Periodical Examinees Identification in e-Test Systems Using the Localized Arc Pattern Method

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Abstract
In this paper, we study an identification method for use in e-Test systems. The e-Test is a tool for assessing knowledge of examinees over the World Wide Web. This type of test is useful for examinees at distant locations. However, some drawbacks of the e-Test have been pointed out, especially when used for strict tests such as the entrance examination tests of universities. One of the most critical drawbacks is the difficulty in confirming examinee identification. Many e-Test systems only ask for the password to confirm identification at the start of the test. Nevertheless, it is difficult to determine impersonations of examinees during the test at remote locations. To overcome this drawback, we propose here an e-Test system that confirms the examinee identification periodically during the test.

Considering that examinees write their answers using pen tablets in e-Test systems, we can use writer identification of the answers for confirmation without disturbing the examinees during the test. We apply the localized arc pattern method (Yoshimura & Yoshimura 1991), conventionally used for off-line identification based on the arc of an individual stroke of a certain sentence on paper, for examinee identification when using pen tablets. The outline of the original method has three steps. First, each character on paper is scanned into a computer and converted to binary images. Next, we count the numbers of matching binary patterns of the images with predetermined numbers. Finally, the writer is identified by comparing the numbers statistically with those of the registered data. This method can identify writers based on signatures in most cases.

Since the original method was investigated in terms of characters written on paper, we first examined whether the method can be applied to characters written on pen tablets. We used characters written by 4 persons, where each person writes 48 sentences with 25 characters each. We take the first 8 sentences as the registered data set for each person and the other sentences remain as the test data set. The two data sets are compared in order to identify the writer. Our experimental results show that approximately 80% of the test data accurately identified the writer. To improve the percentage, we consider a combination of the proposed method and writing characteristics such as pen pressure.

Keywords
e-Test, Identification

1 Introduction
Although asynchronous e-learning, which frees examinees of time and spatial constraints, has been drawing much attention in recent years, the number of universities that extend credits solely through e-learning remains small; only 32% of all universities offer courses in which students can earn credits solely through remote learning (Media Education Development Center 2006). We surmised that e-testing, a mode of testing in which students write tests on the web, would be a very effective method for administering tests in that it poses minimal spatial constraints on examinees in remote areas. However, the large number of IDs and passwords in user authentication systems run by educational institutions (Media Education Development Center 2006) makes these systems vulnerable to illicit activities such as impersonation and cheating. As a result, e-testing has not been widely implemented.

With regard to the issues of cheating and impersonation on e-tests, this study focuses on impersonation and aims to propose an authentication scheme for preventing this problem. Multiple-choice tests are the focus of this study. First, we examine authentication schemes that are suited for e-tests. Next, we study whether the localized arc pattern method (Yoshimura & Yoshimura 1991) – a method for identifying the writer based on one letter written on a
piece of paper — can be applied to e-tests. To this end, we conduct tests to verify whether the localized arc pattern method is equally effective in situations where pen tablets are used. We then conduct tests to verify whether the localized arc pattern method can be applied to letters in the "け" row of the Japanese alphabet which are frequently used in multiple-choice tests. Finally, we propose a localized arc pattern method that utilizes dynamic writing information (writing pressure) which can be obtained on a pen tablet, and verify the effectiveness of this method.

2 Review of e-test authentication schemes

2.1 Proposed authentication for e-tests

Impersonation is easily achieved on ID- and password-based methods of authentication which are currently used in e-tests (Fig. 1). For example, an examinee can provide his or her ID and password information to a third party and this third party can take the test on the examinee's behalf. One way to prevent impersonations during tests would be to implement periodic ID/password-based authentications (periodic authentication). However, asking the examinee for his or her ID and password frequently throughout the test would be disruptive and would not be practical. In any case, impersonation can be achieved easily by communicating the ID and password to a third party before the test.

Biometric methods of authentication (The Biometrics Security Consortium 2006), which are more difficult to impersonate, are effective in countering these problems. Biometric authentication refers to methods of authentication using an individual's physical or behavioral features.

2.2 Handwriting-based authentication

There are two types of authentication methods based on handwriting: one based on static information and the other based on dynamic information.

Static information (off-line information) refers to information on handwriting, letter width, and density. This information can be obtained from letters handwritten by pen or pencil on a piece of paper, by first scanning them and then putting them through image processing. This method is currently used for authenticating signatures on checks as well as in the field of bibliotics.

Dynamic information (on-line information), on the other hand, consists of time series information including x and y coordinates, writing speed, writing pressure, and pen angle. This information can be obtained on a pen tablet. Moreover, because dynamic information describes characteristics of movement, methods using this information make impersonation more difficult. Dynamic signature authentication is used for security on PCs.

Since dynamic information changes over time, authentication precision also declines over time. Therefore, if used alone, authentication schemes based on dynamic information may experience a decline in performance caused by variations in the student's movements that may occur over time due to pressure from the test and other factors. Another important point to keep in mind is that characteristics are difficult to identify from single letters such as those that are used in multiple-choice questions, and this makes authentication difficult (Fujimori, Nakahira & Fukumura 2008). The acquisition of static information on the other hand is a more consistent way of obtaining handwriting data (The Biometrics Security Consortium 2006).

To overcome these issues, we examine how the localized arc pattern method – a method of identifying individuals using static information – can be used for e-test authentication. The localized arc pattern method is a procedure for identifying the writer based on one letter written on a piece of paper. In this study, we first conduct tests to ascertain whether the localized arc pattern method can be used for handwritten answers that are entered on the system's pen tablet. In this study, we aim to prevent impersonation by performing authentication for each multiple-choice question (periodic authentication) (Fig. 2).

Figure 1: Authentication scheme in conventional

Figure 2: Proposed authentication scheme for e-tests (periodic authentication)
3 Localized arc pattern method (Yoshimura & Yoshimura 1991)

3.1 Localization

The localized arc pattern method (Yoshimura & Yoshimura 1991) uses a single letter written on a piece of paper by an unknown writer $Q$ and identifies the writer of the letter in question by referencing the same letter (hereafter referred to as registration data) written by previously registered writers $P_i$ ($i = 1, 2, ..., a$). To do this, the letter is written by pen or pencil, scanned, converted to binary information, and used for identification.

With regard to features with which to identify the writer, we focus on the fact that unique writing characteristics appear as different proportions of straight and curved lines used to write a letter. Specifically, we first consider a binary image consisting of $n \times n$, and define "model patterns $n \times n^p$" with $p$ patterns from among all binary images (of which there are $2^{n \times n}$). An earlier study (Yoshimura & Yoshimura 1991) defines these for $n = 2, 3, \text{and } 5$. In Fig. 2, we select nine binary images from among all binary images in the $2 \times 2$ area, and define five patterns by bringing similar images together to arrive at model pattern $2 \times 2$.

Next, the region of the letter which has been converted to a binary image is divided into $d \times d$. Then, we examine the frequency at which model pattern $n \times n$ exists in each of the divided areas. We define this frequency to be a $p$ ($=p' \times d \times d$) dimensional feature vector.

![Figure 3: Model pattern 2 x 2](image)

3.2 Identifying the writer

Using a letter written by an unknown writer $Q$, the primary component is analyzed for the $p$ dimensional feature vector of the registration data to create a feature space that can be used effectively to perform identification along the axis of the primary component. The corrected Mahalanobis' generalized distance (Kimura F, Harada T, Tsuruoka S & Miyake Y 1986) within the feature space between the feature vectors of the registration data and the letter written by writer $Q$ is calculated using the following equation:

$$D(P_i, Q) = \frac{1}{\lambda_q} \sum_{k=1}^{p} (z_{Q,k}^i - z_{Q,k}^i)^2 + \sum_{k=q+1}^{p} (z_{Q,k}^i - z_{Q,k}^i)^2 / \lambda_q$$  \hspace{1cm} (1)

Where $z_{Q,k}^i$ and $z_{Q,k}^i$ are scores for the $k$th primary components of writer $Q$ and registrant $P_i$, respectively, $q(1 \leq q \leq p)$ is the censored value of the fixed value, and $\lambda_1, \lambda_2, ..., \lambda_p$ are fixed values. This distance is examined for all 'a' number of registrants and the $P_j$ registrant with the smallest value determined to be writer $Q$.

4 Applying the localized arc pattern method to pen tablet data

In this chapter, we describe the two assessment tests that we carried out. In the first test, we verified whether or not we can apply the localized arc pattern method to letters written on pen tablet. In the second, we verified whether the localized arc pattern method can be applied to letters of the "あ" row - letters that are used frequently in multiple-choice questions - when written on a pen tablet.

4.1 Assessment test 1

4.1.1 Overview of assessment test 1

This study considers an e-testing system where students are asked to answer multiple choice questions using a pen tablet. In our test, we attempt to verify whether the localized arc pattern method, which is effective for single letters written on a piece of paper, is equally effective for single letters written on a pen tablet.

The test involved four subjects. Test conditions were defined based on an earlier study (Yoshimura & Yoshimura 1991). The subjects were asked to write the sentence "大学の土地は愛知県名古屋市千種区不老町にもあります" (25 letter types) on a pen tablet. Each subject was asked to write this sentence eight times, after which a break was taken. This was repeated for a total of six times. On the day before the tests, the subjects were given roughly 10 minutes of practice time to familiarize themselves with the pen tablet. Registration data for the subjects were created using two sentences each from the first to fourth sessions for a total of eight sentences. Twenty-four sentences, randomly chosen from the remaining sentences, were used as the identification data. These were compared to the registration data to determine whether or not the writer of the identification data could be correctly identified.

The effectiveness of this method was evaluated by comparing the results of this assessment test, in which subjects were asked to use pen tablets, with results from the earlier study (Yoshimura & Yoshimura 1991). The comparison was performed by comparing the rates at which registrants were correctly identified ($=100 \times \text{correct identification count}/24$). The follow-
Evaluation (1): The appropriate combination of model pattern $n \times n$ ($n=2, 3,$ and 5) and letter division area count $d \times d$ ($d=2, 3,$ and $4$) were studied using three typical types of letters "押", "〇" and "カ.”

Evaluation (2): Based on combinations of results from evaluation (1), the censored value $q$ of the fixed value was studied by varying this value from 10 to 50 in increments of five for three typical letter types "押", "〇" and "カ.”

Evaluation (3): Evaluation was based on the identification rates for the 25 letter types in the $q$ values of the results of evaluation (2).

These three typical types of letters were used for assessment in order to avoid overestimations in identification rates that can occur when all letter types are used (Yoshimura & Yoshimura 1991). Typical letter types were chosen by selecting one type from each of the three groups that Yoshimura et al. defined in an earlier study (Yoshimura & Yoshimura 1989), based on identification rates for the 25 letter types.

4.1.2 Evaluation (1): The appropriate combination of model pattern $n \times n$ and letter division area count $d \times d$

Similar to the earlier study (Yoshimura & Yoshimura 1991), eight combinations were studied from among the model pattern $n \times n$ ($n=2, 3,$ and $5$) and letter division area count $d \times d$ ($d=2, 3,$ and $4$) excluding those that used combinations of $n=5$ and $d=2$. These combinations were excluded because the vector dimension would become $p=1,072$, making fixed value calculations impractical. The censored value $q$ for the fixed value was defined to be $q=30$ as it was in the earlier study (Yoshimura & Yoshimura 1991), with $q=15$ used only when $p<30$.

Table 1 shows the results from evaluation (1). Results from the earlier study (Yoshimura & Yoshimura 1991) show the average identification rate for 24 subjects. Results for this assessment test show the average identification rate of four subjects. The $Sn$ in $SnDd$ in Table 1 denotes model pattern $n \times n$, and $Dd$ denotes division area count $d \times d$. For example, S2D2 denotes a combination of a model pattern of $2 \times 2$ and a letter division area count of $2 \times 2$.

Similar to the earlier study (Yoshimura & Yoshimura 1991), the best results from evaluation (1) were obtained from the S5D2 combination. Test conditions such as the number of subjects, test period, and pen tablet familiarity are likely to have contributed to the fact that results from this assessment test were better than those from the earlier study (Yoshimura & Yoshimura 1991). For evaluation (2) and subsequent evaluations, p-values were performed using S5D2.

4.1.3 Evaluation (2): censored value $q$ of the fixed value

In evaluation (1), the censored value of the fixed value was fixed at either $q=15$ or $q=30$. Therefore, to study the effects of varying $q$ values in S5D2, the change in identification rates was studied by varying $q$ from 10 to 50 in increments of five. Table 2 shows the results of evaluation (2). In the earlier study (Yoshimura & Yoshimura 1991),

<table>
<thead>
<tr>
<th>Dimension $q$</th>
<th>Early study (%)</th>
<th>Assessment tests in this study (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>85.4 72.0 78.0</td>
<td>91.7 88.5 85.4 88.5</td>
</tr>
<tr>
<td>15</td>
<td>89.5 74.0 80.9</td>
<td>94.8 93.8 91.7 93.4</td>
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<tr>
<td>20</td>
<td>91.5 76.0 82.6</td>
<td>94.8 93.8 91.7 93.4</td>
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<td>25</td>
<td>92.4 77.6 82.5</td>
<td>94.8 92.7 91.7 93.1</td>
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<td>30</td>
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<td>35</td>
<td>94.1 79.0 84.0</td>
<td>94.8 92.7 91.7 93.1</td>
</tr>
<tr>
<td>40</td>
<td>94.3 79.2 83.7</td>
<td>94.8 92.7 91.7 93.1</td>
</tr>
<tr>
<td>45</td>
<td>94.4 79.3 84.0</td>
<td>94.8 92.7 91.7 93.1</td>
</tr>
<tr>
<td>50</td>
<td>94.8 78.6 83.0</td>
<td>94.8 92.7 91.7 93.1</td>
</tr>
</tbody>
</table>

$q=45$ produced the best results. Meanwhile, results from this assessment test were largely the same except when $q=10$. While differences in test conditions may have contributed to this result, variances in average identification rates in the earlier study (Yoshimura & Yoshimura 1991) were approximately 1-2% except in cases where $q=10$ was used. Therefore, we may safely conclude that better results can be obtained using a somewhat larger $q$ value. In evaluation (3), we use $q=45$ to compare our results with the earlier study (Yoshimura & Yoshimura 1991).
4.1.4 Evaluation (3): Identification rates of the 25 letter types

In evaluation (3), we examine the identification rates for the 25 letter types using S5D2 and \( q = 45 \), which were obtained from the results of evaluations (1) and (2).

Figure 4 shows the results from evaluation (3). The identification rates in evaluation (3) were partially in line with the results of the earlier study (Yoshimura & Yoshimura 1991). Identification rates that varied widely from that of the earlier study (Yoshimura & Yoshimura 1991) were likely caused by differences in test conditions. Just as in the earlier study (Yoshimura & Yoshimura 1991), an identification rate of 100% was achieved for the entire sentence.

Figure 4: Evaluation (3): S5D2, identification rate of each letter type at \( q = 45 \)

4.1.5 Summary of assessment test 1

The results obtained in evaluations (1) through (3) in this assessment test were similar to those of the earlier study (Yoshimura & Yoshimura 1991). Therefore, we surmised that the localized arc pattern method was effective in identifying the writer using a single letter written on a pen tablet.

4.2 Assessment test 2

4.2.1 Overview of assessment test 2

In assessment test (2), we verify the effectiveness of using the localized arc pattern method for letters in the ".middle" row – letters that are frequently used in multiple choice questions – when they are written on pen tablet.

In this assessment test, six subjects were asked to write the letters "middle" five times each on three separate, nonconsecutive days. Practice time was provided before the tests so that the subjects could familiarize themselves with pen tablets. In line with assessment test 1, eight pieces of registration data were used per letter and the remaining seven were used as identification data.

Assessments were performed based on the average identification rates of the five types of letters in the "middle" row using different combinations of parameters, namely, model pattern \( n \times n \), letter division area \( d \times d \), and censored value \( q \) of the fixed value. The aim of this research is to prevent impersonations by implementing real-time periodic authentications during e-tests. Authentication processes that take time will interfere with examinees taking the test. Computing time, which partially depends on programming, will generally be longer the more features there are to check (Yoshimura & Yoshimura 1991). Using a system that is currently under development, we were able to verify that approximately one second in computing time would be required with a feature count \( p \) of less than 150, making real-time periodic authentication possible. Moreover, while a reduction in the number of features is likely to diminish identification performance, using larger numbers of features does not necessarily result in better performance (Ishii K, Ueda S, Maeda E & Murase H 1998).

In this assessment test therefore, we verify the average identification rates for each of the parameters for letters in the "middle" row for combinations S2D2, S2D3, S2D4 and S3D2 where \( p < 150 \). As in assessment test 1, the censored value \( q \) of the fixed value was varied from 10 to 50 in increments of five. In S2D2, the maximum value for \( q \) will be 20 as the feature count \( p \) is 20. Similarly, in S2D3, the maximum for \( q \) will be 45 as the feature count \( p \) is 45.

4.2.2 Results of assessment test 2

Table 3 shows the results of this test. S2D3 with a \( q \) value of 15 showed the best average identification rate of letters in the "middle" row at 86.64%. Meanwhile, the worst average identification was 78.54% in S2D4 with a \( q \) value of 35 and 40. S2D2 with \( q = 20 \), and S2D3 with \( q = 40 \) and \( q = 45 \) are not shown because these introduce zero into the fixed value, rendering equation (1) unsolvable.

From these results, we surmised that the localized arc pattern method can be applied by selecting the appropriate parameters for letters "middle" through "middle" that are written on a pen tablet.
4.3 Discussion of assessment tests 1 and 2

Results of assessment test 1 suggest that localized arc patterns can be used in pen tablet-based e-tests. Results of assessment test 2 suggest that the localized arc pattern method can be applied by selecting the appropriate parameters for letters "ㄍ" through "ㄊ" that are written on a pen tablet. However, these identification rates are not sufficient to prevent impersonation. Therefore, we consider augmenting the localized arc pattern method with dynamic information, a form of information that is considered to be difficult to impersonate.

5 Proposing a localized arc pattern method augmented with writing pressure which can be obtained on a pen tablet

5.1 Localized arc pattern method augmented with writing pressure

As described in chapter 2, dynamic information (on-line information) consists of time series information including x and y coordinates, writing speed, writing pressure, and pen angle. However, dynamic information alone is not sufficient in discerning features based on simple single letters such as those used in multiple choices, making authentication difficult (Fujimori, Nakahira & Fukumura 2008). Therefore, in this study, we consider augmenting the localized arc pattern method with dynamic information as opposed to using dynamic information alone. The localized arc pattern method uses the proportions of straight and curved lines in a letter, which are static pieces of information, to perform authentication. With these pieces of information, we can expect to find individual variability in the writing pressure; for example, some people may apply strong pressure on straight sections and less pressure on sweeps of a letter. Based on this idea, we propose a localized arc pattern method that incorporates writing pressure.

Conventional localized arc pattern methods uses binary imaging where 1 is registered if writing is present during image processing, and 0 if none is present. This was used as the basis for defining model pattern \( n \times n \) (Fig. 1). The proposed method uses writing pressure that can be obtained on pen tablet (1-1023). Writing pressure is categorized into weak pressure (1-314) represented by 1, normal pressure (342-682) represented by 2, and strong pressure (683-1023) represented by 3 to define model pattern \( n \times n \). Figure 5 shows model pattern \( 2 \times 2 \) which takes writing pressure into account.

Identifications were performed in the same way as in section 3.2.

5.2 Assessment test 3

5.2.1 Overview of assessment test 3

In assessment test 3, we use data from assessment test 2 to compare the results from applying the localized arc pattern method on letters in the "ㄍ" row written on pen tablet (hereafter referred to as method 1), and the proposed method (hereafter referred to as method 2) to verify whether method 2 provides an effective means of authentication. As with other assessment tests, the censored value \( q \) of the fixed value was varied from 10 to 50 in increments of five.

5.2.2 Results of assessment test 3

Table 4 shows the results of tests performed for method 2. P3 indicates the categorization of writing pressure into three groups. S2D2P3 where \( q = 35 \) and \( q = 50 \) provided the best average identification rate for letters in the "ㄍ" row at 90%. S2D2P3 where \( q = 10 \) gave the worst average identification rate for letters in the "ㄍ" row at 87.6%.

This indicates that the best average identification rates for methods 1 and 2 were 86.64% (chapter 4) and 90% respectively, with method 2 showing an improvement of 3.6% over method 1. The worst average identification rates for methods 1 and 2 were
78.54% (chapter 4) and 87.6% respectively, with method 2 showing an improvement of 9.06% over method 1.

Table 5 shows a comparison between methods 1 and 2. In order to compare these two methods, identification rates in method 2 where \( p>150 \) are also shown. This comparison shows that method 2 delivers better results. We also note that in method 2, S2D2P3 where \( p<150 \) gives the best identification rate.

In addition, we inspected the differences in the average results obtained in methods 1 and 2 where \( p<150 \). This is shown in Table 6. We found significant differences in the 5% range between methods 1 and 2 (\( t=8.47, \text{df}=22, \text{p}<0.05 \)). This statistically significant difference suggests the effectiveness of method 2.

### 6 Summary and issues for future research

In this study, we examined methods of authentication for preventing impersonations in multiple choice e-tests. As one method of authentication, we tested and verified whether the localized arc pattern method, which is an effective method for identifying the writer of a single letter written on a piece of paper, would be effective for letters written on a pen tablet (assessment test 1). Results from this test were similar to those of an earlier study (Yoshimura & Yoshimura 1991), verifying that the localized arc pattern method is equally effective in e-tests where pen tablets are used. Next, we conducted tests to verify whether the localized arc pattern method can be applied to letters in the "representation" row – letters that are frequently used in multiple choice questions – when they are written on pen tablet (assessment test 2). This test showed that an identification rate of 86.64% can be achieved using letters in the "representation" row, and suggested the effectiveness of this method. Additionally, based on our assumption that further improvements in identification rates would be required to prevent impersonations, we proposed a localized arc pattern method augmented with writing pressure information (method 2). Results from assessment test 3, which was a comparison of methods 1 and 2, suggested that method 2 was more effective than method 1.

In subsequent studies, we plan to conduct tests in a simulated exam setting where subjects are given only a limited amount of time. We also believe that further improvements in identification rate would be required to prevent impersonations. To this end, we will consider an improvement to method 2 which incorporates other forms of dynamic information in addition to writing pressure.

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