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ELECTRICAL MEASUREMENT OF WRITING PRESSURE AND APPLICATION TO CERTIFICATION

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Abstract − The piezoelectric element is constructed in the ball-point pen in respect of measuring the strength and weakness of the writing pressure of the handwritten characters such as the signatures. The writing pressure can be detected using the phase shift method. The maximum entropy method is used for the time series data of the writing pressure and the frequency spectrum is obtained. The discrimination between the true signatures and the false signatures is got using the frequency spectrum and the MTS (Mahalanobis-Taguchi-System) method.

Keywords: Measurement, Sensor, Piezoelectric-Element, Information Processing and Signal Analysis, Pattern Recognition..

1. INTRODUCTION

We possess various security items such as the social position certification, code number, password, key, etc,. However, these security items may be lost and may be forgotten, and we are surrounded in the dangers by the fact of robbery, falsification, forgeries, copy, etc,. Recently, the open network and the enactment of the law are advanced in order to widely realize the electronic application and the electronic merchandising. The procedure of the electronic application and the electronic merchandising can be simply carried out by the electronic equipments. In the other, the protection of the security of the private information becomes with the problem for exchanging data in order to open all to the people. The biometrics is noticed as the technology for solving these security problems. The research of the certification using bio-information which is peculiar to the humans such as DNA, retina, fingerprint, motion in writing the signature is carried out recently.

The electrically measuring the writing pressure of the signatures using the piezoelectric element is examined and the measuring device of the ball-point pen type is developed. The peculiar and individual features of the writing signatures are extracted from the writing pressure using the ball-point pen. The judgment whether the signatures are genuine or not is obtained from the Euclid distance in the MTS standard space. When the MTS method is applied to the problem, in order to improve the discrimination accuracy, the sufficient learning samples are needed. However, it is difficult to collect many samples from one person in the signature of the individual certification. Then, the method in which the large virtual data group from the small data arises is proposed. It is the method using the orthogonal array.

2. COMPOSITION OF THE PEN FOR WRITING

2.1 Principle of writing pressure detection

When the vibrating rod of the finite length contacts with the measuring object, the resonant frequency of the rod is changed. This change of the resonant frequency is used for measuring the writing pressure. The model of the contact is shown in Fig.1.

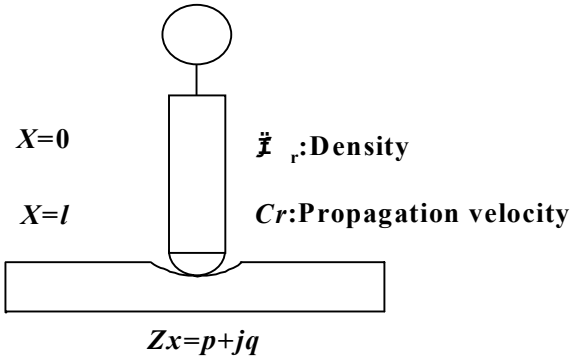

Fig.1. Contact model of the ball-point pen

When the tip of the rod in the resonant state contacts with the measuring object of the unknown acoustic impedance, the plane wave of the length direction in the rod is expressed as the next equation.

$$\frac{d^2\Phi}{dt^2} = C^2r \frac{d^2\Phi}{dx^2} \qquad (1)$$

where, Φ is velocity potential and Cr is the sound velocity in the rod. The equation can be solved by the variables separation method. The change of the resonant frequency when the rod has contacted the writing plane becomes the following equation. The writing pressures in the signatures are measured using the relationship between the change of the resonant frequency and the writing pressure as shown in equation (2).

$$\Delta f = \frac{Cr\, q_r}{2n\pi L Z_r} \quad (2)$$

where, Z_r is acoustic impedance of the rod, q_r is reactance of Z_r, n is vibrating number and L is the length of the rod.

2.2 Structure of ball-point pen

The structure of the ball-point pen for the writing pressure measurement is shown in Fig. 2. The PZT for the vibration and the piezoelectric element which detects the vibration are set in the ball-point pen shaft. The ball-point pen shaft is resonated by the PZT, when the tip of the ball-point pen does not contact with the writing plane.

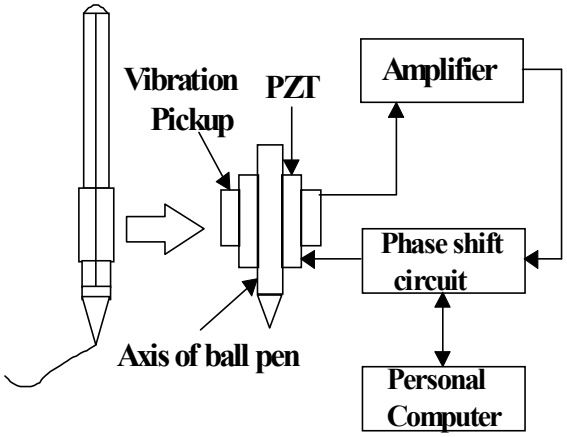

Fig. 2. Structure of ball-point pen and measuring circuit

When the ball-point pen contacts the writing plane, the output signal of the detecting PZT is fed back to the vibrator PZT. The shaft of the ball-point pen is made to be the resonant state using the enforced feedback oscillation circuit by the vibrator PZT.

3. MTS METHOD AND EUCLID DISTANCE

3.1 MTS method

The MTS method is proposed as one of the multi-dimensional information processing techniques and the applications to the various fields are carried out. When the MTS method is applied to the identification problem, lots of learning samples are needed in order to obtain the high discrimination accuracy. It is necessary to collect the large data. But, it is difficult to collect the sufficient signature data in the case of the individual signature. The lowering of the discrimination accuracy is forecasted, if little of the signature data is made to be the database. Then, the method in which the large virtual data group arise from the little data using the orthogonal array is proposed. The virtual data group is made to arise by allocating the collected data to the orthogonal array. In the MTS method, the discrimination is carried out by the Mahalanobis distance, because there are the correlations between the data. When the orthogonal array is used, there are not the correlations between the arisen data and the Euclid distance is taken the place of the Mahalanobis distance.

3.2 Euclid distance

The Euclid distance is expressed as the next equation, when the unknown pattern vector is x and μ is the mean vector of some classes and Σ is the covariant matrix.

$$D^2(x) = (x - \mu)^T \Sigma^{-1} (x - \mu) \quad (3)$$

The vector x is standardised by the mean value m and the deviation σ of the individual data of some classes. The concept in applying the Euclid distance to the discrimination of the signatures is shown in Fig. 3. The distances of the true signatures are around 1.0 and the distances of the false signatures are distributed far from 1.0. The discrimination of the true and false signatures becomes possible by setting the threshold between the both distances.

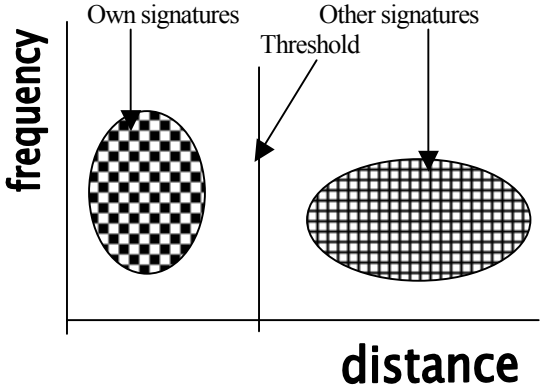

Fig. 3. Concept of signatures discrimination

4. DISCRIMINATION EXPERIMENT OF SIGNATURES

4.1 Experimental method

The names are signed on the writing space using the ball-point pen which is built in piezoelectric device and the frequency spectrum for the time series data of the writing pressure using MEM (Maximum Entropy Method) is made to be the database for the discrimination of the signatures. The discrimination experiments of the true and false signatures are carried out. The experimental procedures are as follows:

(1) The true signatures of ten times are written on the usual printing paper. The time series data of the writing pressure are collected.
(2) The frequency spectrums are obtained using MEM.
(3) The frequency is divided into 127 equally and the average power of the ten times data is calculated in the corresponding frequency.
(4) The two levels data shown in the next equation are allocated to the orthogonal array. The plus (+) in the equation corresponds to the first level in the orthogonal array and the minus (-) corresponds to the second level.

$$\text{Data} = \text{average power} \times (1.0 \bullet 0.05) \quad (4)$$

(5) The L_{128} orthogonal array is made out and the virtual data are got from the orthogonal array. The Euclid standard space is structured from the virtual data got from the orthogonal array.
(6) The other people imitate the signature. Ten persons write two times. The frequency spectrums are obtained for the time series data of these writing pressures and the Euclid distances are calculated for each frequency spectrums.
(7) The true and false signatures are distinguished by the small or large of the Euclid distance.

Japanese, Korean and American write the signatures of each own character. The discrimination experiments of the three kinds are carried out.

4.2 Experiment results

(1) Signature of Japanese character

The time series data of the writing pressure for the signature of [Suzuki Ichiro (Japanese)] are shown in Fig. 4 and Fig. 5. Fig. 4 is the time series data of the true signatures and Fig. 5 is the data of the false signatures. Fig. 6 and Fig. 7 show the frequency spectrums. Fig. 8 shows the final result.

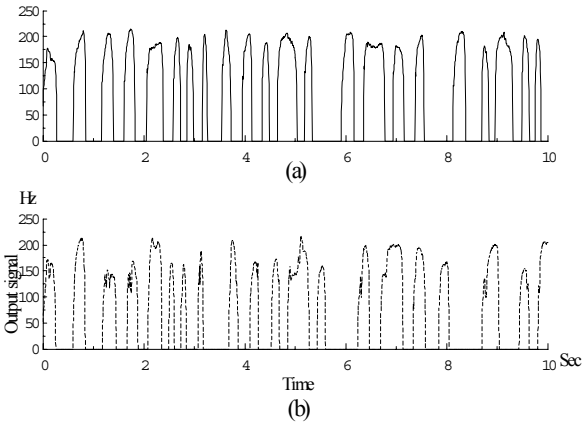

Fig. 4. Time series data of true signatures

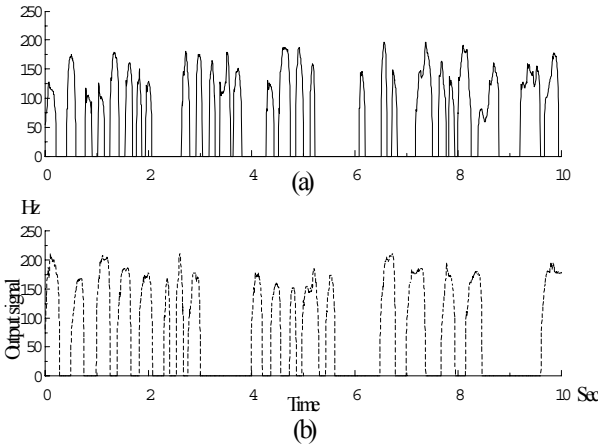

Fig. 5. Time series data of false signatures

(2) Signature of English character

The time series data of the signatures are shown in Fig. 9 and Fig. 10. The discrimination result for these signatures is shown in Fig. 11. When the threshold is made to be 4.0, the discrimination between the true and false signatures of English character.

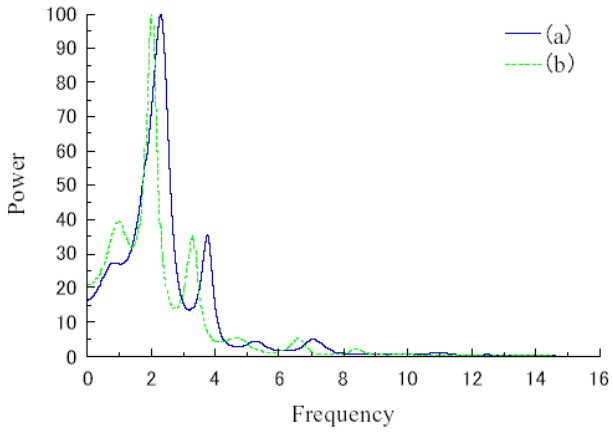

Fig. 6. Frequency spectrum of true signature

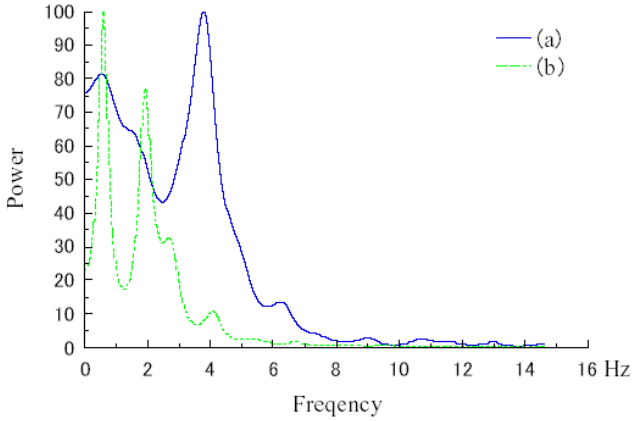

Fig. 7. Frequency spectrum of false signature

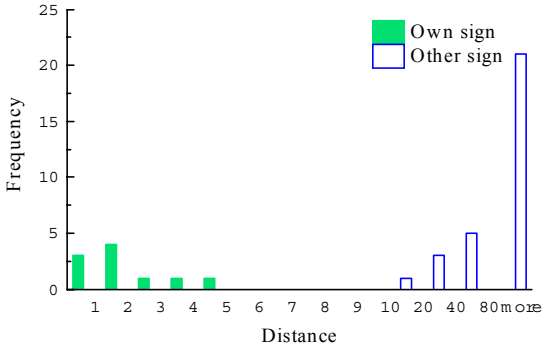

Fig. 8. Discrimination result of Japanese [Kanji]

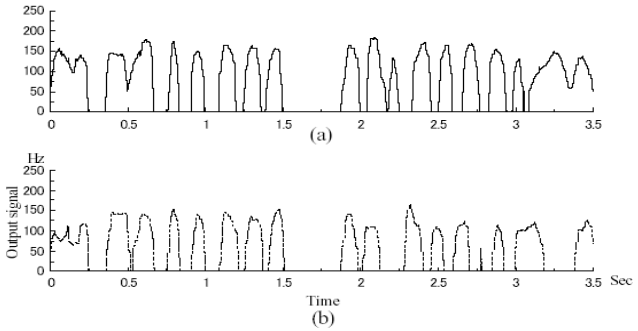

Fig. 9. Time series data of true signature [English character]

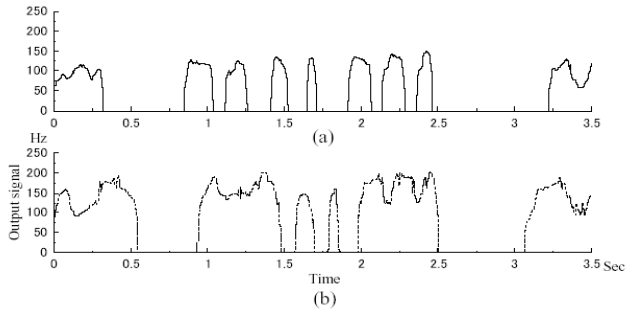

Fig. 10. Time series data of false signature [English character]

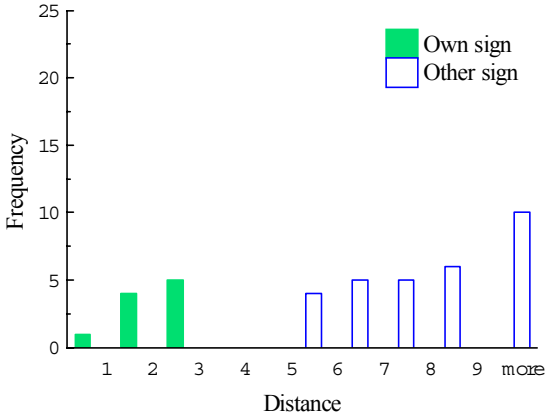

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Fig.11. True and false signatures of English character

(3) Signature of Hangul character

The time series data of Hangul character signature is shown in Fig. 12 and Fig. 13. The result of the experiments is shown in Fig. 14.

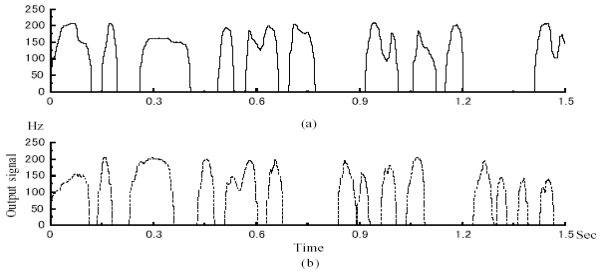

Fig. 12. Time series data of the true signature[Hangul]

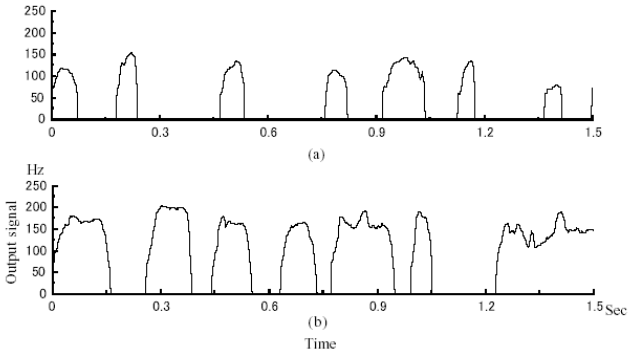

Fig. 13. Time series data of the false signature [Hangul]

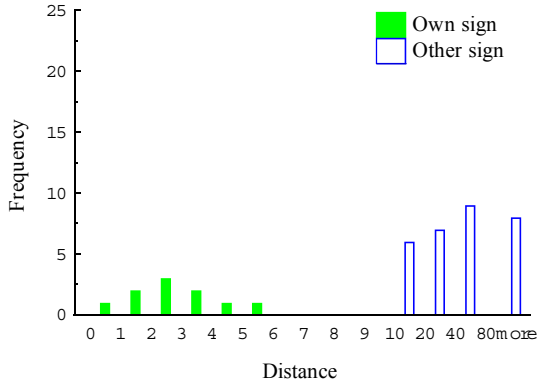

Fig. 14. Discrimination result of Hangul character

3. CONCLUSIONS

The PZT piezoelectric elements were installed in the ball-point pen shaft, and the time series data of the writing pressure in the signatures were measured from the change of the resonant frequency in the ball-point pen shaft. The frequency spectrum analysis for the time series data was carried out using MEM method. In addition, it was shown that the discrimination between the true signatures and the false signatures could distinguish by the Euclid distances using the analysis of the MTS method. In application of the MST method to the problems, lots of learning data are needed, because of heightening the discrimination accuracy. The generating method of the large virtual data group was proposed. The lots of the data were generated from the small number of the learning data using the orthogonal array. The conclusions in the study are as follows:

(1) By the analysis based on the MTS method, the discrimination of whether the signatures are true or false is possible. The signatures for Japanese character, English character and Hangul character can be distinguished by the size of the Euclid distance.

(2) It is possible to carry out the more high-precise discrimination by the frequency spectrum using the MEM (Maximum Entropy Method) analysis for the time series data of the writing pressure as the input data.

(3) It was shown that the discrimination accuracy should be heightened from the virtual data group using the orthogonal array. The high-precise discrimination for the various signatures are possible.

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