Authentication Based on Seating Pressure Distribution using the MT System

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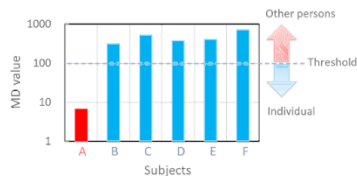
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Graphical abstract

Abstract

This paper proposes a system for authentication based on seating pressure distribution, using the MT system as a new method of biometric authentication that is difficult to forge and does not inconvenience users. The main characteristic is that the only action required of the user is to sit down. Feature values were extracted based on the pressure distribution when individuals seat, and individual users were distinguished from other persons by means of the Mahalanobis-Taguchi (MT) system used in quality engineering. The result of the experiment was a False Rejection Rate of 2.2% and a False Acceptance Rate of 1.1%.

Keywords: Quality engineering; Mahalanobis-Taguchi (MT) System; authentication; seating pressure

Abstrak

Kajian ini menganalisis satu sistem untuk autentikasi berdasarkan penyerakan tekanan tempat duduk menggunakan sistem sebagai kaedah baru bagi autentikasi biometrik yang memang diketahui sukar dan tidak praktikal pengguna. Karektor utama ialah aksi yang dimohon oleh pengguna ialah duduk. Nilai diperoleh daripada penyerakan tekanan apabila sesorang individu itu duduk dan nilai individu dari perspektif individu yang lain dinilaikan dari sistem Mahalanobis-Taguchi (MT) daripada kejuruteraan kualiti. Keputusan dari eksperimen menunjukkan kadar penolakan palsu 2.2% dan kadar penerimaan palsu 1.1%.

Kata kunci: Kejuruteraan kualiti; Sistem Mahalnobis-Taguchi (MT); autentikasi; tekanan tempat duduk

■1.0 INTRODUCTION

The need to identity authentication has been growing in recent years [1]. The methods of authentication are broadly classified into the three categories as listed in Table 1. Authentication by something you know and something you have provide a high level of certainty, but these methods are beset by the risk of memory lapse, loss, theft and forgery. The third method, authentication by something you are (biometric authentication), includes authentication using physical characteristics and authentication using behavioral characteristics [2]. Physical characteristics include, for example, fingerprints, veins, or irises, and the accuracy of authentication is generally high because of their unique and permanent qualities. However, identity fraud using artificial fingers or artificial irises to forge physical characteristics has recently become a problem. In addition, fingerprint authentication inconveniences the user with the need for extra action, such as scanning fingerprints. Authentication by facial image is hardly stress-free because having your face photographed poses a psychological burden [3]. Authentication by keystroke patterns when using a keyboard has also been proposed as a form of authentication using behavioral characteristics [4]. The advantage of methods using such behavioral characteristics is that they are tough to forge or imitate, so identity fraud would be difficult, but since the reproducibility of behavioral characteristics is low, the disadvantage is a lower authentication accuracy.

The search is still on for a highly accurate authentication method that places no burden on the user.

Table 1 Authentication methods

Authentication types	Examples
Something You Know	Password, Code number ・・・
Something You Have	Magnetic card, IC card, Key ・・・
Something You Are	Fingerprints, Veins, Irises, Face ・・・

1.1 Proposal for a System of Authentication by Seating Pressure

This paper proposes a system of authentication by seating pressure distribution using the MT (Mahalanobis-Taguchi) system [5] as an authentication method that would be difficult to forge, and that would not inconvenience the user. The main characteristic of the system for authentication by seating pressure distribution is that it verifies identity based on the distribution of pressure when an individual sits on a chair, or in the driver's seat of a vehicle, without the need for the user to take any action other than sitting.

■2.0 EXPERIMENTAL

2.1 Identification using the MT method for Quality Engineering

We use the MT method of quality engineering developed by Dr. Taguchi for the user authentication. With the MT method, we create a unit space based on the feature values for a particular individual, and then we calculate the distance from there (the Mahalanobis distance). If the value is small, the system recognizes the person as a particular individual; if the value is large, the system recognizes that the person is someone else. Multiple feature values are converted into a single evaluation indicator referred to as the Mahalanobis distance, and based on this value, the system distinguishes between a particular individual and other persons.

The method for calculating the Mahalanobis distance D is explained below. To start with, before creating the unit space, we standardize the mean for each feature value as 0, and standard deviation as 1. Then, if the number of standardized feature values u is k, and the number of measured data is n, the squared value of the Mahalanobis distance D for p-th data is given in the following equation. Below, we refer to the square value of the Mahalanobis distance as the MD value. Then, u_{ip} is the standardized feature value, and r_{ij} is the correlation coefficient for the feature value u_i and the feature value u_j. The matrix for the correlation coefficient is referred to as the correlation matrix.

$$D^2 = \begin{bmatrix} u_{1p}, u_{2p}, \cdots, u_{kp} \end{bmatrix} \begin{bmatrix} 1 & r_{12} & \cdots & r_{1k} \\ r_{21} & 1 & \cdots & r_{2k} \\ \vdots & \vdots & & \vdots \\ r_{k1} & r_{k2} & \cdots & 1 \end{bmatrix}^{-1} \begin{bmatrix} u_{1p} \\ u_{2p} \\ \vdots \\ u_{kp} \end{bmatrix}$$

In addition, with the MT method, the MD value is divided by the number of feature values k, so that the mean value of the Mahalanobis distance, calculated by using the individual's unit space sample data, is 1. If the feature value matches the mean value for the unit space data, the MD value is 0. Consequently, when calculating the MD value using feature value data for the individual, the MD value should be close to the data recorded for that unit space, so the expectation is for a small MD value close to 0. Conversely, when the feature value of another person is concerned, the MD value will be high if it is calculated using the individual's correlation matrix when the unit space was created because the feature value for the other person has a different pattern than that of the individual. Consequently, if it is possible to set a threshold value between the MD value for the individual and the MD value for someone else, the individual can be distinguished from other persons.

2.2 Seating Pressure Distribution and Feature Values

2.2.1 Measuring Seating Pressure Distribution

As indicated in Figure 1, the driver's seat of a vehicle is fitted with a pressure sensor sheet (Conform-Light by NITTA Corporation), and when the individual sits in the seat, it is possible to obtain the kind of pressure distribution measurements shown in Figure 2. The pressure sensor sheet has a grid of 18 by 20 pressure sensor cells measuring about 1 cm in diameter with each cell outputting the pressure on a 256-point scale. Figure 2(a) shows an example of a two-dimensional measurement, while Figure 2(b) shows a three-dimensional example. Pressure distribution data can be obtained at a speed of 50 frames per second. The data can be processed in the same way as image data and runs on many image processing technologies.

(a) Driver's seat in vehicle

(b) Pressure sensor sheet

(c) Measuring seating pressure distribution
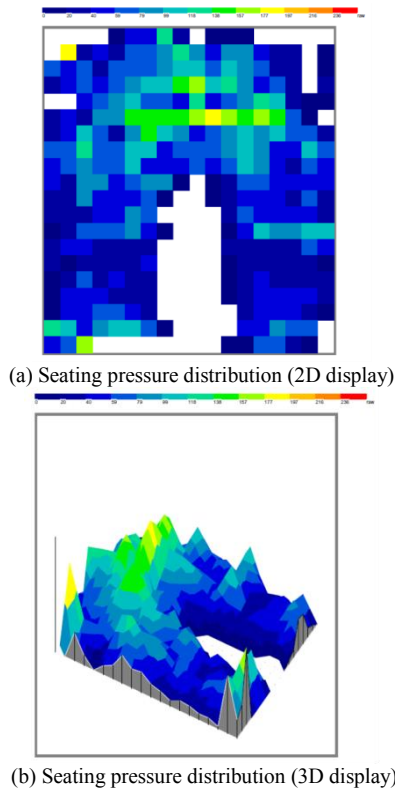
Figure 1 The experimental device

(a) Seating pressure distribution (2D display)

(b) Seating pressure distribution (3D display)

Figure 2 Measurement example of seating pressure distribution

2.3 Extracting Feature Values

Figure 2 shows the results of measuring pressure distribution in the seat, but the pattern characteristics vary with the individual. For authentication purposes, the differences in the patterns are digitized in the form of feature values. For example, the feature values used here include maximum pressure value, average pressure value, hip print area, and so on. Needless to say, it is important to figure out which feature values are highly effective for distinguishing between individuals. In the present example, we devised a total of 39 feature values and used the MT recognition technique used in quality engineering to distinguish between individuals.

2.4 Creation of the Unit Space

The MT system requires that the individual to be authenticated must initially set his feature values data as the unit space. Sample data used to create the unit space of the individual is collected by the following method. The individual sits on the pressure sensor sheet, as illustrated in Figure 1 for 10 seconds. 500 samples of data are captured in the 10 seconds. This process is repeated 5 times to capture a total of 2500 samples of data, from which the unit space is registered. Sample of a unit space is described in Table 2.

Table 2 Sample of a unit space

Sample No.	Feature No.				
	1	2	3	···	39
	Max pressure	Average pressure	Hip print area	···	Thigh area
1	211	63.2	240	···	69
2	193	59.1	230	···	77
3	207	61.9	217	···	72
···	···	···	···	···	···
2500	207	65.4	235	···	78

2.5 Authentication based on the Mahalanobis Distance

For this research, we identified the authentication by calculating a single MD value based on 39 feature values and using the value as the indicator. For example, we created a unit space with individual data for the owner of a vehicle, and then we calculated the MD value based on unit space for unidentified data (the individual or other persons). In this instance, the smaller the MD value compared to the predetermined threshold value, the likelier that the person was the owner of the vehicle. Conversely, if the MD value was high compared to the threshold value, the person was identified as someone else.

Six subjects (Mr. A to Mr. F) collaborated with the present experiment where we calculated the MD value for the unit space of Mr. A. The result is shown in Figure 3. The subjects each sat for 10 seconds. 500 samples of data were captured in the 10 seconds. From the collected 500 samples data, 500 MD values were calculated. Figure 3 shows the average MD values calculated from the six subjects. The MD value for Mr. A is the smallest and the only one below 10, while the Mahalanobis distance for Mr. B to Mr. F is large and far exceeds the threshold value of 100. In this case, it is easy to distinguish between the individual and other persons using the MD value as the indicator.
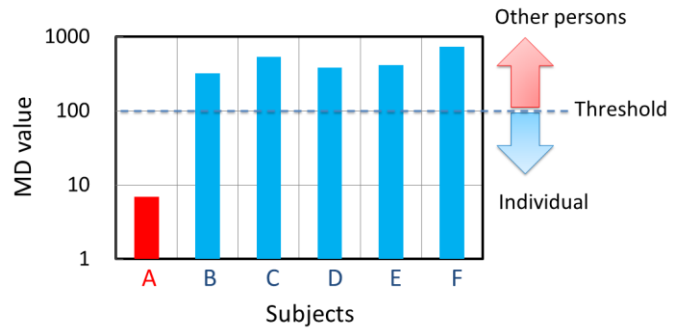

Figure 3 Distinguishing between the individual and other persons based on the Mahalanobis distance (MD value)

■3.0 RESULTS AND DISCUSSION

3.1 Result of Experiment

Next, we discuss the results of the experiment since we conducted the experiment for the identification rate for authentication based on seating pressure distribution. Authentication is always beset by two error rates. Namely, the False Rejection Rate when the individual is not recognized, and the False Acceptance Rate when someone else is accepted as the individual. We made an experimental study of these two error rates.

For each of the six subjects (Mr. A to Mr. F), we conducted two experiments. In one of the experiments the individual sat down 15 times to see whether he was correctly identified or not, and for the other experiment, we brought in another 25 persons, who sat down three times each for a total of 75 times, to see whether or not they were mistakenly identified as the individual in question. In the experiments, the threshold value for the Mahalanobis distance was set to 100 for identification. The results are shown in Table 3.

Table 3 Identification rates for authentication by seating pressure distribution

Subjects	False Rejection Rate	False Acceptance Rate
A	0.0%	0.0%
B	6.7%	1.3%
C	0.0%	0.0%
D	0.0%	5.3%
E	6.7%	0.0%
F	0.0%	0.0%
Average	2.2%	1.1%

According to Table 3, the average value for the False Rejection Rate is 2.2%, while the average value for the False Acceptance Rate is 1.1%. That is, the identification success rate for particular individuals is 97.8%, while the identification success rate for other persons is 98.9%. In addition, in Table 3, the False Rejection Rate is 6.7% because there was one case of misidentification in 15 events. When recognizing an individual, there is a high likelihood that even if there is one failure, the individual will be correctly identified if the identification is attempted again. The False Acceptance Rate of 1.3% is due to one failure in 75 events, and the False Acceptance Rate of 5.3% represents a ratio of 4 failures in 75 events.

3.2 Uses for Authentication by Seating Pressure Distribution

To start with, there are practical applications for the driver's seats in vehicles. For example, to stop thefts by preventing the engine from starting unless the individual is authenticated, or to automatically set the seat position or tilt the angle of the steering wheel once the driver has been authenticated. It would also be possible to develop a range of services such as automatically setting the air conditioning, car audio and car navigation systems. In the future, another effective application might be in offices. These days many offices use hot desking where employees no longer have assigned desks. One might imagine applications in the field of office security where employees are automatically identified and logged into a PC when they arrive at the workplace and sit down in a chair.

■4.0 CONCLUSION

This paper proposes a system for authentication based on seating pressure distribution, using the MT system as a new method of biometric authentication that is difficult to forge and does not inconvenience users. The main characteristic is that the only action required of the user is to sit down. Feature values were extracted based on the pressure distribution when individuals sat down in the seat, and individual users were distinguished from other persons by means of the MT system used in quality engineering. The result of the experiment was a False Rejection Rate of 2.2% and a False Acceptance Rate of 1.1%. Adopting this technology in the driver's seats of vehicles would serve to prevent automobile theft.

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