Three-dimensional handwriting visualization method and implementing it software system

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Abstract

In this work a data visualization method and the DA 3D+ Handwriting program system, designed for the on-line analysis of inputted by means of modern input devices (pen tablets, graphic digitizers, etc.) handwriting and signature, are presented. Several new solutions, allowing the increase of the handwriting analysis efficiency, are applied.

Keywords: *visualization, handwriting, signature.*

1. INTRODUCTION

Nowadays various means that allow gaining information about individual characteristics and a state of a person currently attract a lot of attention. One of the reasons for this is the wide application of access control means, data protection means, and diagnostic systems. Abovementioned information can be gained by means of the biometric parameters analysis systems. One of these parameters is handwriting or signature. For years the relationship between the handwriting or the signature and the individual characteristics or a state of a person is used in such fields as the criminalistics (the identification of the person) [1, 10], the graphology (the person character detection) [4, 8, 9]. The signature is one of the common and usual ways to identify the person.

Emersion of computers and modern handwriting input devices resulted in the considerable extension of handwriting research possibilities. The new handwriting input devices allow to gain with a high accuracy not only two-dimensional coordinates of handwriting points, but also hard-to-gain with old ways, using figure on a paper: pen tip pressure value, movement direction, movement speed, and also unavailable with old ways pen slope.

Thus, the modern handwriting input devices provide gaining considerable greater amount of handwriting information that allows to increase performance and reliability of the writer identification and to gain more information about writer state.

Let's note that total replacement of paper documents with the electronic, application of automation in various fields inevitably results in the computerization of the inputting and storing not only printed, but also the handwriting that facilitates and makes usage of the handwriting for mentioned purposes more topical.

New possibilities of handwriting input stimulate a development of new handwriting analysis methods [1, 5, 12, 13, 14] and new tools for the analysis. It could be said that existing methods use tools not aimed for the handwriting analysis that reduces their efficiency.

In this paper, the data visualization method and the DA 3D+ Handwriting program system, designed for the analysis of handwriting inputted by means of mentioned modern input devices, are presented. Several new solutions, allowing to increase the handwriting analysis efficiency, are applied in this system. The program system was designed with state-of-the-art technologies and tools.

Novelty and features of the proposed handwriting visualization and the program system:

- The three-dimensional data visualization method with a usage of the time markers, allowing to display pen tip coordinates, pen tip pressure, the movement speed, measurement time, movement direction simultaneously.
- The natural way of navigation through the text curve, zooming and selection the text curve fragments, by means of a usage of two windows (the preview window and the view window), and a virtual video camera.
- The simultaneous analysis of two and more curves of inputted handwriting with overlapping and scaling support.
- The support of inputted handwriting curves visualization:
  - in an orthogonal projection to view not distorted two-dimensional projection of the text like an image of the text written on a paper, and not distorted curves of dependence of pressure on any of pen coordinates;
  - in a perspective projection to gain an impression of the text curve three-dimensionality on a two-dimensional screen that facilitates sizing up of three-dimensional image depth.
- The possibility to work with most of existing handwriting input devices.
- The support of input, storing and analysis of all inputted handwriting parameters (pen tip coordinates, pen tip pressure, the movement speed, measurement time, movement direction and pen slope) and measurement parameters (time and date of the measurement, information about writer, etc.).
- Expansibility, scalability and the support of upgrade with backward compatibility.
- The usage of the authoring "active" data technology for data storing implementation.
- The usage of state-of-the-art technologies and tools during design of the program system.

2. THE DATA VISUALIZATION METHOD

As it was said, for the handwriting analysis, following parameters are used: pen tip coordinates, pen tip pressure, the movement speed, measurement time, movement direction and pen slope. Most of handwriting researcher does not visualize the gained data or uses traditional methods with usage of two-dimensional plots [1, 5, 11, 12, 13, 14]. Thus the text is represented as two-dimensional image or as a set of two-dimensional plots, corresponding to dependencies of each parameter on a time. In the first case it is possible to visualize time points by means of time markers on displayed curve, but it is difficult to visualize pen pressure and slope in each point of the curve. The pressure visualization by means of change of line width, implemented in some drawing programs (for example, PenSigner, Figure 1), is not convenient as it does not allow to display precisely all of 512 or 1024 pressure levels which is provided by pressure sensors of modern input devices. In the second case (a set of two-dimensional plots, corresponding to dependencies of each parameter on a time) it is difficult to visualize a spatial structure of the text. There is the three-dimensional visualization method applied in ForensicXP-4010 system, in which the image of the text, written on a paper, is represented in the form of a three-dimensional surface (Figure 2), however thus measurement times and pen slopes are not displayed.

Figure 1: The pen pressure visualization by means of a line width change in the PenSigner program.

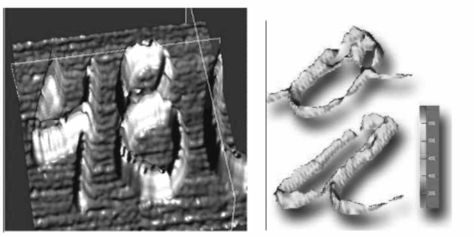

Figure 2: The visualization of a handwriting, written on a paper, in the ForensicXP-4010 system.

Proposed in this work representation of the gained parameters in the form of a three-dimensional curve is more convenient, coordinates of each point of which are corresponded to one of the gained parameters (except measurement time, pen slope and movement direction, which are displayed with the special form of time marker). Implementation of this method is complicated by two-dimensionality of image on the screen of a computer monitor, so the three-dimensional object can be presented on it only indirectly - by means of auxiliary axes, usage of a perspective. Nevertheless this way of representation owing to greater information comprehension is preferable. Implementation of this method is possible by means of some programs which are not specialized for handwriting analysis, for example, computer mathematics and mathematical simulation program systems like Maple, Mathcad, MATLAB, Mathematica. However the handwriting analysis (and especially matching of different samples) by means of these programs is not convenient as they does not support relative moving and scaling of three-dimensional curves directly. Besides in these systems the pen movement directions, pen slope visualization is complicated.

Thus, it is possible to state that the specialized program system for handwriting analysis in which such data visualization method is implemented, not having the abovementioned disadvantages, will increase the analysis efficiency.

The handwriting curve visualized by proposed method is shown on Figure 3. Two curve point coordinates (x, y) correspond to pen tip coordinates, and the third (z) corresponds to pen tip pressure value. The measurement time is represented by means of time markers placed on the gained curve with an equal time period (Figure 4). Thus, the number of markers between readouts corresponds to a time interval between readouts, and the density of markers corresponds to the pen movement speed. Time markers are displayed in the form of pyramids which vertex is directed to the next readouts, i.e. visualize the movement direction.

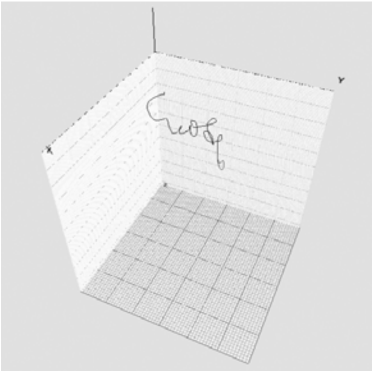

Figure 3: A view of a handwriting curve, the data visualization is implemented by proposed method.

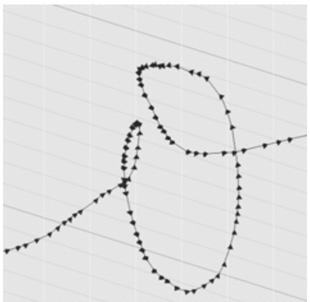

Figure 4: A curve fragment of a handwriting curve.

Measurement of coordinate and pressure values can be performed by means of a millimeter grid (Figure 5) or by means of the special markers, the distance between which is displayed in a corresponding window. The pressure value can be displayed additionally by the line saturation change or the line color transition from the original to inverse

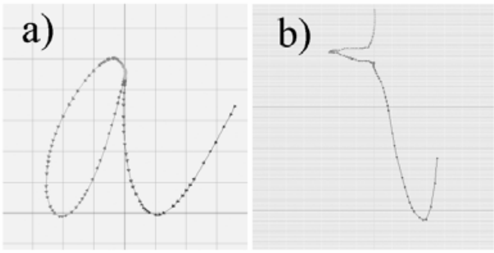

Figure 5: A view of a handwriting curve with a millimeter grid.
a) x and y coordinates,   b) pressure and y coordinate

The designed visualization method is realized with a usage of two windows (the preview window and the view window), which are shown simultaneously, and a virtual video camera (further — camera) (Figure 6). In the preview window coordinate axes, a three-dimensional image of the text (x, y – pen coordinates, z - pressure) and the camera connected by a segment with the center of a view area (the camera axis) are displayed; in the view window coordinate axes, the image gained by means of the camera, and millimeter grids in XOY, XOZ, YOZ planes are displayed. The positions of the camera and the center of the view area, the angle between the camera axis and OZ axis, the angle of the camera rotation in the plane XOY, the distance between the camera and the center of the view area (defines image scale in the view window) can be changed. Besides a three-dimensional image of the text can be moved parallel to OX and OY axes and rotated in XOY plane around the text center. The usage of the preview window, in which all considered curves and the camera position being relative to the curve are shown, facilitates the choice of the necessary view of considered curves.

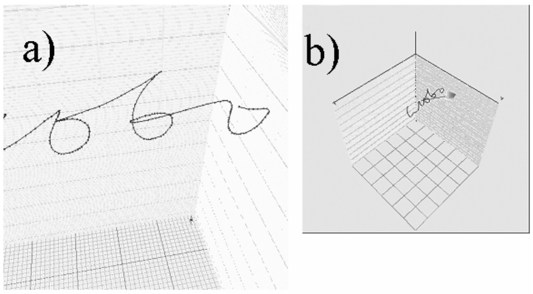

Figure 6: A view of two windows.
a) the view window,   b) the preview window

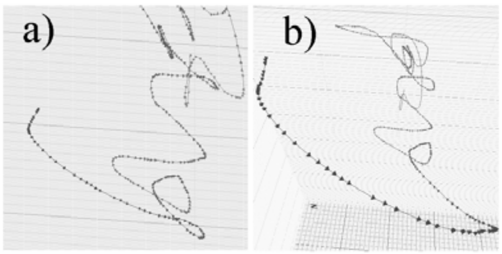

Figure 7: A view of text in the view window.
a) an orthogonal projection,   b) a perspective projection

The image, displayed in the view window, can be shown with orthogonal or perspective projection (Figure 7).

The proposed visualization method assumes simultaneous display of two and more different text curves (Figure 8). Thus curves of different texts can be shown with different or same colors that facilitate matching of the curves and visualization of their common characteristics. To support matching of any segments of the curves, independent moving of any curve parallel with OX and OY axes and rotation in XOY plane around center of the curve are provided.

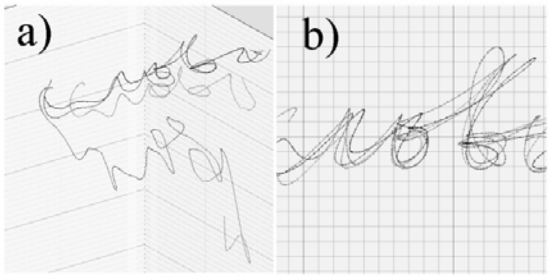

Figure 8: Simultaneous showing different curves of the text.
a) a side view,   b) a top view,

3. GAINING UNIFORM READOUTS

Most of input devices (in particular, pen tablets) generates non-uniform readout sequence (in which time interval between adjacent readouts are not equal) while to visualize the time markers the uniform readout sequence are required as the time interval between adjacent time marker must be equal. The readout is a set of several parameters, that is readout corresponds to a vector of handwriting parameters. The values of readouts placed between measurements are gained by means of interpolation. In our case the number of required readouts can attain several thousands.

To solve such problem, a piecewise-linear interpolation and a spline interpolation are applied [3, 6, 7]. In this work, Hermite spline interpolation, providing not only continuous derivative interpolation function but also its (derivative) equality to the given values, is used. As the exact values of curve slope tangents in measurement points, which are necessary for evaluation Hermite spline interpolant, are unknown, it is convenient to use expression Catmull-Rom spline interpolation, being special case of Hermitian spline interpolation. In case of Catmull-Rom spline interpolation it is enough to know readouts between which the interpolated readouts are placed and their previous and next readouts.

4. DA 3D+ HANDWRITING PROGRAM SYSTEM

The complexity of the solution and limitation of allocated for program system development resources demanded to choice the most effective and reliable design technologies and tools. In this case, one of the best solutions was a usage of the Microsoft Visual Studio 2005 IDE, C++ and C# languages, Microsoft .NET technologies, .NET Framework, DirectX9 components.

The decisions, taken during the development of the program system structure, were determined by the chosen handwriting visualization method and the necessity of support of expansibility, scalability and upgrade with backward compatibility.

To support of mentioned program system quality features following structural decisions has been taken:

1. The system consists of subsystems which supports the basic independent functions.
2. The subsystems interact among each other only by means of a set of interfaces.
3. Interfaces are related with inheritance associations. This and previous decisions allow to realize the subsystem expansibility mechanism which requires to change only the subsystems using new functions.
4. The set of rules, used for creating interfaces, is defined that allows to minimize number of needed for system modification classes.

The program system structure is shown on UML diagram (Figure 9).

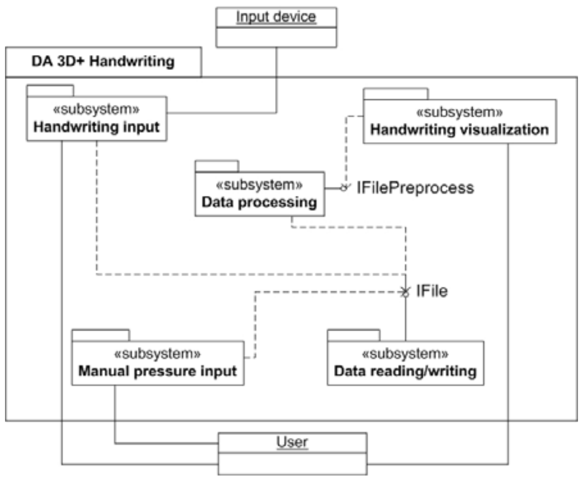

Figure 9: The program system structure.

To support required level of performance during image rendering, two independent sets of graphical resources (the output device objects, vertex buffers, etc.) were used. Thus, to simplify the process of synchronization of images in preview and view windows, a set of the data domain class, performing synchronization and control of graphical resources, was developed. Thus, to each graphical object (the coordinate axes, the millimeter grids, the camera, the three-dimensional handwriting curve, etc.) a special class is corresponded. Design of the graphic interface was performed with usage of standard Windows Forms components, being part of the .NET Framework class library.

5. CONCLUSION

The designed three-dimensional handwriting visualization method and implementing it software system can be used for developing person identification methods, the analysis of person characteristics, the automated identification of the person, applied in electronic document circulation systems, using handwriting or signature analysis, criminalistical expertise of handwriting/signature authenticity.

The proposed program system is tested and used in Institute of Developmental Physiology of Russian Academy of Education for an estimation of children's writing skill development extent, and also for a design of person state analysis, and handwriting identification of person.

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