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On-line Signature Verification based on Pen Inclination and Pressure Information

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ABSTRACT

In this paper, the features that have personal characteristic using pen inclination and pressure information are discussed. Forging a pen inclination and pressure information is difficult because it is not visible. Four features using invisible information are proposed and their characteristics are discussed. Proposed features calculated by physical vector analysis are verified by SVC2004 database using DP matching algorithm. As a result, the new feature named Down improves the recognition rate and reliability. Average of correct verification rate is 94.57 % and variance is 0.667.

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1. INTRODUCTION

Recently, biometrical authentication systems are suggested, such as using fingerprint, vein and retina which are inherent characteristic to a person[6]. However, some people hesitate for collecting biometrical characteristic, such as fingerprint. Signing name is much more common and people dose not fell resistance[8].

The signature data is classified into two kinds of format, one is on-line data and other is on-line data. Recent on-line signature data has six dimensions data along time, whereas on-line data is static image data written by a person. The on-line signature data enable to obtain invisible information and personal characteristics[1, 5].

Many researchers use xy coordinates information that is inputted from the pen tablet for on-line signature verification[2, 3, 4]. However, the pen tablet can also obtain pen pressure and pen inclination information. Those information are difficult to forge other person's signature because those are not visible [6, 7]. They include personal characteristics, such as the person how to grip a pen and how to move it. Some researchers verify the signature by complex features using weight factor, however it is not always success because weight factor is calculated by features of signature database. When other database is used, those factor need to be changed in many case.

In this paper, we propose two invisible features named PenRad and Down which are calculated physically for on-line signature verification. The recognition rate of on-line signature verification is improved by our proposed features.

The later parts of this paper is organized as following. Sec. 2 discusses on-line signature information, Sec. 3 proposes four features using invisible information, Sec. 4 explains about verification method, Sec. 5 shows verification result.

2. PEN TABLET INFORMATION

The general pen tablet obtains six dimensions data see Figure 1: x coordinate, y coordinate, pen pressure, pen direction (θ), pen altitude (φ) and time. When pen-up, accurate pen incline information is not obtained. We can not use pen information when pen-up.

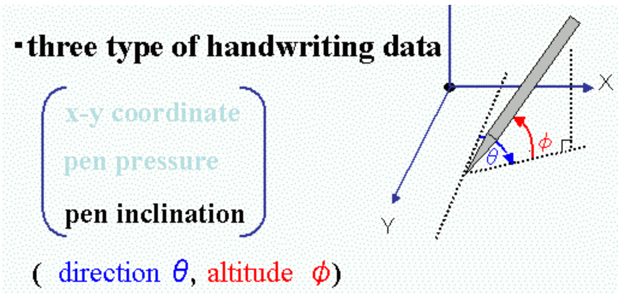

Figure 1. Pen tablet inputting information

3. DEFINITION OF PERSONAL FEATURES

In this paper, we define the personal features using pen inclination and pressure information obtained by pen tablet. Pen inclination information consists of pen direction and altitude. However, it is difficult to use them in unison, because their ranges (eq.1,2) are different. We need a new feature what calculated from the pen incline information if we refuse the use of weight. In this section, we propose four features: absolute pen top point(*apt*), related pen top point(*rpt*), *PenRad* and *Down*.

$$0 \le direction < 2 * \pi \quad (1)$$
$$0 \le altitude < \pi \quad (2)$$

3.1. Absolute Pen Top Point

We define absolute pen top pointapt that is three dimensions coordinate calculated by spherical polar coordinate equation. The conversion equations of pen inclination information to three dimensions polar coordinate are follow:

$$atp_x = r \times \sin \varphi \times \cos \theta, \quad (3)$$
$$atp_y = r \times \sin \varphi \times \cos \theta, \quad (4)$$
$$atp_z = r \times \cos \varphi, \quad (5)$$

r where a pen length factor that means as the weight how much pen inclination information is reflected, φ is pen direction and θ is pen altitude. The absolute pen top point represents relative movement of a pen from where pen touches tablet as illustrated in Figure 2.

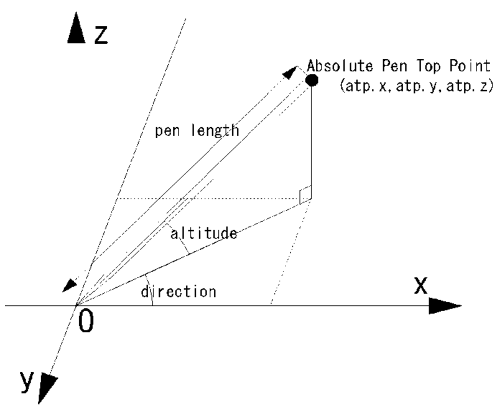

Figure 2. Illustration as absolute pen top point. It is around the original coordinate.

3.2. Relative Pen Top Point

The pen tablet obtains pen nib coordinate as the *xy* coordinate information. Relative pen top point reflects the person how to grip and incline the pen. *Relative pen top point* contains *xy* coordinate and pen inclination. *Relative pen top point* is calculated by following equation:

$$rtp_x = atp_x + x\ , \quad (6)$$

$$rtp_y = atp_y + y\ , \quad (7)$$

$$rtp_z = atp_z\ , \quad (8)$$

Relative pen top point is added *xy* coordinates and *absolute pen top point*. It is a big problem to calculate an appropriate pen length, because *relative pen top point* contains the *absolute pen top point* as illustrated in Figure 3. When weight factor of pen length is big, *relative pen top point* close to *absolute pen top point* and when pen length is small, pen inclination data not reflect to *relative pen top point*.

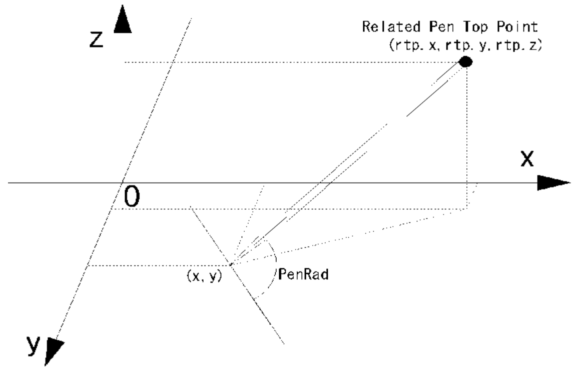

Figure 3. Illustration as relative pen top point. Relative pen top point is added xy *coordinate and* absolute pen top point.

3.3 PENRAD

Relative pen top point needs proper pen length that is used by *atp*, however it is difficult to calculate the effective it. We introduce an another angle feature *PenRad* which does not require weight factor to calculate. *PenRad* is an angle between vector *atp* and vector (*dx, dy*) as illustrated in Figure 3. It represents a pen inclination to the direction of pen movement. *PenRad* is calculated by follow:

$$l = \sqrt{\mathrm{dx} \times \mathrm{dx} + \mathrm{dy} \times \mathrm{dy}} \quad (9)$$

$$PenRad = \arccos\left(\frac{atp_x \times dx + atp_y \times dy\ |}{r * l}\right) \quad (10)$$

PenRad is influenced by the person how to grip a pen and which height of a pen is griped.

3.4 DOWN

When a person writing a signature, he/she forces two kind of power vectors: the forces to the drawing face and to the movement of a pen. The direction of pen pressure information originally obtained by pen tablet equal to the vector of pen inclination, not equal to perpendicular to the drawing face. It means the pen pressure is influenced by pen movement inclination. Some researchers use original pen pressure[8,9], however, we define *Down* feature to represent the perpendicular vector to the drawing face. *Down* feature is calculated by (*dx,dy*) feature, *PenRad* feature, pen inclination and pen pressure information as illustrated in Figure 4. First, the (*dx,dy*) vector is separated into the perpendicular vector and parallel vector to pen inclination. Next, the parallel vector of pen inclination is added to pen pressure information (eq.13). Finally, angle of the added to pressure vector is corrected by pen altitude (φ) (eq.14).

$$v = \sqrt{\mathrm{dx} \times \mathrm{dx} + \mathrm{dy} \times \mathrm{dy}}\ , \quad (11)$$

$$\mathrm{move_p} = v \times \cos(PenRad)\ , \quad (12)$$

$$\mathrm{pressure'} = pressure \times w + move_p\ , \quad (13)$$

$$\text{Down} = pressure' \times \sin(altitude),\qquad (14)$$

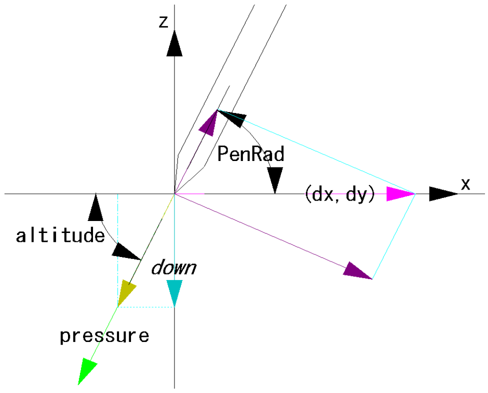

Figure 4. Down is calculated with physically vector analysis. Direction of *x*-axis is same to pen movement.

To calculate *Down* feature, the weight factor w is needed because the range of pressure and pen movement is different. Weight factor w is experimentally calculated in Section 5.1.

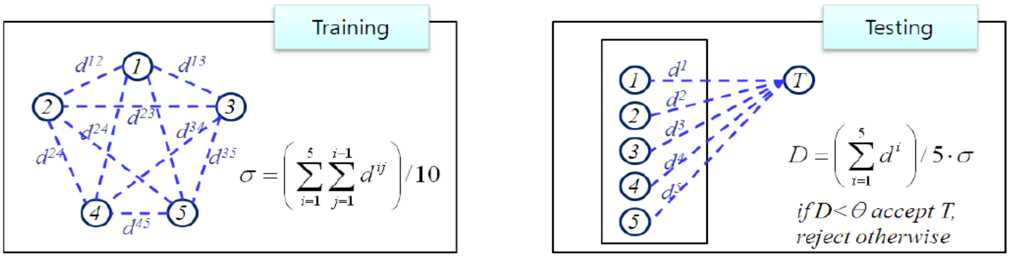

Figure 5. On-line signature verification system. θ is threshold about accept or reject [3].

4. SIGNATURE VERIFICATION

In this paper, we use the database of Signature Verification Competition 2004 (SVC2004) Task2 that include the pen incline and the pen pressure information [10] to verification. SVC2004 database have 20 genuine signatures and 20 skilled forgeries written by 40 users. We use randomly selected 5 genuine signature data as training data and calculate the signature distance between training signatures and test signatures using Dynamic Programming matching algorithm. The signature distance is calculated by follow equation (eq.16, 17) and Figure 5:

$$g(i,j) = min\begin{pmatrix} g(i-1,j) \\ g(i-1,j-1) \\ g(i-1,j-2) \end{pmatrix} + dist(i,j), \quad (15)$$

$$\sigma = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} d^{ij}}{n \times (n-1)} \quad (i \neq j), \quad (16)$$

$$D_k = \frac{\sum_{i=1}^{n} d^{ik}}{n \times \sigma}, \quad (17)$$

where *dist(i,j)* is a distance between *i*-th point of signature *A* and *j*-th point of signature *B*. n is a number of test signatures. d^{ij} is distance of signature *i* and signature *j*, and regularly d^{ij} is not equal to d^{ij} because of DP matching algorithm (eq.15). σ is variance of *n* training data and D_k is evaluation value of signature *k*. Since the training data are selected at random, 100 training patterns combinations are tested to increase reliability of verification.

5. RESULT AND DISCUSSION

In this paper, the signature verified by four features: derivation of xy coordinates (*dx,dy*), derivation of *relative pen top point* (drtp), *PenRad* and Down feature. We calculate the FRRs (false reject rates) and the FARs (false accept rates) about the signature distance and calculate the EERs (equal error rates). As a result in Table 1, the *Down feature* is the best effort.

Table 1. EER result about four features. Smaller standard deviation means the verification method is more stable.

Feature	Average(%)	Stdev
dx,dy	6.844	0.857
pressure	11.783	0.687
drtp	6.865	0.883
PenRad	7.397	0.697
Down	5.430	0.667

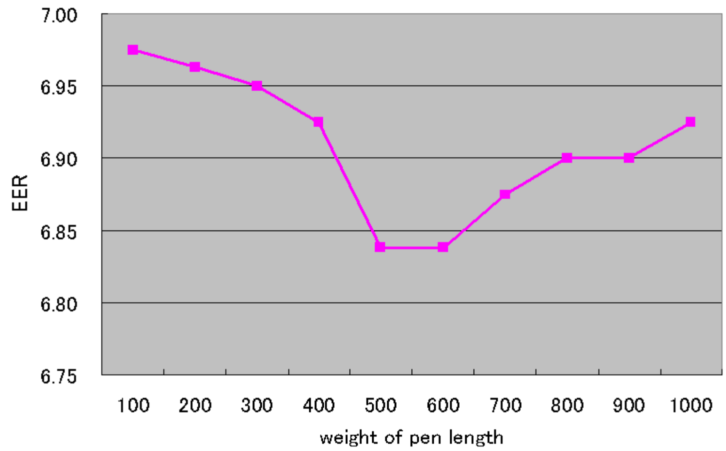

Figure 6. EERs varying in pen length of *relative pen top point*. In calculating *relative pen top point*, the best weight of pen length *w* is 500. When pen length equal to 0, *pen top point* is same to xy coordinate.

Relative pen top point and *Down* have weight factors that are pen length and pressure weight. We calculate those weight factor by experiment. We calculate an EER with varying in weight factor. Figure 6 is the result of *relative pen top point* and Figure 7 is the result of *Down* feature.

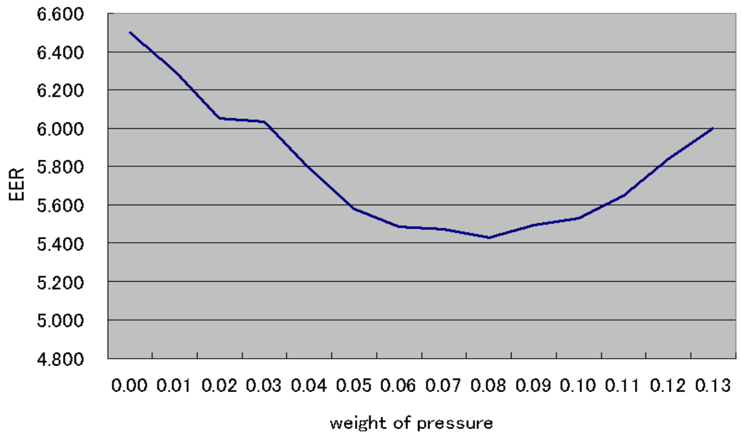

Figure 7. EERs varying in weight of pressure. In calculating *Down*, the best weight of pressure *w* is 0.08. EER is sensitive by changing of weight.

6. CONCLUSION AND FUTURE WORKS

We have presented new features using pen inclination and pen pressure. Some features have weight factor that is calculated by experiment. However, we require equation of calculating a proper weight, because when we use other signature database to verification, weight factor is change. In this paper, pressure information is used to calculate Down feature and average of correct verification rate is improved to 94.57%. In the future, we will propose another feature calculated by pen inclination information without weight factors.

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Jungpil Shin received a B.A. in computer science and statistics and an M.S. in computer science from Pusan National University, Korea in 1990 and 1994, respectively. He received a Ph.D. in communication engineering from Kyushu University, Japan in 1999. He became an assistant professor and associate professor in the Department of Computer Software, the University of Aizu, Japan, in 1999 and 2004, respectively. His research interests include pattern recognition, character recognition, image processing, and computer vision. He is currently researching the following advanced fields: pen-based interaction system, realtime system, oriental character processing, mobile computing, computer education, human recognition, and machine intelligence. He is a member of the IEEE Computer Society; Information Processing Society of Japan; Institute of Electronics, Information, and Communication Engineers; and Korea Information Science Society.

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