A Study on Feature Extraction and Matching of Enhanced Dynamic Signature Verification

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Abstract

This paper is a research on feature extraction and comparison method of dynamic (on-line) signature verification. We suggest desirable feature information and modified DTW(Dynamic Time Warping) and describe the performance results of our enhanced dynamic signature verification system.

Key Words : Dynamic, On-line Signature Verification, Feature Extraction, Comparison Method, DTW Matching

1. Introduction

The need to be able to identify other individual human beings is fundamental to the security of the family unit and has been true since the beginning of human history. Members of a tribe needed to be able to identify other members of the tribe quickly, easily and usually from a distance. Using the remembered physical or behavioral characteristics of each member achieved this. How a person looked, what they were wearing, how they moved or combinations of these were used to authenticate the person as a member. The biometric technology allows for a greater reliability of authentication as compared with badges, card readers or password systems. The chances of an individual losing his/her biometric information are far less the forgetting a password or losing a card. Through these types of verification, comes an increased role of responsibility, and security.

All biometric techniques have false accepts generated by the imperfections of the classification method or by errors in the acquisition device. However, dynamic signature verification using behavioral biometric technique, compared with physiological biometric techniques such as fingerprint, face, iris or retina, have additional advantage that a forger with not-enough information about the true signature could not deceive the verification algorithm because multi-dimensional feature information of dynamic signature, that is, speed of stroke, size of signature, pressure, variable shape, pen down/up information and so on, decrease the risk of accepting skilled forgeries since they are not available to the forger

2. Dynamic Signature Verification System

Dynamic (On-line) signature verification field has gained increasing attention in recent times [5]. As one of the biometric authentication methods, signature has been widely accepted in real life, because it is user-friendlier than fingerprint, iris, retina and face. Signatures are acquired using digitizing tablet that captures both temporal and spatial information, such as coordinates, pressure, inclinations, etc.

Two aspects pose challenges in the field of dynamic signature verification. On one side, intra-personal variation can be large. Some people provide signatures with poor consistency. The speed, pressure and inclinations pertaining to the signatures made by the same person can differ greatly, which makes it quite challenging to extract consistent features. On the other side, we can only expect few samples from one person and no forgeries in practice. This makes it very difficult to determine the consistency of extracted features. According to our experience, one of the most reliable features is the shape of the signature. The next reliable feature is the speed of writing. Due to lack of benchmark databases for on-line signatures, we will not argue the consistency of these features here but propose a novel similarity measure for signature verification.

The errors of verification can be classified in two categories False rejection rate (FRR) indicates the rate of genuine signatures rejected that is, evaluates the number of false signatures classified as real one False acceptance rate (FAR) indicates the rate of accepted forgeries that is, measures the number of genuine signatures classified as forgeries. The Equal Error Rate (EER) corresponds to the error value for which FAR is equal to FRR. These rates determine the quality of an authentication system, but the acceptable values depend on the level of security desired for a specific application.

3. Proposed Feature Extraction

We introduce useful feature points in our on-line signature verification system. Finding out the best method to calculate the degree of similarity is very important. The previous approach for that is to select and arrange distinctive points [3,8,16]. For the best signature verification, it is important to reduce the range of variation of the true signature and to extend distinctiveness between the true and forgeries. Assigning the adequate weight for each feature is another important point.

The useful feature points are below:

- Speed, velocity, acceleration, pressure information
- Shape of coordinates, direction and slope between two points
- Number of pen down/up points
- Information of pen down/up movement
- Total time taken in signing
- Pen down/up time between strokes
- Number of strokes
- Total number of coordinates

Our system primarily uses directions and absolute distances (in Fig. 1)between two points for the pen down/up strokes. We know that these two features include many information of the signature that is, the shape and speed, information of strokes, elapsed time and so on with our experiment and experience.

The feature vectors of pen down movement have values of 1 to 36 directions. And the feature vectors of pen up movement have values of 91 to 126 directions. But, distances have absolute length of value between two points as Fig. 2. All distances are defined less than 128. So, these directions and distances can be stored in byte strings of small memory.

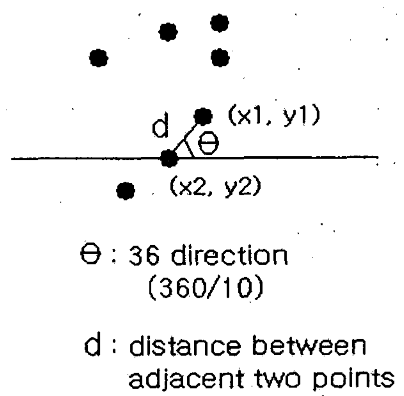
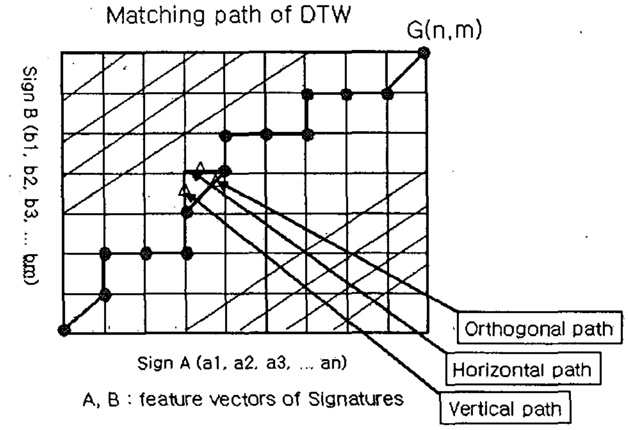


Fig. 1. Signature features of direction and distance

4. Proposed Comparison Method

One of the most important difficulties in authentication using on-line signatures is the choice of the comparison method. On-line signatures are given by a sequence of points sorted with respect to acquisition time. Since two signatures of the same person cannot be completely identical, we must make use of a measure that takes into account this variability. Indeed, two signatures cannot have exactly the same timing, besides these timing differences are not linear. Dynamic Time Warping as Fig. 3 is an interesting tool; it is a method that realizes a point-to-point correspondence. It is insensitive to small differences in the timing. Calculation distances between signatures with DTW [6,41] allows to achieve a verification system more flexible, more efficient and more adaptive than the systems based on neural networks or Hidden Markov Models, as the training phase can be incremental. This aspect is very important when we envisage to elaborate an authentication method that takes into account the evolution of the signature along the years [4].



$$G(i,j) = \left. \left\{ \begin{array}{l} cost(a[i], b[j]) + \\ \min \begin{pmatrix} G(i-1,j) + w1, \\ G(i,j-1) + w1, \\ G(i-1,j-1) + w2 \end{pmatrix} \end{array} \right\} * \max(i,j) / \min(i,j) \middle/ (i+j) \right.$$

$\forall$ 0<i<n, 0<j<m, w1>w2 : fixed weights
G(i,0) = ∞, G(0,j) = ∞ , G(0,0) = 0

Where Sign A : (a[1], a[2], ... , a[n]),
Sign B : (b[1], b[2], ... b[m])
i and j are length of features,
a[i] and b[j] are feature vectors
w1, w2 are weight values such that w1 > w2.

Fig. 2. Proposed Method of Dynamic Time Warping

[Pseudo code of modified DP matching algorithm]

```
#define INIT_SUMM 100000 /* arbitrary large number∞ */
#define MAX_CPNT 500/* max number of feature vectors */
BYTE iv[MAX_CPNT], rv[MAX_CPNT];
/* feature vectors of two signatures */
int ifp, rfp;
/* number of feature vectors for two signatures */
int dp_sum1[MAX_CPNT], dp_sum2[MAX_CPNT];
int *sum1, *sum2;
/* temporary arrays to store the DP Matching results */
int DP_result;
for(int i=1; i<(int)rfp; i++)
{
int minimum;
minimum = INIT_SUMM;
```

```
if ( i%2 != 0 ) { sum1 = dp_sum1; sum2= dp_sum2; }
  else { sum1 = dp_sum2; sum2 = dp_sum1; }

  for(int j=1; j<(int)ifp; j++)
  {
  WORD diff, hori, vert, center;
  diff=cost(iv[pos_y], rv[pos_x]);
  hori=sum1[pos_y] + diff + (W1);
  vert=sum2[pos_y-1] + diff + (W2);
  center=sum1[pos_y-1] + diff+ (W2);
  sum2[pos_y] = min(hori, center, vert);
  /* choose minimum value of three values */
  DP_result = sum2[pos_y-1]*max(i,j)/min(i,j)/(i+j);
  if(minimum > DP_result) minimum = DP_result;
  }
 sum1[0]=INIT_SUMM;
 sum2[0]=INIT_SUMM;
}
minimum ⇨  final G(n,m)
```

W1 is a weight value adopted in case horizontal path or vertical path, and w2 is a weight value adopted in case orthogonal path. To calculate the DTW distance G(A,B) for the two sequences A = (a[1], a[2], ..., a[n]) and B = (b[1], b[2], ..., b[m]), we can first construct an n-by-m matrix, as shown in Fig. 2. Then, we find a path in the matrix which starts from cell (1, 1) to cell (n,m) so that the average cumulative cost along the path is minimized. If the path passes cell (i, j), then the cell (i,j) contributes cost(a[i], b[j]) to the cumulative cost. The cost function can be defined flexibly depending on the application, for example, cost(a[i], b[j]) = |a[i]-b[j]|*weight. This path can be determined using dynamic programming, because the recursive equation holds:

$$G(i, j) = [\ cost(iv[i], rv[j]) + \min\{G(i-1, j)+w1,\ G(i-1, j-1)+w2,\ G(i, j-1)+w1\}\ ]* \max(i,j)/\min(i,j)/(i+j).$$

The path may goes several cells horizontally along A or vertically along B, which makes the matching between the two sequences not strictly one-one but one-many and many-one. This is the robustness that DTW provides to align sequences. Also we suggest that w1 and w2 are very important weight value for the measure of similarity in DTW.

5. Performance Results

The characteristics of our system are as follows;

1) Dynamic Time Warping (DTW) well known for excellent pattern matching algorithm has been modified and applied to this system. Reliability for checking the similarities of the signatures is high and a newly developed fast algorithm in processing time is adopted in the system. To make access easier, we considered efficient user interface design in Fig. 3.

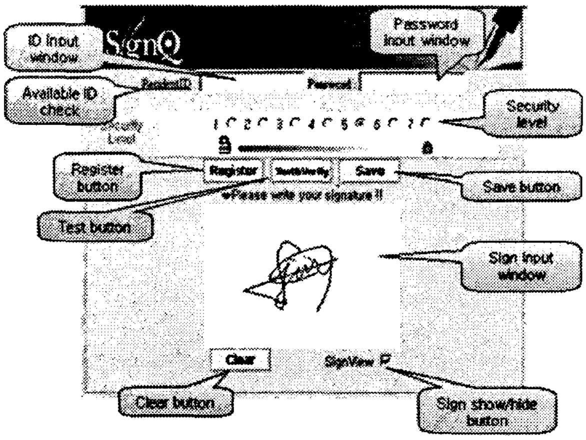


Fig. 3. User Interface for Signature Register

2) Size of feature vector for the signature is very small. It needs 20byte-250byte of memory capacity to register feature information of signature in average.

3) Processing time must be fast for the verification. In general DTW system, it is good to check similarity between patterns, but it has defect to make processing time because of computing complexity of data to be processed. But in our system we make compressed data and the data structure well designed which is not affected by time so that the verification is processed within 0.01 second at IBM compatible PC (CPU: 650MHz, Main Memory 64MB).

4) Security must be excellent. By recommendation of the feedback system, the signer can choose the security level of seven classes according to skillfulness of the signer.

5) The size of signature engine is small. Our engine's size is 32KB for Win9x/ME/2000, 6KB for WinCE, 6KB for JAVA. So, our system can be used in small handy device.

6) This system can be applied to a wide range of security systems with low cost because of strong independence of input device such as electronic pen, mouse, digitizer and so on.

7) Like changing PIN number and password, user can change his (her) signature, as he (she) want.

8) Using dynamic information makes nearly hacking impossible.

9) Error rate is low and robust for weather, temperature, physical condition, outside noise and so on.

10) Especially in case of using PDA, Web pad, Tablet PC, Panel PC, smart-phone etc., signature security system is economical and simple because you install just our software program without purchasing any input devices.
(http://www.mmigroup.net/en/mmi_products_signq.php)

11) Error rate (rejection rate for true signer and acceptance rate for forgery signature) is very low. (Nearly 0 for random forger)

6. Conclusions

The importance of security is emphasized more and more at present.

In conclusion, it is quite evident that the DSVS is here to say as the most valuable form of not only computer-related security, but in a plethora of other forms also. Markets to be penetrated include using the DSVS for passports, birth certificates, forensics, banking, ticket-less air travel, computer log-in, driving licenses, automobile ignition and unlocking, anti-terrorism, anti-theft, and to replace the archaic use of PIN and passwords. As the technology becomes increasingly produced and the market fully embraces the newest forms of biometric security, biometric solutions will inevitably become cheaper and more abundant in the information systems market and therefore available to almost anybody with a need for enhanced security measures.

We have described feature extraction, matching method and the performance results of our enhanced dynamic signature verification system. The experimental results show very accurate degree of similarity for two similar signatures, quick processing time, small signature template (feature vectors) size, etc.

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