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# LINGUISTIC PATTERN DESIGN OF USER BIOMETRIC MOVEMENTS

***Annotation.*** *This article is devoted to variety of solutions in collecting user biometric data, comparison of linguistic patterns of trajectories of movements of user cursor and development of visual reflection linguistic patterns and result of their comparison.*

***Keywords:*** *authentication, biometric authentication, linguistic modelling, manipulator mouse, pattern comparison, heuristics, transition matrix, pattern recognition.*

## Introduction

In last several decades our lives more and more transfers into virtual plane. Therefore human-machine interface needs more interaction depending on physical and emotional state of PC user. Today it can be differentiated two types of biometric interaction systems: static and dynamic analyzers. Last attracts more attention in case of providing ability to analyze behavioral characteristics of a person, define differences in PC user actions. They are based on analysis of properties which are inherent to unconscious human movements in process of performing of some acts.

Recognition of computer handwriting is one of methods of dynamic identification. Computer handwriting is a set of dynamic characteristics of user interaction with computer manipulator. This method provides ability to measure such values as speed of reaction, smoothness of moves etc. As an input parameters we used data which generates manipulator namely timeline of coordinates of manipulator in system of axes of screen.

Less common is usage of biometric data in field of recognition of emotional state of user. It is considered that being nervous or emotionally depressed negatively effects productivity of a human. Lack of information about every employee in a company creates massive losses in general. The only way to reduction of these costs is development of system which will provide collecting and processing biometric data with further recommendations to each user of system. Current tool will provide not only safety announcements, it can help to

cut costs on medical treatment of employees due to advance prevention of some types of diseases connected with movement dysfunctions.

Not only medical issues are needed to be mentioned. System which analyses user behaviour can be helpful in systems which are connected with high responsibility of PC user or probability of critical mistakes. Some workplaces in this particular companies assumes exceptional concentration on working process, electro stations military objects, etc. In this case system will control user behaviour and his emotional state during critical actions. This additional check will help to prevent accidental mistakes, which will decrease waste of money on coating damage. Following can be assumed that current system must be essential part of this type of systems.

This article is devoted to research about development of software package, which allows collecting data about trajectories of movement of user manipulator's cursor and process this data. Also this software package will reflect difference between variety of methods for designing linguistic patterns for next comparison of users and defining most effective method of comparison. Main aim of current system is improving security of continuous authorization using user biometric characteristics based on trajectories of moves of manipulator and diagnosis of emotional state of current PC user.

*System analysis of individual user movement's pattern.* Current research is quite a complex system, that's why it needs to be described from different points of view. It can be divided into three parts:

1. Creation of users account which includes collecting data such as, name, age, sex, frequency of collecting coordinates of manipulator, time of collecting data, testing coordinates;
2. Sending movement trajectories of cursor of manipulator from client side to server
3. Updating user account data;
4. Deleting all connected to user data;
5. Choice of criteria for comparison linguistic patterns;
6. Detecting linguistic patterns of compared user based on etalon linguistic model of current user;
7. Comparison of each pair of transition matrix (etalon and compared user) according to chosen criteria;
8. Output transition matrix of selected difference range;

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9. Output results of intervalisation of selected difference range;

10. Output number of results elements of difference range in selected intervals;

11. Output results of comparison of two transition matrix of selected differential range.

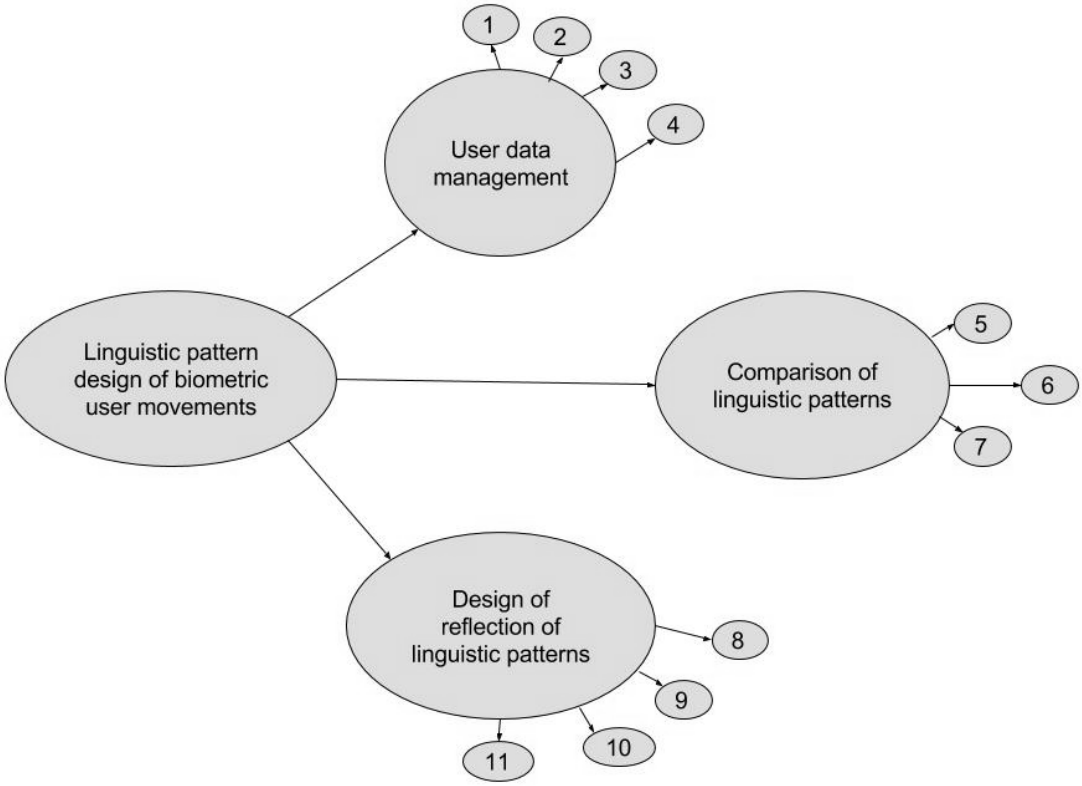


Fig. 1 – Structure of linguistic pattern design of biometric user movements

Client server interaction was built according to architectural pattern CRUD, which assumes existence typical operations such as creating, reading, updating and deleting data connected with user accounts.

The process of user authentication requires definition of differences between behaviours of different users (or even between same user in different time periods). Namely it is needed to define to which category current user linguistic pattern belongs: “user of system” or “alien”. Generally speaking system needs wider differentiation than two categories, to transfer current task to claster analysis.

*Mathematical description of comparison linguistic user patterns.* Aim of this research is to define mark for two linguistic patterns that states their similarity.

Given:

Quadratic matrix of rational numbers $\overline{P_1}$ size $n_1 = \left|\overline{P_1}\right|$;

Quadratic matrix of rational numbers $\overline{P_2}$ size $n_2 = \left|\overline{P_2}\right|$.

Results:

Rational number $l$.

Restrictions:

$$\forall x_{ij} \in \overline{P_1} : x_{ij} \in [0.0; 1.0], \quad (1.1)$$

where $i, j \in [0; n_1)$;

$$\forall x_{ij} \in \overline{P_2} : x_{ij} \in [0.0; 1.0], \quad (1.2)$$

where $i, j \in [0; n_2)$;

$$\forall i \in [0, n_1) : \sum_{j=0}^{n_1-1} p_i^j = 1.0 \vee \sum_{j=0}^{n_1-1} p_i^j = 0.0, \quad (1.3)$$

where $p_i^j \in \overline{P_1}$;

$$\forall i \in [0, n_2) : \sum_{j=0}^{n_2-1} p_i^j = 1.0 \vee \sum_{j=0}^{n_2-1} p_i^j = 0.0, \quad (1.4)$$

where $p_i^j \in \overline{P_2}$;

$$n_1 = n_2; \quad (1.5)$$

$$l \in [0.0, 1.0]. \quad (1.6)$$

Number of $l$ should be interpreted in such way: the closer $l$ to 1, the similar transition matrix are.

*Description of solution methods.* To solve this problem would be used the following approach: simultaneous passage through transition matrices $\overline{P_1}$ and $\overline{P_2}$, processing their elements with selected heuristic metrics $f$ and normalisation results of processing according to measures

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in formula 1.6. That is to say that metric $f$ is a set of two functions – accumulation function and normalization function [8].

*General algorithm for comparison of transition matrix.*

Step 1. Define summary of accumulation of values of metric as $compareSum = 0$.

Step 2. FOR ALL $i \in [0; n), where\ n = |\overline{P_1}|$ EXECUTE

2.1 FOR ALL $j \in [0; n), where\ n = |\overline{P_1}|$ EXECUTE

a. GATHER result of function $f^0$ metric $f$ for elements $p1_i^j \in \overline{P_1}$ and $p2_i^j \in \overline{P_2}$ and INSERT INTO $x$.

b. ACCUMULATE gathered result as $compareSum = compareSum + x$.

Step 3. GATHER result of function $f^1$ metric $f$ and summary of $compareSum$ and $n = |\overline{P_1}|$ and INSERT INTO $s$.

Step 4. RETURN $s$, STOP.

*Comment.* Transition matrices $\overline{P_1}, \overline{P_2}$, and metric $f$ are input data for algorithm.

Now will be described heuristic metrics, which are used in current research:

- Metric of absolute differences;
- Metric of null and unit elements.

*Metric of absolute differences.* Consider matrix $\overline{P_1}$ *and* $\overline{P_2}$ , which are taken according to formulas 3.1-3.5:

$$\overline{P_1} = \begin{pmatrix} 0.0 & 0.3 & 0.7 \\ 0.1 & 0.4 & 0.5 \\ 0.0 & 1.0 & 0.0 \end{pmatrix}; \overline{P_2} = \begin{pmatrix} 0.0 & 0.6 & 0.4 \\ 0.2 & 0.2 & 0.6 \\ 1.0 & 0.0 & 0.0 \end{pmatrix}.$$

Next heuristic will be used: find absolute summary of differences respective elements of matrices. According to formulas 1.1-1.4 for each row of matrix this summary can not enlarge value 2.0. Then accumulated value for whole matrix can not enlarge $2 * size$, where *size* – dimension of matrix.

For this particular example:

Absolute maximum value for summary of differences of elements:

$$2 * 3 = 6.$$

Absolute summary of differences of respective elements:

$$sum = (0.0 + 0.3 + 0.3) + (0.1 + 0.2 + 0.1) + (1.0 + 1.0 + 0.0) = 3.0.$$

Resulting similarity of matrices $l = \frac{3}{6} = 0.5$.

In fact, this heuristic shows absolute deviation of transition matrix to different transition matrix. Here are step by step algorithms that are necessary for this metric.

*Algorithm accumulating absolute differences between elements*

Step 1.COMPUTE difference of elements as $diff = x - y$.

Step 2.COMPUTE absolute value of difference as $abs = |diff|$

Step 3.RETURN value of *abs*, STOP.

*Note.* Input data for algorithm are two rational numbers $x$ *and* $y$.

*Algorithm for normalization metric of absolute differences*

Step 1.COMPUTE absolute limiting value of summary of differences as $limit = 2 * size$.

Step 2.COMPUTE normalized value of null and unit elements as $l = \frac{sum}{limit}$.

Step 3.RETURN $l$, STOP.

*Note.* Input data for algorithm are dimension of transition matrix *size* and absolute value of accumulated summary of differences of elements *sum*.

*Metric of null and unit elements.* Consider matrices from previous section.

$$\overline{P_1} = \begin{pmatrix} 0.0 & 0.3 & 0.7 \\ 0.1 & 0.4 & 0.5 \\ 0.0 & 1.0 & 0.0 \end{pmatrix} and \ \overline{P_2} = \begin{pmatrix} 0.0 & 0.6 & 0.4 \\ 0.2 & 0.2 & 0.6 \\ 1.0 & 0.0 & 0.0 \end{pmatrix}.$$

Next heuristic will be used: check the total number of zeros or units that are located in the same positions in both matrices. It is obvious that this normalization is to divide the total amount by the total number of elements in the matrix.

For example:

Amount of elements in matrix– 9 (computes as $n * n$, where $n$ – dimension of quadratic matrix);

Total amount of nulls and units, matched – 2.Elements on positions(1,1) *and* (3,3).

Thus, the total similarity of matrices $l = \frac{2}{9} = 0.22(2)$.

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This heuristic is due to the fact of how significant the position of the same transition matrix elements is during linguistic analysis [9]. Present general step-by-step algorithm for comparison of transition matrices needed by this metric.

*Accumulating algorithm for null and unit elements*

Step 1.IF true $((x = 0) \wedge (y = 0)) \vee ((x = 1) \wedge (y = 1))$, THEN GO TO Step 2, ELSE GO TO Step 3.

Step 2.RETURN 1, STOP.

Step 2.1 RETURN 0, STOP.

*Note.* Input data for algorithm are two rational numbers $x$ *and* $y$.

*Normalization algorithm for null and unit elements*

Step 1.COMPUTE amount of elements in matrix as $count = size * size$.

Step 2.COMPUTE normalised value of amount of null and unit elements as $l = \frac{sum}{count}$.

Step 3. RETURN $l$, STOP.

*Note.* Input data for algorithm are dimension of transition matrix *size* and absolute value of accumulated summary of differences of elements *sum*.

## Conclusions

Current research described general and mathematical formulation of problem of comparison linguistic patterns of trajectories of movements of manipulator. Problem was divided on two parts: general (comparison of linguistic patterns, which are presented by transition matrices) and residual (heuristic metrics, which present sets of two functions). Each part was discussed in details step-by-step algorithms, described input data for algorithms. Likewise for residual part were presented examples and results of usage of heuristic metrics and stated purpose of their usage.

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