UDC 004.9-519.6

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BIOMETRY AUTHENTICATION SYSTEM BASED ON ON-LINE SIGNATURE VERIFICATION

New mathematical model, methods of preprocessing, diagnostic attributes, methods of statistical analysis of the dynamic handwritten signature for authentication of the person in computer information systems are proposed. Authentication module as a part of the corporate information system is presented.
Keywords – authentication, on-line signature, biometry.

Broad application of e-commerce systems in different web-services, which anticipate the identification of a person demand the development of comfortable, reliable and available systems for authentication of the person.

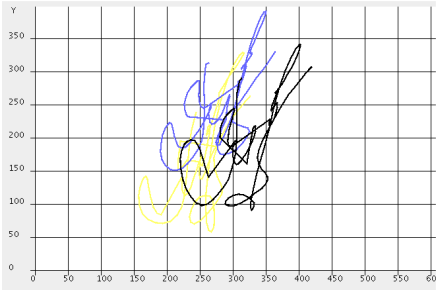

Fig.1. Three static signatures of person

Besides usual password and card authentication developers use more often two types of biometry authentication in their information systems: static authentication (by fingerprint, retina, hand geometry, etc.) and dynamic (on-line) authentication (by keyboard “handwriting”, on-line signature, voice pronouncing phrase). Among the mentioned methods handwritten signature is classic one, historically reasoned and comfortable way of the person authentication. That is why on-line signature verification has a chance to replace the usual password authentication.

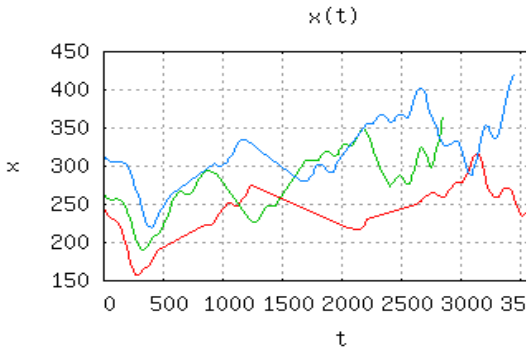

Fig.2. Three on-line signatures *x(t)* realization of person

The difference between on-line and off-line signature is the following:

- off-line signature – signature for which there is only a static visual two dimensional record (Fig.1);
- on-line signature – a signature during production of which the pen trajectory or dynamics is captured (Fig.2, Fig.3).

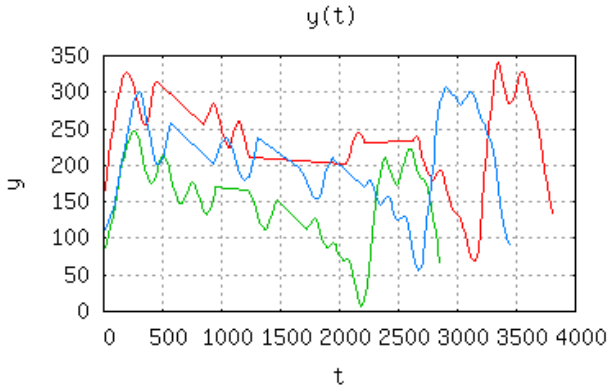

Fig.3. Three on-line signatures y(t) realization of person

Off-line signature doesn't allow to get dynamic (on-line) characteristics and input sequence from it. On-line signature – is discrete signal, which consists of the set of dots, every of which has at least three dimensions: *x*-coordinate, *y*-coordinate and coordinate of time *t*.

By means of the graphic tablet[2,3,6], positioned pen, video camera[1] the stylus of the pocket PC, etc. on-line signature can be captured. Some input devices can increase information characteristics of signature – they allow to capture the slope angle and the pressure.

Development of the automatic on-line signature verification system is of great importance.

Authentication system of a person which is based on on-line signature verification can be created in the following stages:

1. Design of mathematical model of dynamic signature.
2. Choice and substantiation of diagnostic attributes for authentication of person.
3. Development of methods and algorithms for estimation diagnostic attributes.
4. Determination of criteria for making decision: on-line signature belong to authenticated person or not.
5. Development of software of authentication system (authentication module).
6. Integration authentication system (authentication module) into information infrastructure.

Mathematical model development of the authentication system is one of the most important stages of the development of the system in whole. At this stage diagnostic attributes and methods of the signature preprocessing, are reasoned. The choice of the mathematical model type is of a great importance: deterministic or stochastic. This choice should be constructive and caused by the nature of the investigated signal. Stohastic model is chosen, because the signature has variable character in:

1. the signature input time duration;
2. the amplitude relatively to the axis *x* and *y* (variation);
3. the first input point.

Nevertheless, there are some random processes, which characterize the signature of the person independently to the first input point on the tablet, to the variation and the duration of signing of the signature.

The model of the on-line signature is a vector of two random processes: $\xi(\omega,t)$ - trajectory of moving the pen tip along the *x* axis and $\eta(\omega,t)$ - trajectory of moving the pen tip along the *y* axis through the time of signing:

$$\Theta(\omega,t) = \{\xi(\omega,t),\eta(\omega,t)\},\ \omega \in \Omega,\ t \in [0,\infty), \quad (1)$$

here Ω - the set of elementary events, and random processes $\xi(\omega,t)$ and $\eta(\omega,t)$:

$$\xi(\omega,t) = A_\xi(\omega)\cdot\xi_0(\omega,\alpha_\xi(\omega)\cdot t) + B_\xi(\omega),$$
$$t \in [0,\infty),\ \omega \in \Omega, \quad (2)$$
$$\eta(\omega,t) = A_\eta(\omega)\cdot\eta_0(\omega,\alpha_\eta(\omega)\cdot t) + B_\eta(\omega),$$
$$t \in [0,\infty),\ \omega \in \Omega, \quad (3)$$

here $A_\xi(\omega)$ and $A_\eta(\omega)$ – random values, which reflect variation of the on-line signature;

$\xi_0(\omega,t)$ and $\eta_0(\omega,t)$ - random processes, which corresponding to the components of the invariant signature;

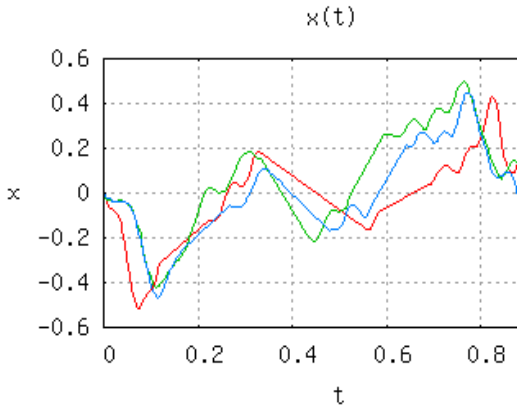

Fig.4. Results of on-line signatures x(t) realization preprocessing of a person

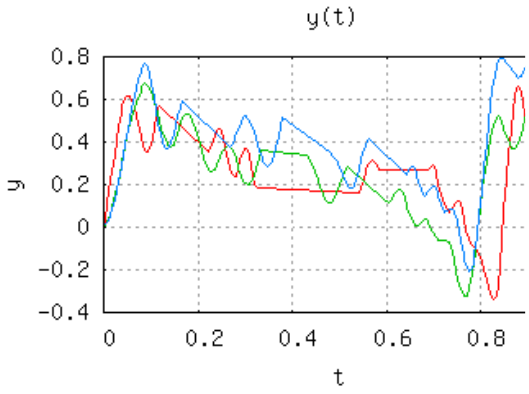

Fig.5. Results of on-line signatures y(t) realization preprocessing of a person

$\alpha_\xi(\omega)$ and $\alpha_\eta(\omega)$ - random value, which reflects the on-line signature duration;

$B_\xi(\omega)$ and $B_\eta(\omega)$ – random values, which represent the trend of the signature and are equal to coordinates (x,y) in the plane at the initial moment of time.

Diagnostic attributes can be divided into two classes:

1. Statistic characteristics of vector of random values $\{A_\xi(\omega),A_\eta(\omega),\alpha(\omega)\}$: mean, deviation, cross-correlation, frequency and function of distribution.
2. Statistic characteristics of invariant signature $\{\xi_0(\omega,t),\eta_0(\omega,t)\}$: moment functions, distribution functions, frequency distribution, mixed moment functions.

On-line signature preprocessing includes the following operations:

- Determination of signature trend and movement of every signature realization to the origin $(0,0)$.
- Signature duration scaling:

$$\alpha(\omega_i)=\frac{1}{t(\omega_i)},\ \omega_i\in\Omega, \qquad (4)$$

here $t(\omega_i)$ - duration of *i*-signature from the set of realizations of signatures.

- Determination of the amplitude scale coefficient and scaling of the realization of the processes $\xi(\omega,t)$ and $\eta(\omega,t)$:

$$A_\xi(\omega)=\frac{1}{Var\xi(\omega,t)}=\frac{1}{\left|max_{\xi(\omega,t)}-min_{\xi(\omega,t)}\right|}, \qquad (5)$$

$$A_\eta(\omega)=\frac{1}{Var\eta(\omega,t)}=\frac{1}{\left|max_{\eta(\omega,t)}-min_{\eta(\omega,t)}\right|}. \qquad (6)$$

- Invariant signatures determination of processes $\xi(\omega,t)$ and $\eta(\omega,t)$:

$$\xi_0(\omega,t)=\frac{\xi\left(\omega,\frac{1}{\alpha_\xi(\omega)}\cdot t\right)-B_\xi(\omega)}{A_\xi(\omega)}, \qquad (7)$$

$$\eta_0(\omega,t)=\frac{\eta\left(\omega,\frac{1}{\alpha_\eta(\omega)}\cdot t\right)-B_\eta(\omega)}{A_\eta(\omega)}. \quad (8)$$

Results of preprocessing are shown in Fig.4 $\xi_0(\omega,t)$ and Fig.5 $\eta_0(\omega,t)$.

Details preprocessing and statistic processing of signature in paper [3] are shown. For example, mean estimation of invariant signature process $\xi_0(\omega,t)$ is:

$$m_{\xi_0}(t)=\frac{1}{M}\cdot\sum_{i=1}^{M}\xi_{0_{\omega_i}}(t),\ t\in[0,1). \quad (9)$$

Deviation estimation of invariant signature process $\xi_0(\omega,t)$ is:

$$\sigma^2_{\xi_0}(t)=\frac{1}{M-1}\cdot\sum_{i=1}^{M}[\xi_{0_{\omega_i}}(t)-m_{\xi_0}(t)]^2, \quad (10)$$

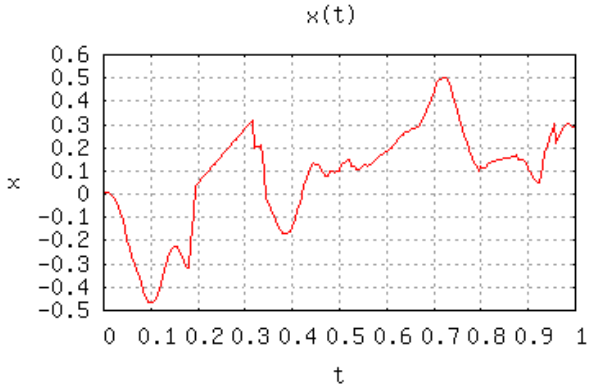

Fig.6. Invariant signature process $\xi_0(\omega,t)$ mean

Results of on-line signatures statistic processing of a person in Fig.6 and Fig.7 are shown.

To minimize diagnostic attributes realization are expand in series. Choice of series type is determined by the energy criterion: trigonometric series, Chebyshev series, Kravchuk series, etc.

All stages described above are shown in Fig.8. According to the Fig.8 algorithm of identification person, determination and preprocessing diagnostic attributes can be developed.

Similarly to the scheme in Fig.8 authentication module which is shown in Fig.9 can be developed. The key part of authentication module is the decision making system, which after preprocessing new input on-line signature and after comparison with diagnostic attributes of person in database make decision: is the person legal or forger. Stochastic way of building model allows us to develop a strict system of rules for person authentication. These rules are developed according to estimation of diagnostic attributes.

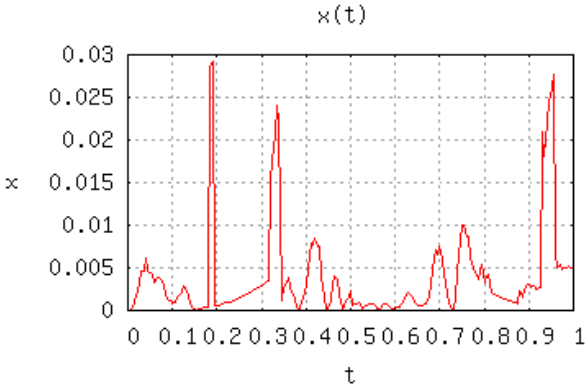

Fig.7. Invariant signature process $\xi_0(\omega,t)$ deviation

Usually all modern companies which efficiently use new informational technologies have complicated distributed information infrastructure, which include: remote (which operate behind the local area network of the company) and local employees(which operate inside the local area network of the company), large databases, web applications and clients (which are using web-services). In this case usually administrators create central database of users and their rights in the systems. Central user database (central authentication system) is usually realized on Lightweight Directory Access Protocol (LDAP)[5]: Active Directory (Microsoft Windows) and OpenLDAP (UNIX) systems.

LDAP is standardized open protocol which gives great advantages[4] to administrator:

- support in programming languages (C++, JAVA, Perl etc.), which make possible the development and modification of their own software (web-services in particular);
- main application servers support it;
- different operating systems support it.

The local area network users authentication in central user database may be realized by mean of Pluggable Authentication Module – PAM. On-line signature authentication module may be added to PAM-modules and used by users according to system administrator configuration of the system.

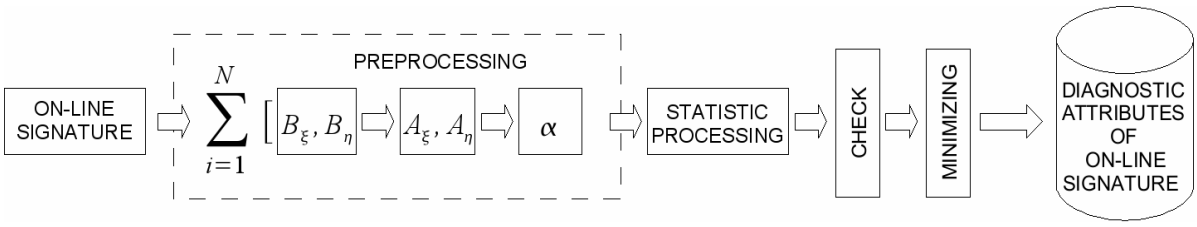

Fig.8. On-line signature identification scheme (adding new user on-line signature to database)

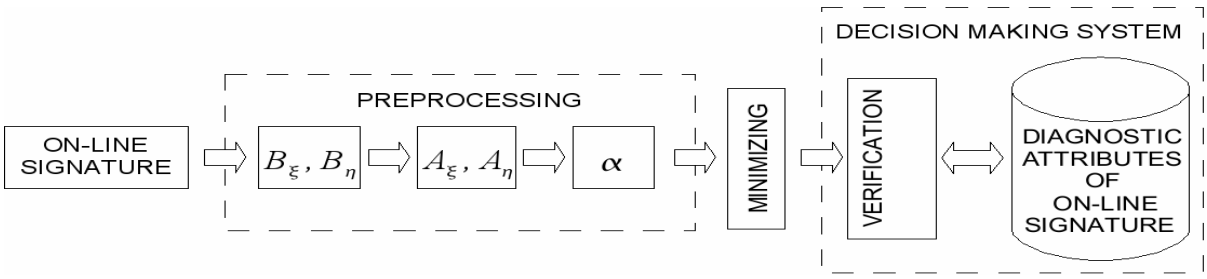

Fig.9. On-line signature authentication scheme

Remote users authentication may be realized by interoperation between application server and LDAP. For example, JAVA API has support of LDAP protocol and has few types of drivers to interact with LDAP-server. Client-side web-service software may be realize as JAVA applet which appears in users web-browser. This applet captures data from the input device (graphic tablet, Tablet PC, pocket PC, etc.). The author reminds that JAVA technology allows to neglect the differences between different operating systems and hardware. On-line signature authentication system in information infrastructure in Fig.10 is shown.

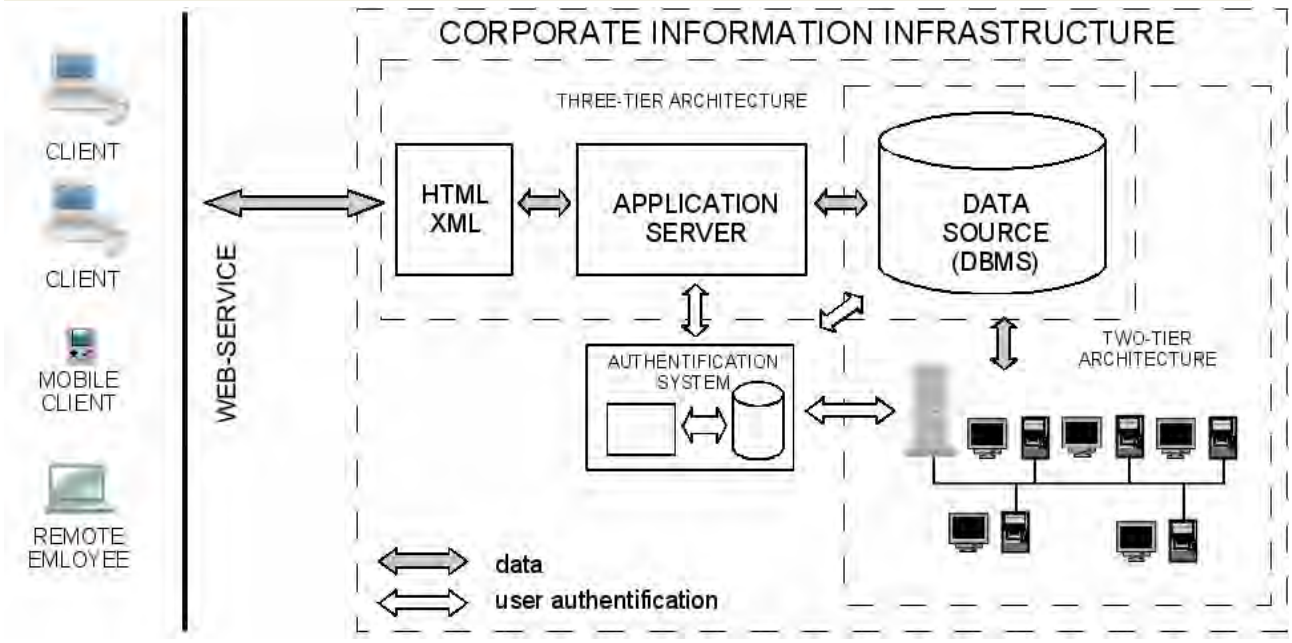

Fig.10. On-line signature authentication system in information infrastructure

In conclusion, the stochastic mathematical model, diagnostic attributes and methods of preprocessing and statistic processing are submitted. Presented mathematical model allows to develop authentication module as a part of complex information system.

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