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# Software of Dynamic Signature Authentication Using Global and Local Features

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## Abstract

This paper deals with authentication of dynamic signatures written on a tablet and an electronic pen. From a dynamic signature, it is possible to extract global features as well as local features. Global features mainly distinguish the personal differences, and it is not much affected by the signature shape. On the contrary, local features depend on the shape and various local manner of writing.

This paper describes the criteria and software used for dynamic signature authentication. A number of global and local features are used, and the parameters for them were tuned heuristically.

**Keywords**: dynamic signature authentication, multicriteria, software, graphical user interface

## 1. INTRODUCTION

In this paper, a software for the authentication of dynamic signatures is discussed in detail, where dynamic signatures are the ones written with a tablet and its e-pen for personal identification [1]-[3]. In the highly-networked society, the importance of biometrics is becoming more and more important to securely identify a person. Among numerous biometrics methods, methods such as fingerprint, iris, vein of palm, vein of finger, and face have been used in the real world. Each method has its merits and drawbacks. The authors have been paying attention to signature authentication[4]-[5]. Signature verification is intrinsically low in recognition rate compared to the methods listed above. This is due to the large variation of the true signature, and the distribution of features of true signatures and the forgeries are hard to be completely separated. In spite of the low recognition rate, we have been investigating this method due to several reasons: first, signature has been used for personal authentication, and hence it is widely accepted in real life. Second, once a forger appears who can imitate the true signature, the targeted person can change his/her signature quite easily. It is not easy for other biometrics. Third, it seems to have a niche such as examination or official procedures with document. People are necessary to write their names in such occasions, and they don't have to do any other actions if appropriate instruments are prepared in such places.

Dynamic signature(e.g. [1],[2],[3]) is the one written on the tablet with an electronic pen. For the signature verification problems, we considered a two-stage method [6, 7, 8, 9]: the first stage is to match the signatures of the whole signatures point-wise, and the second stage is to compare the points where some special features of the signature holder appear.

Our software shown here is the test bed for future development, and the algorithm has not been fixed. We have so far included criteria both in global features and local features. Global features are numerous feature values that come from the whole signature, which includes features such as the mean values of the pressure or speed, the length of the signature writing time, and so on. On the other hand, local features come from various points of the signature, and they come from the comparison between the current signature and the registered one. Global features express the personal manners, and we can expect the similar global features for different character strings written by the same person. To get the local features, it is necessary to match the current signature to the registered one, where the dynamic programming (DP) matching is used here. This is a simple algorithm, and we don't need many signatures to get a stochastic model. This fact (that we need only one signature as the model) is very important in biometrics, where we can get only one of a couple of data as the registered data.

Section 2 explains the data and pre-processing we use in this paper. Section 3 describes the criteria to be used in our current software. Section 4 describes the software GUI (graphical user interface) and the functions of each button or window. Section 5 shows some experimental result, and we conclude the paper in Section 6.

## 2. DATA ACQUISITION SYSTEM

### 2.1 System and data

The tablet we are using is Intuos 2 by WACOM, with WinTab driver. The computer is with Windows XP. The program is coded by Microsoft Visual C++.net. Figure 1 shows the authentication system.



**Figure 1. Signature authentication system.**

The available data comes every 10ms approximately. Data acquisition is by a software that is now separated from authentication program. One signature is denoted by $p(k), k = 1, \ldots, n$, where $k$ is the discrete-time of the pen information, and $n$ varies according to the signature drawing time. Note that $p(k)$ is a vector that includes various pen information, *i.e.*

$$
p(k) = \begin{bmatrix} x \text{ position} \\ y \text{ position} \\ \text{pressure} \\ \text{angle} \\ \text{direction} \end{bmatrix} \tag{1}
$$

The data is recorded when the pen is close enough to catch the position even when the pen is not touching the tablet. Hence vectors with 0 at the pressure element are included before and after the vectors where pressures are positive.

### 2.2 Normalization of signatures

It is necessary to normalize signatures for extracting various feature values. It seems necessary to cut the points before and after the signatures.

In signatures of Japanese characters, for example, they consist of several characters, and most of the Japanese people write their signatures just as writing the characters separately. This situation seems more or less similar in east Asian countries. When a person finishes writing one character and moving the pen apart from the tablet, he/she sometimes takes a break, and the idling time is not always very similar.

Hence we exclude the idling time part from the signature. The procedure is as follows.

1. Delete the points when the pen is in the air.

2. Confine a signature in a fixed size rectangular, where the width is fixed. The height is not fixed because the freedom of the height variation is kept. The top line of the re-scaled test signature is moved to that of the registered one.

## 3 CRITERIA FOR AUTHENTICATION

### 3.1 Global features

The global features available from dynamic signatures is worth considering for verification.

Lee *et al.* [1] developed a method to use a number of global features, then extracting the statistical parameters such as mean and the standard deviation, and finally make a judgment by voting based on the result whether each feature is within the normal deviation. However, the method requires sufficient amount of signatures of same person, which is not appropriate for signature verification problem.

We here develop another method that also uses the same kinds of global features, and is valid even if the number of signatures is only one in the extreme case.

Now we define the feature vector of a signature by $\boldsymbol{x}^i \in \mathbf{R}^n$ where $i$ denotes the signature number. We define these features by our intuitive consideration, but they can be defined in more systematic ways, *i.e.* by using genetic algorithm or other soft computing methods.

### 3.2 Distance between two signatures

The registered signature sequence and the test sequence are expressed as

$$
\begin{aligned}
\mathbf{p} &= [p(1)\ p(2)\ \cdots\ p(P)] \\
\mathbf{q} &= [q(1)\ q(2)\ \cdots\ q(Q)]
\end{aligned} \tag{2}
$$

where $p(k)$ and $q(k)$ are vectors expressed by equation (1). It is possible to use the 5-dimensional data for this problem, and it is also possible to use some selected items of the vector for this problem, e.g. $x$ and $y$ positions. This selection can be made in the actual computation: thus we don't

## Table 1. The global features

| 1 | the total signing time |
|---|---|
| 2 | the number of strokes |
| 3 | the maximum pen pressure |
| 4 | the maximum speed of the pen |
| 5 | the maximum of the pen angle |
| 6 | the minimum of the pen angle |
| 7 | the maximum of the pen direction |
| 8 | the minimum of the pen direction |
| 9 | the width of the signature (*) |
| 10 | the height of the signature (*) |

(*) these features are applicable only when the frame for
the signature is the fixed standard size
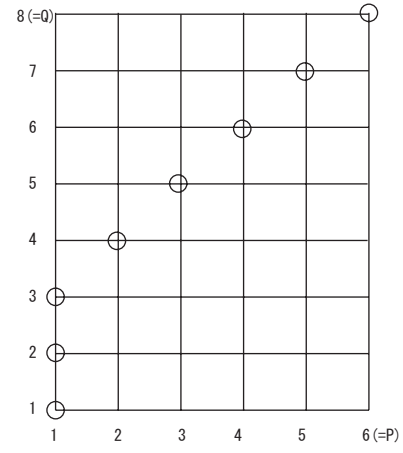


**Figure 2. Matching of two sequences**

specify which elements to use. The matching problem is to
derive the correspondence relation.

The problem to measure two similar vector sequences also
exist in speech recognition, and there is a popular method
named Levenshtein Distance [4].

Levenshtein distance is a measure for two character strings.
For example, if the two strings are "word" and "world",
the two strings become the same if "l" in the second string
is deleted. The measure is 1 in this case. For "tanaka"
and "tanaca", these become the same if the "c" in the
second string is changed to "k". In this way, by deleting and
inserting characters, it is possible to match any two strings
whose length are not necessarily the same.

As an example, "tanaka" matches "muranaka" as "t-
-anaka" where "-" indicates that there is no correspond-
ing character to the other string. Table 2 shows the corre-
sponding characters between "tanaka" and "muranaka"
by assigning $p(1)$ =t, $p(2)$ =a, $\cdots$, and $q(1)$ =m, $q(2)$ =u,
$\cdots$, respectively. Figure 2 shows the plot of corresponding
points in a 2-D grid.

### Table 2. Example of correspondence

| $p(1)$ | - | - | $p(2)$ | $p(3)$ | $p(4)$ | $p(5)$ | $p(6)$ |
|---|---|---|---|---|---|---|---|
| $q(1)$ | $q(2)$ | $q(3)$ | $q(4)$ | q(5) | $q(6)$ | $q(7)$ | $q(8)$ |

We can define the delete $(r)$, insert $(s)$ and replace $(d(i, j))$
cost appropriately, where $d(i, j)$ is the cost to replace the
specified character. Then we can obtain the strings corre-
spondence relation which has the minimal cost. It can be
done by defining the optimal cost $g(i, j)$ for partial strings
$\mathbf{p} = p(1)p(2) \cdots p(i)$ and $\mathbf{q} = q(1)q(2) \cdots q(j)$, where
$1 \le i \le P; 1 \le j \le Q$. Then by the optimality principle,

we have

$$g(i,j) = \min \begin{cases} g(i-1,j) + r \\ g(i-1,j-1) + d(i,j) \\ g(i,j-1) + s \end{cases} \quad (3)$$

In signal processing, the problem is similar to character
matching, but is not the same. That is, the sequences con-
sist of vectors, not a character. The vectors are not the same
even if they are considered to match. Hence the recursive
form

$$g(i,j) = \min \begin{cases} g(i-1,j) + d(i,j) \\ g(i-1,j-1) + 2d(i,j) \\ g(i,j-1) + d(i,j) \end{cases} \quad (4)$$

is obtained, where $d(i, j)$ is the Euclidian distance between
two vectors.

To solve this problem, we first compute $g(P, Q)$ start-
ing from $g(0, 0) = 0$, and then compute backward from
$g(P, Q)$ to $g(0, 0)$.

### 3.3 Local features

**Criterion 1 (CR1)** where v1 and v2 are two signature
vectors, N is the number of the corresponding point set ob-
tained in DP matching, N1 and N2 are the number of points
in signatures 1 and 2, respectively. The elements of v1 can
be defined arbitrary in the software. Our experience is that
using the positional values $(x, y)$ gives the best result.

**Criterion 2 (CR2)** In Fig.3, we can see a red line. This
shows how the points in two signatures correspond. x1 axis
shows the sampling time for the signature 1, and x2 axis is
for the signature 2. If this line is a straight slope, it means

the data points were correctly matched. If the line goes right or up (0 or 90 degree directions), it means the corresponding was not uniformly. Second criterion is the ratio of this value among all the correspondence.

**Criterion 3 (CR3)**    If the correspondence to the right or up persists, the quality of correspondence becomes extremely bad. In this experiment, the count for this was set to 10. The criterion 3 shows the ratio of this kind of correspondence among all the corresponding points.

These three values are shown in the small windows in the upper-right part of the window.

The local features include various local information such as the speed of certain bending point, the pen direction when the signature finishes, etc. The objective of this subsection is to create a "standard" signature as well as the distribution model from signatures of the same person.

First, we normalize the signatures in such a way to confine the signatures to a same rectangular which is derived from the specified signature.

Next, we use DP matching to make correspondence between the given signature and the sample one, and make the number of points the same among all the signatures.

Finally we will calculate the mean values of the adjusted signatures and the eigenspace obtained from the primal orthogonal eigenvectors of the covariance of the signatures.

In the following, we will explain the procedure in detail for each step.

### 3.4   Total judgment

If one or more of the following conditions fail, the signature is judged to be a forgery. Otherwise it is considered to be a genuine one.

The threshold for acceptance for each criterion will be shown in the item 18 in the next section.

## 4   SOFTWARE DESCRIPTION

Figure 3 shows the graphical user interface (GUI) of the authentication system.

We will explain the buttons and the display windows in detail.

1. Message window.

2. Enter the initial.

3. Click this button when the initial has been set.

4. To decide which registered signature to use, click this button. Then a file dialog appears. Select one of the files to use for authentication.

5. Selected file name is set here.

6. For the experimental work, use this file dialog box to select the test signature to be used for offline authentication. In the actual authentication procedure, this is not used.

7. Same as the window 5.

8. It is possible to see the registered signature.

9. If one clicks after setting the registered file name, the trajectory of the pen movement is drawn.

10. This is the button to authenticate. It is necessary that the test signature has been drawn by using the input program.

11. This figure window shows the obtained corresponding points, and is a graphical version of Fig. 2. Both axes denote the sampling time of the registered signature and the test one, respectively, where the points when the pen is not touching the tablet are omitted. The red line connects the corresponding points obtained by DP matching.

12. Push this button to delete all the information displayed on the windows; i.e. this is the reset button.

13. The trajectories of the selected registered signature and the test signature are displayed by blue and red lines, respectively. Moreover, the corresponding points obtained by DP matching are connected by black lines.

14. A criterion related to local features is shown here. The value Cr1 is defined as

$$Cr1 = \frac{\frac{1}{l}\sum_{t=1}^{l}\left(p(i_t) - q(j_t)\right)^{\top}\left(p(i_t) - q(j_t)\right)}{\sqrt{\frac{1}{n_p}\sum_{i=1}^{P}p(i)^{\top}p(i)}\sqrt{\frac{1}{n_q}\sum_{i=1}^{Q}q(i)^{\top}q(i)}}$$

which is the normalized square error between the corresponding points in the registered and test signatures.

15. The proportion of the "delete" and "insert" positions over the length of the correspondence length (the horizontal length of the table in Table 2). If this value (Cr2) is small, the correspondence curve is very smooth.
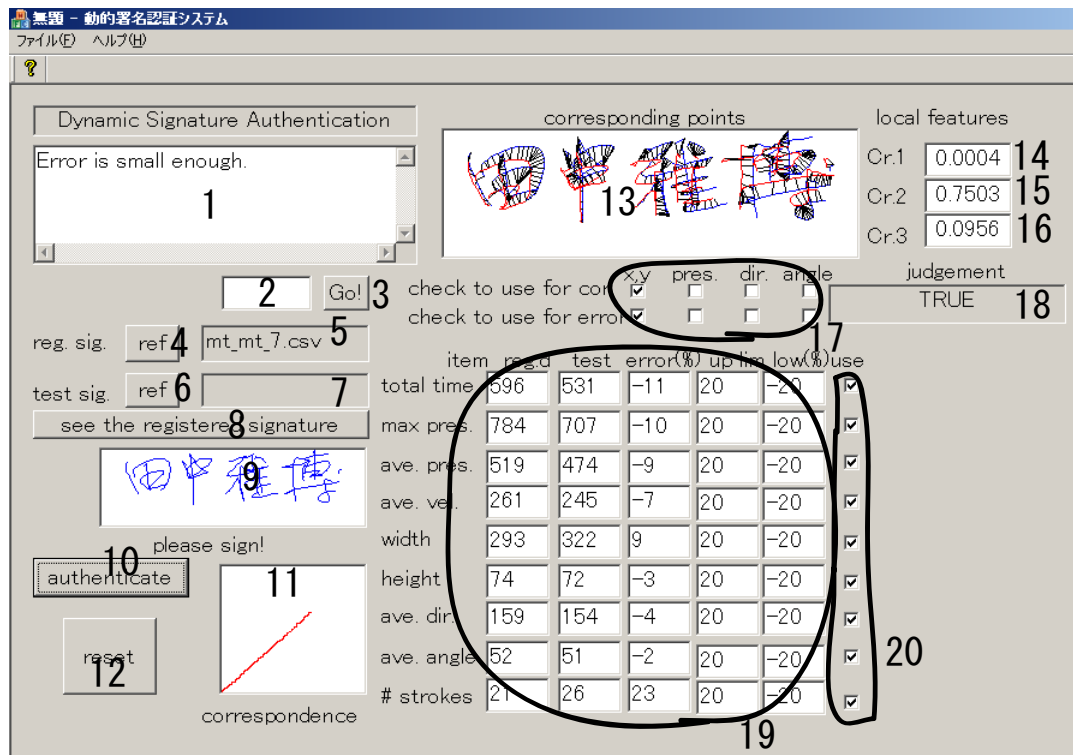
Figure 3. GUI of the system.

Dynamic Signature Authentication

Error is small enough.

corresponding points

local features
Cr.1 0.0004 **14**
Cr.2 0.7503 **15**
Cr.3 0.0956 **16**

check to use for cor...
check to use for erro...

judgement
TRUE **18**

reg. sig.   ref **4**   mt_mt_7.csv **5**
test sig.   ref **6**
see the registered signature **8**

please sign!
authenticate **10**
reset **12**
correspondence

| item | reg'd | test | error(%) | up | low(%) | use |
|---|---|---|---|---|---|---|
| total time | 596 | 531 | −11 | 20 | −20 | ✓ |
| max pres. | 784 | 707 | −10 | 20 | −20 | ✓ |
| ave. pres. | 519 | 474 | −9 | 20 | −20 | ✓ |
| ave. vel. | 261 | 245 | −7 | 20 | −20 | ✓ |
| width | 293 | 322 | 9 | 20 | −20 | ✓ |
| height | 74 | 72 | −3 | 20 | −20 | ✓ |
| ave. dir | 159 | 154 | −4 | 20 | −20 | ✓ |
| ave. angle | 52 | 51 | −2 | 20 | −20 | ✓ |
| # strokes | 27 | 26 | 23 | 20 | −20 | ✓ |

**16.** This (Cr3) is a similar criterion as Cr2. This is mainly to detect the different character or written in wrong orders. When a matching is far from successful, the correspondence curve consists of a lot of vertical and horizontal segments. This criterion reflects this phenomenon. When the vertical or horizontal movement persists, the counter is couted up.

**17.** These small boxes ($2 \times 4$) are to select for the inclusion/exclusion of the calculation of the elements of the pen information in equation (1) in the calculation. The upper row is for the calculation of DP matching, and the lower row is for the calculation of Cr1. The buttons from left to right are the following items.

**(i) x,y** coordinate

**(ii) pres** pressure of the pen (0-1023)

**(iii) dir** direction (0-359)

**(iv) angle** angle from the tablet (0-90)

For the DP matching, using only the coordinate information gives the best matching property.

**18.** The final result is shown here. TRUE or FALSE is displayed. The judgment parameter was used as shown in Table 3:

**Table 3. Threshold values for judgement**

| parameter | threshold |
|---|---|
| CR1 | 0.002 |
| CR2 | 0.9 |
| CR3 | 0.2 |

These values were decided based on numerous experimental works for the case of evaluating using $x, y$ values in item 17 (second row of the check boxes, of course). The threshold values should be redefined for other cases of check, which has not been done yet.

**19.** This numerical table deals with the global features. Each row indicates a certain global feature. The following is the meanings:

**total time** total time (unit: 10ms) when the pen is touching the tablet

**max pres** maximal pressure during the signature action

**ave pres** average pressure during the signature action

**ave vel** average velocity (calculated from coordinates) when the pen is touching the tablet

**width** the width of the signature area confined in a rectangular parallel to the axes

**height** the height of the signature area confined in a rectangular parallel to the axes

**ave dir** average direction

**ave angle** average angle

**# strokes** the number of strokes in the signature

The columns mean the followings:

**reg.d** the numbers come from the registered signature

**test** the numbers come from the test signature

**error** this value is the error value

$$\text{error} = \frac{\text{test} - \text{reg.d}}{\text{reg.d}}$$

**up lim** the upper limit of the tolerance of the error. This value can be manipulated by changing the value in the frame.

**low lim** the lower limit of the tolerance of the error. This value can be manipulated by changing the value in the frame.

20. The number of accepted items decides the acceptance/rejection of global features. Now, global features are approved if the portion of rejection is less than 20% of the items whose check box (named "use") is checked. It is possible to exclude any items for the decision.

### 4.1 Other related programs

Currently the signature input program and signature registration program are separated from this authentication program.

The signature input program is used both for the signature registration and the signature authentication procedures. This program outputs a signature file to a specified directory. The authentication program refers this file as the test file all the time.

The registration program moves the signature file that is at the specified directory to a registration directory with the initial name.

## 5 EXPERIMENTAL RESULT

Figure 4 shows a successful result for a true person to authenticate. Figure 5 shows a failure result: i.e. the same person signed, but the signature was written very faithfully to the printed character. By looking at the note that appeared

on the main message box, we can see that only the static feature didn't match. We can see that the test signature was written slowly and discontinuously.

Figure 6 shows a failure case by writing wrong characters. Although the same person signed, the signature didn't match by DP matching. Note that the global feature was close to the acceptance level.

By looking at the correspondence curve shown in the bottom-mid place, we can see that these two signatures didn't match at all. This means the signatures were something like the case when the characters were wrong.

## 6 CONCLUSIONS

This paper described a GUI interface and its function for dynamic signature authentication. The verification method used now is a mixture of criteria based on global features and local features.

We have already investigated various authentication methods, and we are going to use useful methods among those in this system.

### Acknowledgment

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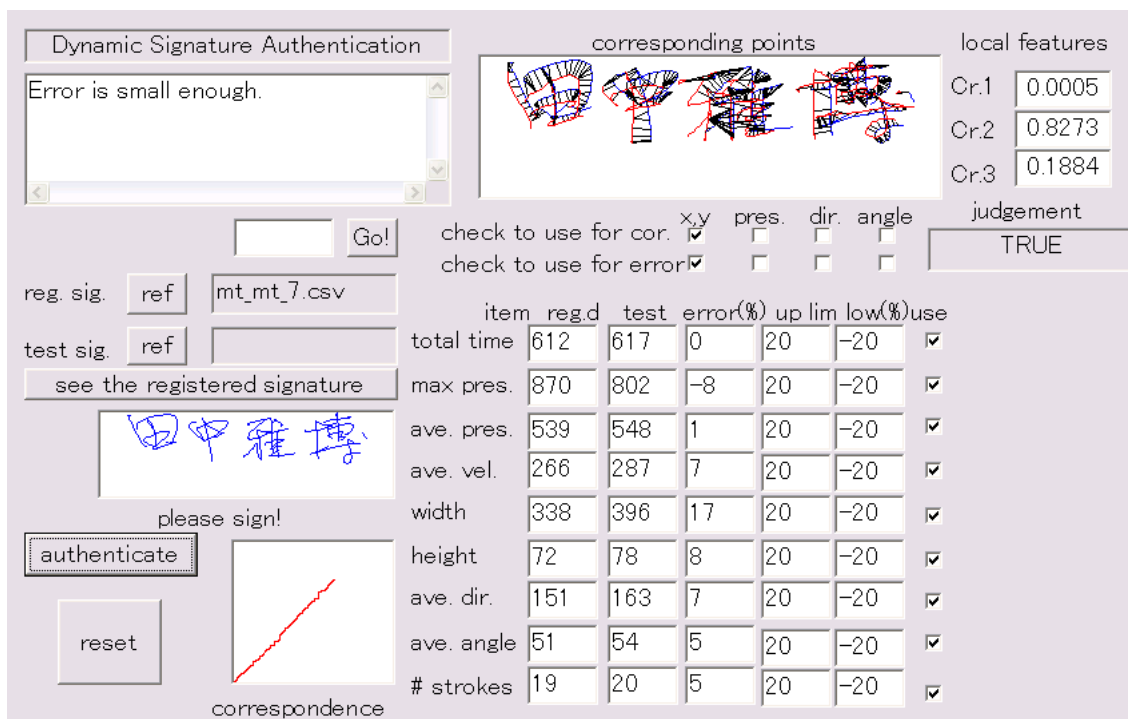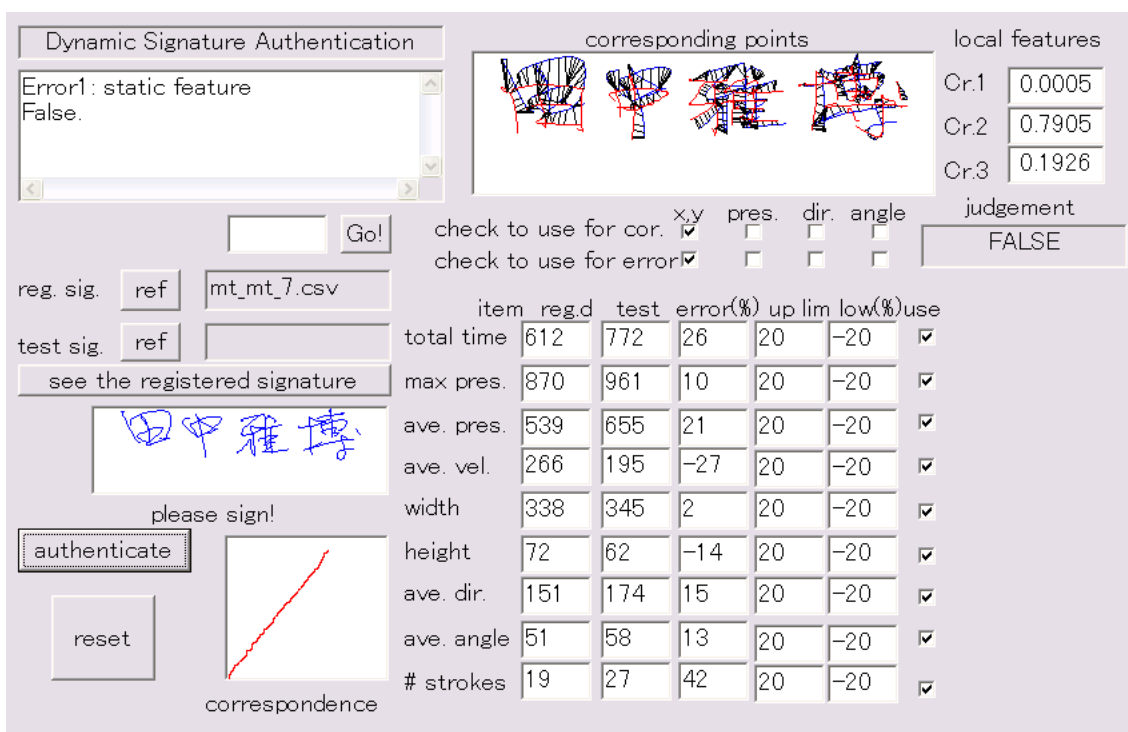
**Figure 4. A successful case.**



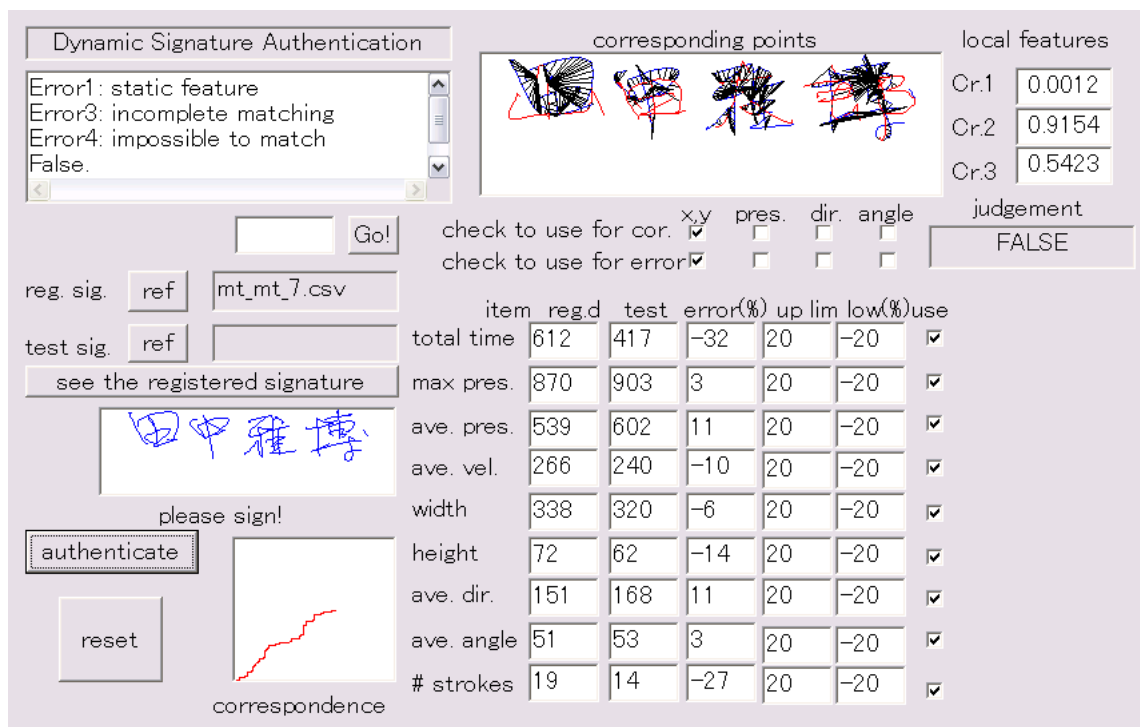**Figure 5. False decision. The writer intentionally wrote the signature in a rigid way.**

**Figure 6. False detected.**

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