tactile stimuli time series through color tones, arranged from 1 to 4 for one test. Three subjects A, B, and C completely reproduced the register pattern after five months had passed. Five subjects (subjects E, F, G, H, and I) had shown an uneven result in the first part of the trials. However, they could reproduce the register pattern successively while repeating the enforcement. Three subjects (J, K and L) could not reproduce one pattern out of the six that they chose as the register pattern. As for subject M, he could not remember the register pattern at all and reproduced an entirely different pattern. These results imply that there was insufficient practice in advance. Also, the results imply that subjects felt insecure because they did not know their real register patterns. From the result of the experiment of the memory property, we could confirm that eight subjects among twelve subjects could remember and reproduce correct patterns over the long term of five months. In addition, even though subjects J, K, L and M could not reproduce all the patterns correctly according to the register pattern, there is room for improvement because they showed a reproduction of the regular pattern in reverse order.

5 Analysis

5.1 Cluster analysis

By interpreting the tendency of reproduced patterns of 10 enforcements of 17 subjects, it is possi-

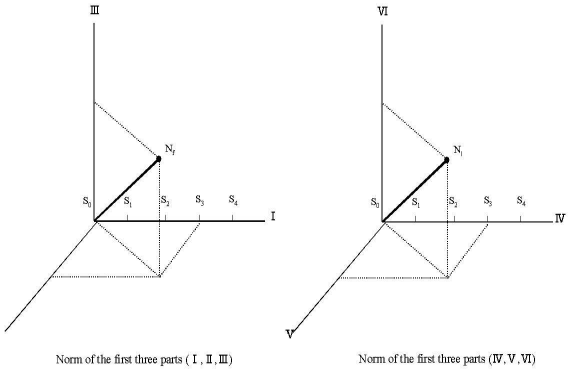

Figure 6: The norm of 3-dimensions

ble to presume that some subjects chose easier tactile stimuli. We divided the pattern of tactile stimuli time series into a first group (I, II and III) and a second group (IV, V and VI). Then, considering three tactile stimuli as three changeable regular numbers, we obtained each norm after transforming each number into a three-dimensional vector. The tendency for the

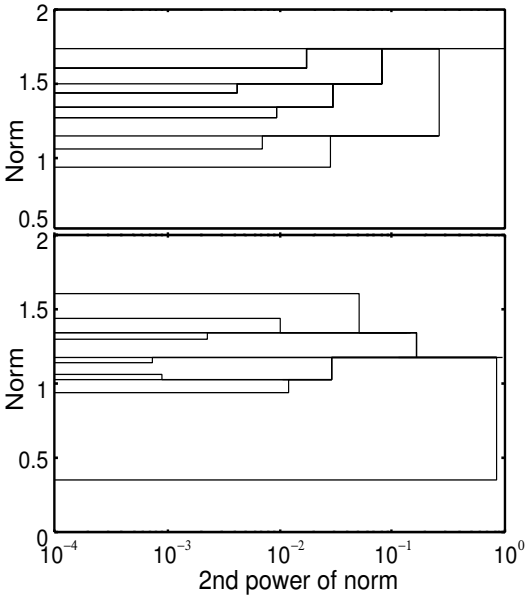

Figure 7: Result of cluster analysis

frequency of the subject may come from the fact that the proportion of subjects choosing the low frequency tactile stimuli is large if the norm is low. Taking the calculated norm as a variable, we estimated the similarity of the reproduced pattern by the median method of cluster analysis.

Figure 7 is the dendrogram from the cluster analysis. The left part is the result of the former half and the right is the result of the latter half. It shows the square of the norm on the horizontal axis and the 17 subjects on the vertical axis in ascending order.

It does not recognize the difference of the prescription from the fact that the norm which subjects chose was around from 1 to 1.5 on the vertical axis. It can be recognized that 1 cluster is formed at 0.9 for the second group while the square of the norm is formed on the horizontal axis, and 1 cluster is formed at 0.3 for the first group. These results show that subjects were thinking that they were going to correctly identify the pattern in the second group more so than did the first group.

5.2 Correlation analysis

For this research, we needed to clear up the relation of the strength and weakness of the tactile stimuli element. Therefore, we carried out another experiment to clear up the relation of the strength and weakness.

We confirmed that the tactile stimuli elements have a relation which is $S_0 < S_1 < S_2 < S_3 < S_4$, as given in another experiment[11]. We calculated the

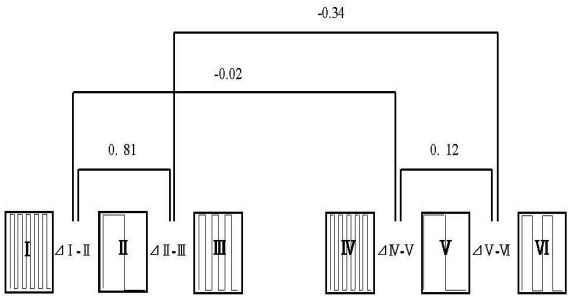

Figure 8: Correlation of coefficient

quantity of change for each element of the pattern. For convenience, we just use the expressions ΔI-II, ΔII-III, ΔIV-V and ΔV-VI instead of the quantity of change from I to II, from II to III, from IV to V and from V to VI. And then, each quantity of change was calculated.

Figure 8 shows the result of the calculations. The correlation of the coefficient of ΔI-II and ΔII-III is 0.81. This is a strong correlation for ΔI-II and ΔII-III. However, the other correlations of the coefficient are weak at 0.12, −0.02, and −0.34. Specifically, this shows us a high significance in the quantity of change

of the first group (I, II, III). These results authenticate that subjects choose easy perception of the tactile stimuli in first group.

6 Conclusion

This paper proposes a system that uses the pattern of a tactile stimuli time series instead of a password number as an identification key. To verify the proposed system, we carried out an identification experiment and a memory property experiment.

The results of the identification experiment confirmed that 18 subjects could remember the pattern of the tactile stimuli time series that was chosen by each subject. The results of the memory property experiment confirmed that the some subjects could remember the pattern of tactile stimuli time series for a long period (5 months). Also, through cluster analysis and the correlation analysis of two groups of subjects, we confirmed that subjects chose easy perceptions for the pattern of tactile stimuli time series in the first group, and subjects choose various patterns of tactile stimuli time series in the second group.

In the future, we intend to research definite tactile stimuli in humansf perception, including easy-to-perceive tactile stimuli.

References

[1] "Biometrics is unbelievable" *Asahi shimbun Weekly AERA* Vol.19 No.15 (982),3,April 2006

[2] Atsushi noguchi, Shuichi kezuka, Akio nozawa, Masafumi uchida, Hideto ide: "Training and oblivion characteristics about figure discrimination on tactile display using the modulated vibration" *Technical meeting on instrumentation and measurement*, IEEJ IM-05-69,pp.27-30,2005

[3] Reiko ohira, Masafumi uchida: "An individual study of EEG to the task of a-point stimulus" *Technical meeting on instrumentation and measurement*,IEEJ IM-05-70,pp.31-34,2005

[4] H.Takagi: "Statistics in Clinical Studies- (I) Methods of the Comparison for the Independent Samples", *Igaku-Shoin Ltd*,40(7),pp559-564(1986)

[5] N.Hotta, M.Uchida, H.Hisaya, A.Nozawa, H.Ide: "The difference threshold of Modulated Vibration Using a Summantion"

[6] Naoko Mori, Masafumi Uchida, Akio Nozawa, Hideto Ide: "Estimation of Frequency Differential Limen to Modulated Vibratory Stimuli" *Instrumentation and Measurement,Tech.Report IEEJ Trans.* FM, Vol.126, No.6, 464-469,2006

[7] Reiko Ohira, Masahumi Uchida, Akio Nozawa, Hideto Ide: "The Single-trial Analysis of P300 and the Difference Threshold of Modulated Vibration" *Instrumentation and Measurement,Tech.Report IEEJ Trans.* FM, Vol.126, No.6,pp.478-483, 2006

[8] S.Sutton, etal: "Evoked potential correlates of stimulus uncertainty", *Science*,150,pp.1187-1188, 1965

[9] M.Uchida,H.Tanaka,H.Ide and S.Yokoyama: "A Tactile Display by 16 kinds of modulated wave vibration Used Only One PZT Vibrator", *IEEJ Trans. EIS*, Vol.120, No.6, pp.825-830,6,2000

[10] W.Sommer,J.Matt and H.Leuthold: "Consciousness of attention and expectancy as reflected in event-related potentials and reaction times", *Journal of Experimental Psychology Learning, Memory and Cognition*,Vol.16, pp.902-915,1990

[11] K.Sato, T.Hirai, J.Yamaoka: *The Basis and Clinic of Evoked Potentials*,pp209-214,1990