THE MATHEMATICAL MODEL OF SIGNATURES FOR COMPACT STORAGE AND OPERATIVE PERSONAL IDENTIFICATION IN BANK SYSTEMS*

V. Cheushev† , J. Miller‡, D. Popel†

†Belarusian State University of Informatics and Radioelectronics, Laboratory of Image Processing and Pattern Recognition. Brovky Str., 6, 220600, Minsk, Republic of Belarus, Tel.: (++172) 398-946, Fax: (++172) 310-914, E-mail: moroz@kivt.minsk.by

‡Napier University, Dept. of Computer Studies, Colinton Road, 219, Edinburgh, EH14 1DJ, UK, Fax (++0131) 455-4552, E-mail: j.miller@csu.napier.ac.uk

Abstract: *A compression method of signature image and any shape images is described. This method is based on construction of mathematical model of a signature, which requires considerably less disk space and can be effectively used hereinafter for automatic personal identification.*

Keywords: *Personal Identification, Authenticity Conformation, Automatic Signature Expertise*

INTRODUCTION

Authenticity conformation and personal identification of financial documents are main tasks that guarantee sufficient safety in bank activities and business spheres. At present there is a sharp growth of crime such as forgery of signatures and documents. The practically widespread way of solving this problem is automatic client identification systems by his signature on personal cheques, credit card receipt, and other documents. Often only signatures can transform an ordinary paper into legal document. As a example, it should be said that the whole number of payments and remittances are made based only on signature and passport. Together is guarantee sufficient authenticity of an individual. It would be ideal if client personality (e.g. signature and handwriting) and document validation (e.g. stamps and seales) is identified by computer in automatic mode. However both technical and organizational problems are required to decide for this purpose. Now visual comparison of customer signatures is widely used in bank offices, where signatures are represented as one from the document and another from a database (from paper cards or from computer memory). The size of this database depends on the signature amount which may range from 100 000 (for a small bank) up to six million or more for large institutions. Certainly, the storage of the images in a computer database is more effective and convenient. But a lot of disk space (about several Kb for images compressed by traditional methods) is required for storage of bitmap images of signatures. This method leads to unsuitable usage of bank system resources.

1. PROCESS OF PERSON IDENTIFICATION

For checking of signature authentic by described method a bank system should be equipped by the following components (Fig. 1):

- input unit for signatures and handwritten text;

* The present paper is a result of Belarusian- Polish scientific co-operation of Lab. of Image Processing and Pattern Recognition (State University of Informatics and Radioelectronics, Minsk, the Republic of Belarus) and Institute of Computer Science (Technical University, Szczecin, Poland) under supervising Prof. Dr. V. Shmerko.

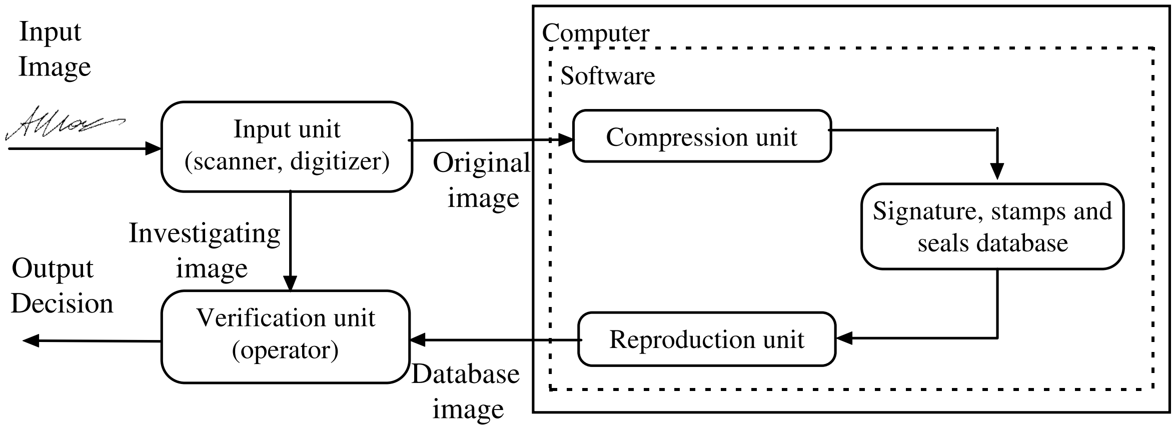
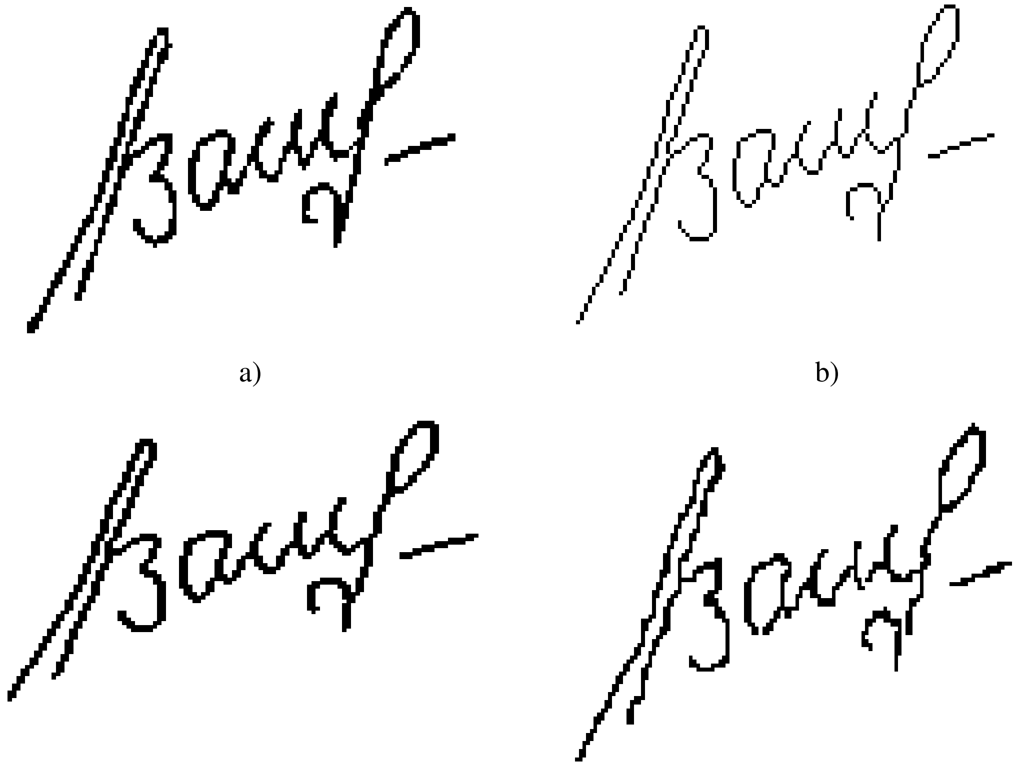


Fig. 1. The signature processing system

- the program of shape image compression, that involves in bank database management systems;
- the program of compressed signature reproduction;
- verification module.

A compression technique of signature image and any shape images based on construction of mathematical description, which requires considerably less disk space and can be effectively used hereinafter for automatic personal identification is described.

The process of an authentic signature addition to the database consists of the following steps: scanning of binary signature image from a



a) b) c) d)

Fig. 2. a) - Source signature; b) - Image skeleton; c) - Image, restored by described method; d) - Vector representation, obtained by CorelTrace 5.0.

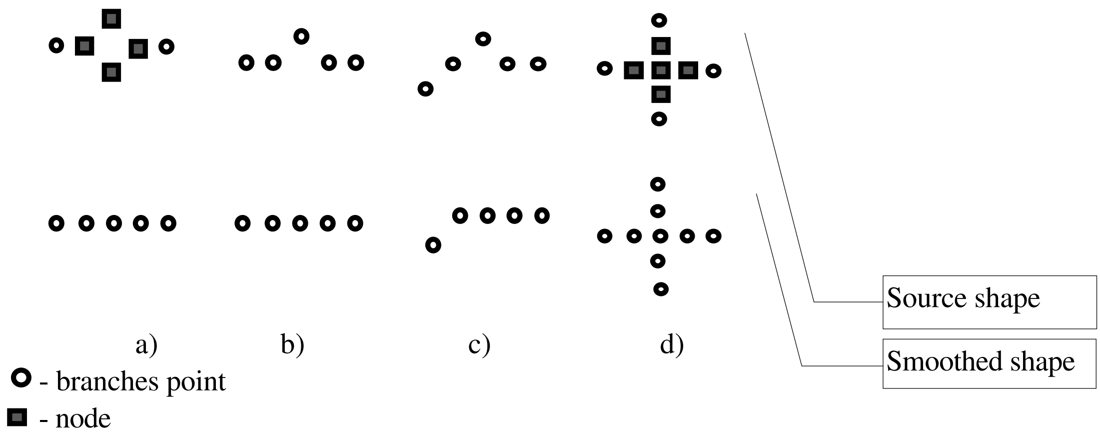


Fig. 3. Smoothing of image shape.
a) - False nodes, b), c) - Broken contour, d) - Nodes with index 4.

document, building mathematical model, and placing it as a separate record in the database. Afterwards the model is extracted by some key (for example, by client account number), and the reproduction program restores the original view of a signature to the screen. The examined signature is also scanned and displayed on the screen. Thus, a bank clerk has a opportunity during some seconds to access to original client signature and to compare it with the current image.

To be noted, the information stored in such way is insufficient to match criminological expertise, which required from 6 to 20 original objects (depending on signature complexity).

However, the method described below assumes the next step to construct of generalized signature model, that stores essential and invariable features for one person and can be used as a basis to provide high-grade handwriting expertise, including automatic.

2. Signature Image Transformation

The transformation of scanned image consist of following stages:

I. Image thinning
II. .Image representation as a graph.
III. Shape smoothing.
IV. Graph minimization.
V. Shape compression.

Image thinning (skeletonization) is an iterative procedure of bitmap processing, when all contour lines transform to singular pixel ones. The Naccache - Shinghal algorithm is used in the described method. It provides good results for handwriting objects. The thinning results are shown on Fig. 2b. The lines average width is measured during skeletonization stage.

Transformation of bitmap to graph-like representation

The thinned bitmap is transformed to its description as a graph, where nodes are pixels that have indexes[1]1,3 or 4, and arcs are contour branches, connected at these nodes.

The graph is represented in memory as two lists: a nodes list and a list of contour branches descriptors. The nodes list item contains the X, Y coordinates of pixel location and pointers for contour branches, which started from these nodes. The contour branch descriptor is chain code (Freeman code [5]), where each item contains 8-bit code of next contour direction.

Shape smoothing

As the scanned image has different distortions, thinning shape contains the drawback of false nodes. These defects do not have serious influence on the quality of the restored image, but their description requires a lot of additional memory. The shape is smoothed to eliminate of these defects. This operation consist of erasing false nodes, all nodes with index = 4 and smoothing broken contours (see Fig. 3).

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[1] Pixel index is the number of neighboring image pixels in 3x3 window around current point. Pixel with index 1 named endpoint (start or end of line), with index 2 - line point, and pixels with indexes 3 and 4 are nodes points (junction and crossing of lines).

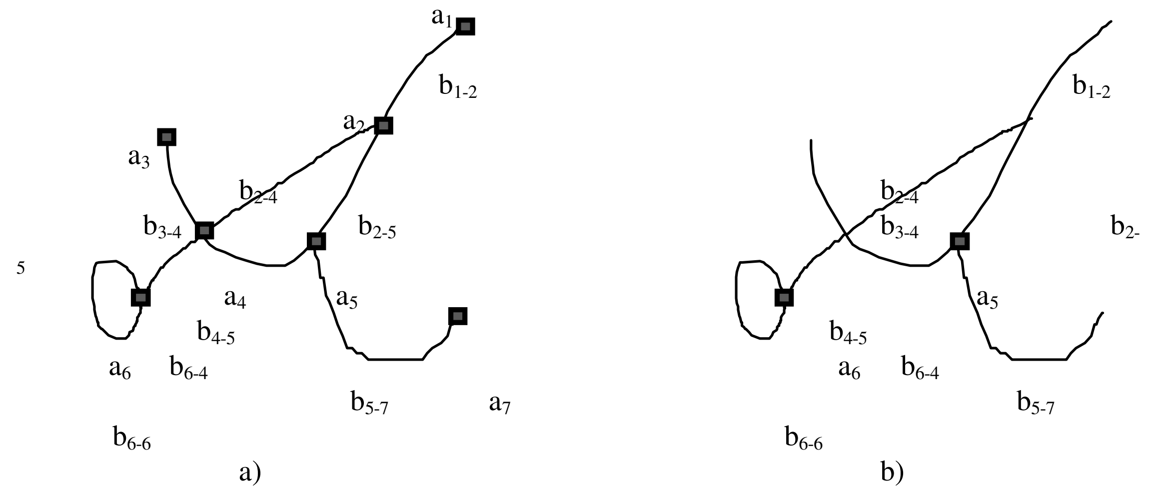


Fig. 4. Connected subgraph for example.
a) Before minimization; b) After minimization

Graph minimization

Every node-point and end-point in the graph, received at stage II, corresponds to graph nodes and branch is contour part, connects two nodes. From the point of view of description compactness this representation is redundant, therefore it is expedient to conduct graph minimization by means erasing some nodes and connecting corresponding contour branches.

The minimal total number of nodes and branches a site to allow reproduction of the connected subgraph as authors show is determined as follows:

$$N_s^{\min} = \frac{1}{2}\sum_{j=1}^{n} I_j ,$$

where n - nodes number of source subgraph, I_j - index of j-th node(without nodes that have index 4).

Nodes number N_a and nodes itself can be chosen by various ways: $N_a^{\min} \le N_a \le \frac{1}{2} N_s^{\min}$. As far as total length of contour branches can not be changed, for description reduction it is necessary to select minimal nodes number $N_a^{\min}$. The branches, that start from these nodes have to cover the contour completely and without repeating.

Example.

Connected graph is shown on Fig. 4. It has seven nodes a_1, ... , a_7 and eighth branches $b_{1\text{-}2}$, $b_{2\text{-}5}$, ... , $b_{6\text{-}6}$.. During smoothing operation the node a_4 will be removed, and the branches $b_{2\text{-}4}$, $b_{4\text{-}6}$ and $b_{3\text{-}4}$, $b_{4\text{-}5}$ are transformed into branches $b_{2\text{-}6}$ and $b_{3\text{-}5}$ accordingly. Before minimization the graph description contains six nodes and six branches. It is enough to have six elements (two nodes and four branches or three nodes and three branches) to reproduce the contour.

For example, the minimal variant contains of two nodes a_5, a_6 and four branches $b_{5\text{-}7}$, $(b_{5\text{-}2} + b_{2\text{-}1})$, $b_{5\text{-}3}$, $(b_{6\text{-}6} + b_{6\text{-}2})$. So the nodes number is reduced from seven to two.

Contour compression

The contour received after thinning and smoothing (see Fig. 3c) has such features as exclusion of sharp shifts of direction in a contour branch. In other words, the next contour point can have only three positions in relation to current one (see Fig. 5). This property permits us to represent in branch descriptor not the absolute values of direction but its change (-1, 0, 1) using only L $log_2 3$ (≈1.6 L) bits instead of eight L bits for the chain with length L. Thus, the size of branch description reduces to a fifth.

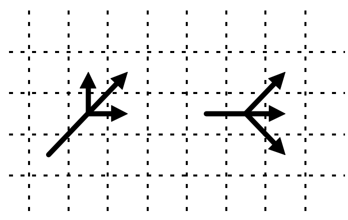


Fig. 5. Possible contour directions after smoothing

In addition, contour branches are compressed by modification of widely used Run-Length Encoding algorithm (RLE).

3. The Reproduction of Signature Image

The process of reproduction based on received description is simple enough and executed in two stages:

- skeleton reproduction;
- contour thickening.

The skeleton reproduction is fulfilled by sequential passage through graph nodes and transformation of contour branches into bitmap form. Contour thickening is fulfilled by moving received bitmap image in various directions until average width of initial image is achieved.

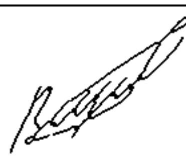
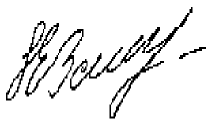
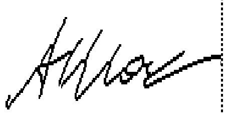
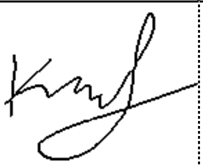
Obviously the described method does not permit us to reproduce the initial image with pixel accuracy. However as analysis shows this aspect does not influence signature comparison in the context of discussing this problem. If exact image reproduction is necessary, it is possible to use a modified description, where line width corresponds to each point of contour.

4. Results and Prospects

The method described above is realized as separated tools, which can be included in a structure of integrated systems, for example bank system. Vector - matrix tools of image processing elaborated by authors are used during algorithms synthesis and programs construction [6, 7].

Experiments have shown that signature image is compressed by given method by 6 - 20 times,

Table 1. Some examples of represented method with images scanned at 100 dpi.

Initial image	Image size (byte)	Initial numbers of nodes and branches	Restored image	Current size (byte)	Current numbers of nodes and branches	Compression value
	2966	104/ 143		324	26/ 74	9.15
	2538	76/ 94		251	18/ 44	10.11
	4478	26/ 32		247	7/ 19	18.13
	3742	44/ 54		193	10/ 28	19.3
	4158	20/ 22		210	6/ 12	19.8

depending on signature complexity (see Table 1). Such results exceeds in some cases a compressing degree achieved by well known archiving programs. For example shown on Fig. 2: initial image in BMP format has 1962 bytes, compressed by ARJ - 706 bytes, compressed by given method -168 bytes. The signature compression degree is 11.7, that is 4.2 times more than using bitmap compression.

The achievements of high compression parameters is not, however, the unique development purpose of the described method. It is noted that the development assumes building of general model of person signature and using it in automatic identification of signature authenticity. Such model has characteristics of probability and attributes, reflecting structural features of handwriting objects. These essential and steady peculiarities for certain person are as follows: dynamics and signature biomechanics, the special points and other attributes.

Thus, the offered method of compact description of handwriting object can be considered as a next step on the way towards wide application that guarantee safety in automatic person identification.

ACKNOWLEDGMENT

The authors would like to thank Er. Ing. Phil Phillips, BA (Hons), CEng MIEE for helpful remarks and comments on this paper.

REFERENCES

1. Shmerko V.P., Kochergov E., Mikhaylenko S., Cheushev V., and others, Systems for Personal Identification using Methods of Signature and Handwriting Verification. *Proc. of the 3-rd Int. Conf. on Pattern Recognition and Information Analysis*, Vol. 3, Ed. S. Ablameyko, Minsk, Republic of Belarus, 1995, pp. 25 - 35.
2. Gazzolo G. and L. Bruzzone, Real Time Signature Recognition: A Method for Personal Identification, *Proc. of 2-nd Int. Conf. on Document Analysis and Recognition*, IEEE CS Press, Los Alamitos, Calif., 1993, pp. 707 - 709.
3. Kochergov E., Up-to-Data Information Technology in Financial Document Identification and Security, *Proc. of the Int. Conference on New Information Technologies in Education*, Ed. V. Smerko, Minsk, Republic of Belarus, 1994, pp. 48 - 50 (In Russian).
4. Naccache N.J., Shingal R. SPTA: A Proposed Algorithm for Thinning Binary Patterns, *IEEE Trans. Systems. Man. Cybern.*, SMC - 14, No. 3, 1984, pp. 409 - 418.
5. Freeman H. On the Encoding of Arbitrary Geometric Configurations. *IEEE Trans. Elect. Computers*, Vol. ES-10, 1961, pp. 260 - 268.
6. Cheushev V. Vector - Matrix Tools for Image Processing. *Proc. of the 3-rd Int. Conf. on Pattern Recognition and Information Analysis*, Vol. 1, Ed. S. Ablameyko, Minsk, Republic of Belarus, Sept. 19 - 21, 1995, pp. 65 - 70 (In Russian).
7. Cheushev V. Regular Algorithm of Cellular Logic and its Applications for Image Processing. *Proc. of the 3-rd Int. Conf. on Pattern Recognition and Information Analysis*, Vol. 1, Ed. S. Ablameyko, Minsk, Republic of Belarus, 1995, pp. 60 - 65 (In Russian).
8. Kochergov E., Cheushev V. Handwriting and Signature Identification. Analysis of Achievements and Experimental Results. *Proc. of the Conf of CIS countries. Pattern Recognition and Image Analysis* (PRIA - 93). Minsk, Republic of Belarus, 1993, pp. 190-192 (In Russian).
9. Henn H., Automatic Signature Validation, *Bulletin (IBM),* No 10, Sept. 1993, p. 7.
10. Signature Systems Under Development, *Biometrics Technology Today,* 1995, pp. 9-10.