Notes on Intuitionistic Fuzzy Sets
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Generalized net model of a biometric authentication system based on palm geometry and palm vein matching using intuitionistic fuzzy evaluations

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Abstract: In the current research work a multimodal biometric system is investigated. It combines the palm vein authentication and palm geometry recognition methods. The system will be used to manage the access control. The apparatus of generalized nets is applied to model the biometric authentication processes. The constructed generalized net model of biometric authentication system based on palm geometry and palm vein matching using intuitionistic fuzzy evaluations can be used for simulation of the real processes. The intuitionistic fuzzy evaluations are used to compare the user traits with the templates stored in database.

Keywords: Biometrics, Generalized nets, Intuitionistic fuzzy sets, Palm vein authentication, Palm geometry authentication.
2010 Mathematics Subject Classification: 03E72, 68Q85.

1 Introduction

The standard process of biometric pattern recognition problem contains a sequence different stages: acquisition, image quality assessment, preprocessing, region of interest (RoI) determination (templates), feature extraction and biometric comparison. Types of biometric authentication methods include face recognition, fingerprint recognition, eyes–retina–iris

recognition, ear recognition, hand geometry recognition, odor identification, vein recognition, gait recognition, typing recognition, voice – speaker authentication, signature recognition and etc. Depending of the traits for capturing the algorithm can be modified. Hand-based biometric systems measure and analyze the structure, shape and proportions of the hand or extract characteristics of the skin surface of the palm. The scan devices are measuring and recording the length, width, thickness, and surface area of the hand of an individual. Hand geometry systems use a camera to capture a silhouette image of the hand. Palm vein authentication uses palm veins as the biometric feature. In the palm vein scan the infrared light maps the unique vein structure of the palm. The infrared light observes the palm vein, which is normally unobservable by the human eye. The similarity between the captured palm vein and the template stored in the database can be calculated using different methods. The resulting similarity score is verified using predetermined threshold [18].

2 Generalized net model of biometric authentication system based on palm geometry and palm vein matching using intuitionistic fuzzy evaluations

The theory of Genelarized Nets (GNs) is introduced in [1, 6, 7]. GN models for pattern recognition processes are published [2–5, 10]. GN model of biometric access-control system and GN model of multimodal biometric systems are constructed [2, 8]. The biometric methods as iris recognition [11, 17], face recognition [14–16], fingerprints recognition [9] and signature verification [10], image classification [13] are already modeled using the apparatus of GNs. In the current paper a generalized net model of biometric authentication system based on palm geometry and palm vein matching using intuitionistic fuzzy evaluations is constructed using GNDraw software [12]. It contains 9 transitions and 39 places (Fig. 1). The set of transitions A has the following form:

$$A = \{Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7, Z_8, Z_9\},$$

where the transitions describe the following processes:

- Z_1 – users;
- Z_2 – scanning the user traits: palm vein trait and palm geometry trait;
- Z_3 – image quality assessment and preprocessing the palm vein and palm geometry images;
- Z_4 – region of interest (RoI) determination and palm vein templates extracting;
- Z_5 – region of interest (RoI) determination and palm geometry templates extracting;
- Z_6 – storing templates and passwords in database;
- Z_6 – passwords validation;
- Z_8 – biometric comparison (pattern matching);
- Z_9 – calculating intuitionistic fuzzy evaluations.

Initially, there is one α_{14}-token that is located in place L_{28} with initial characteristic: "*database*". In the next time-moments this token is split into two or more. The original α_{14}-token will continue to stay in place l_{28}, while the other α-tokens will move to the next transitions.

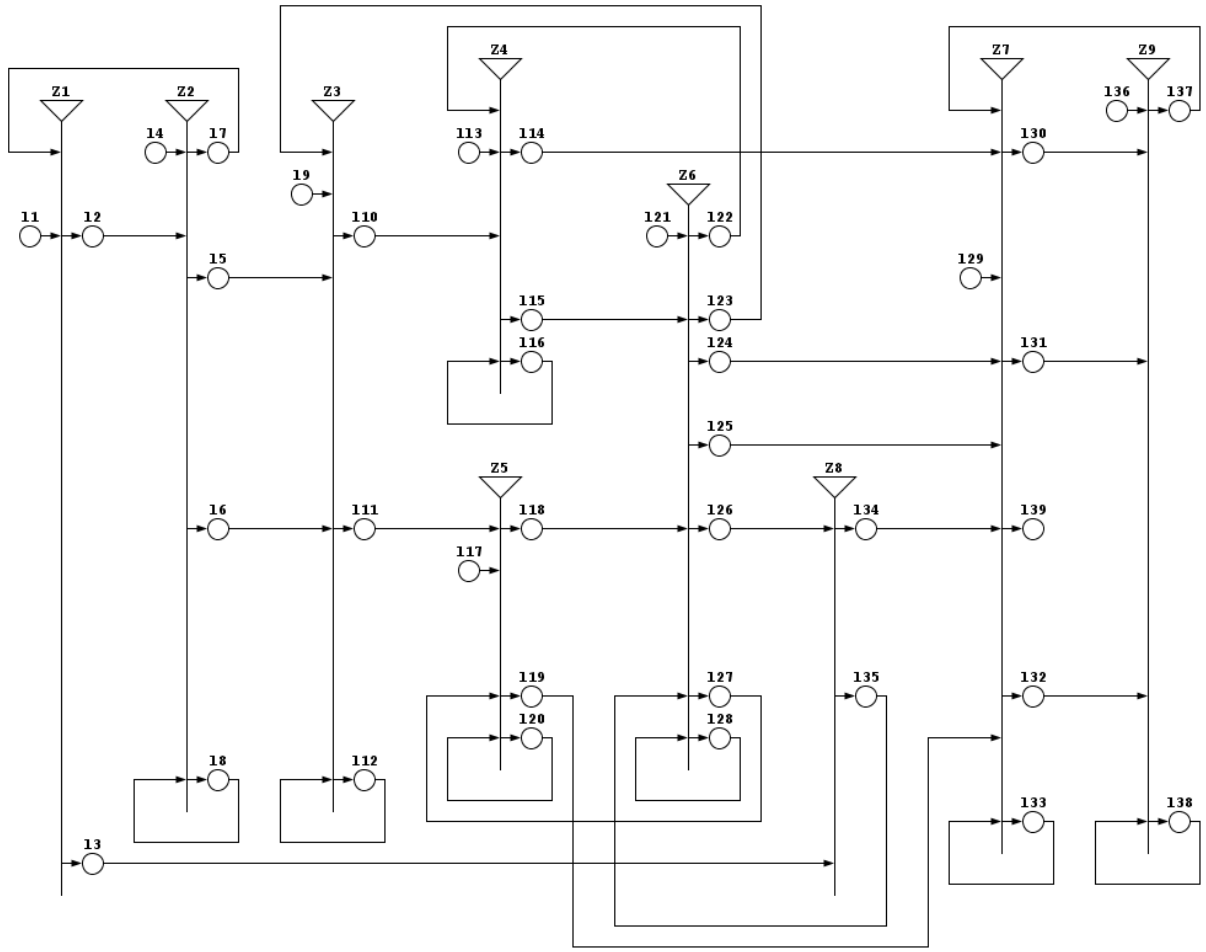

Figure 1. Generalized net model of biometric authentication system based on palm geometry and palm vein matching using intuitionistic fuzzy estimations

The token α_1 enters the net via place l_1 with initial characteristic: "*user*".

The transition Z_1 has the form:

$$Z_1 = \langle \{l_1, l_7\}, \{l_2, l_3\}, R_1, \vee(l_1, l_7) \rangle,$$

where:

$$R_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & W_{1,2} & W_{1,3} \\ l_7 & true & false \end{array}$$

and

- $W_{1,2}$ = "there are user for scanning";
- $W_{1,3}$ = "there are user for password".

The α-tokens that enter places l_2 and l_3 have the following characteristics: "*user for scanning*" in place l_2, and "*user for password*" in place l_3.

The token β_1 enters the net via place l_4 with initial characteristic: "*scanning parameters*".

The transition Z_2 has the form:

$$Z_2 = \langle \{l_2, l_4, l_8\}, \{l_5, l_6, l_7, l_8\}, R_2, \vee(\wedge(l_2, l_4), l_8) \rangle,$$

where:

$$R_2 = \begin{array}{c|cccc} & l_5 & l_6 & l_7 & l_8 \\ \hline l_2 & false & false & false & true \\ l_4 & false & false & false & true \\ l_8 & W_{8,5} & W_{8,6} & W_{8,7} & W_{8,8} \end{array}$$

and

- $W_{8,5}$ = "there is scanned palm geometry";
- $W_{8,6}$ = "there is scanned palm vein";
- $W_{8,7}$ = "the user traits is needed to scan again";
- $W_{8,8} = \neg (W_{8,5} \wedge W_{8,6} \wedge W_{8,7})$.

The α-tokens that enter in the places l_5, l_6 and l_7 have the following characteristics:

- "*scanned palm geometry*" in place l_5,
- "*scanned palm vein*" in place l_6, and
- "*the user traits to scan again*" in place l_7.

The token β_2 enters the net via place l_9 with initial characteristic: "*parameters for preprocessing*".

The transition Z_3 has the form:

$$Z_3 = \langle \{l_5, l_6, l_9, l_{12}, l_{23}\}, \{l_{10}, l_{11}, l_{12}\}, R_3, \vee(\wedge(l_5, l_6, l_9, l_{23}), l_{12}) \rangle,$$

where:

$$R_3 = \begin{array}{c|ccc} & l_{10} & l_{11} & l_{12} \\ \hline l_5 & false & false & true \\ l_6 & false & false & true \\ l_9 & false & false & true \\ l_{12} & W_{12,10} & W_{12,11} & W_{12,12} \\ l_{23} & false & false & true \end{array}$$

and

- $W_{12,10}$ = "there are preprocessed palm vein images";
- $W_{12,11}$ = "there are preprocessed palm geometry images";
- $W_{12,12} = \neg (W_{12,10} \wedge W_{12,11})$.

The α-tokens that enter places l_{10} and l_{11} have the following characteristics: "*preprocessed palm vein images*" in place l_{10}, and "*preprocessed palm geometry images*" in place l_{11}.

The token β_3 enters the net via place l_{13} with initial characteristic: "*parameters for palm vein templates extraction*".

The transition Z_4 has the form:

$$Z_4 = \langle \{l_{10}, l_{13}, l_{16}, l_{22}\}, \{l_{14}, l_{15}, l_{16}\}, R_4, \vee(\wedge(\ l_{10}, l_{13}, l_{22}), l_{16}) \rangle,$$

where:

$$R_4 = \begin{array}{c|ccc} & l_{14} & l_{15} & l_{16} \\ \hline l_{10} & false & false & true \\ l_{13} & false & false & true \\ l_{16} & W_{16,14} & W_{16,15} & W_{16,16} \\ l_{22} & false & false & true \end{array}$$

and

- $W_{16,14}$ = “there are extracted palm vein templates for comparison”;
- $W_{16,15}$ = “there are extracted palm vein templates for storing in database”;
- $W_{16,16} = \neg (W_{16,14} \wedge W_{16,16})$.

The α-tokens that enter in the places l_{14} and l_{15} have the following characteristics: “*extracted palm vein templates for comparison*” in place l_{10} and “*extracted palm vein templates for storing in database*” in place l_{11}.

The token β_4 enters the net via place l_{17} with initial characteristic: “*parameters for palm geometry extraction*”.

The transition Z_5 has the form:

$$Z_5 = \langle \{l_{11}, l_{17}, l_{20}, l_{27}\}, \{l_{18}, l_{19}, l_{20}\}, R_5, \vee(\wedge(l_{11}, l_{17}, l_{27}), l_{20}) \rangle,$$

where:

$R_5 =$

	l_{18}	l_{19}	l_{20}
l_{11}	*false*	*false*	*true*
l_{17}	*false*	*false*	*true*
l_{20}	$W_{20,18}$	$W_{20,19}$	$W_{20,20}$
l_{27}	*false*	*false*	*true*

and

- $W_{20,18}$ = “there are extracted palm geometry templates for storing in database”;
- $W_{20,19}$ = “there are extracted palm geometry templates for comparison”;
- $W_{20,20} = \neg (W_{20,18} \wedge W_{20,19})$.

The α-tokens that enter places l_{18} and l_{19} have the following characteristics: “*extracted palm geometry templates for storing in database*” in place l_{18} and “*extracted palm geometry templates for comparison*” in place l_{19}.

The token β_5 enters the net via place l_{21} with initial characteristic: “*previously generated user traits data and passwords*”.

The transition Z_6 has the form:

$$Z_6 = \langle \{l_{15}, l_{18}, l_{21}, l_{28}, l_{35}\}, \{l_{22}, l_{23}, l_{24}, l_{25}, l_{26}, l_{27}, l_{28}\}, R_6, \vee(l_{15}, l_{18}, l_{21}, l_{28}, l_{35}) \rangle,$$

where:

$R_6 =$

	l_{22}	l_{23}	l_{24}	l_{25}	l_{26}	l_{27}	l_{28}
l_{15}	*false*	*false*	*false*	*false*	*false*	*false*	*true*
l_{18}	*false*	*false*	*false*	*false*	*false*	*false*	*true*
l_{21}	*false*	*false*	*false*	*false*	*false*	*false*	*true*
l_{28}	$W_{28,22}$	$W_{28,23}$	$W_{28,24}$	$W_{28,25}$	$W_{28,26}$	$W_{28,27}$	$W_{28,28}$
l_{35}	*false*	*false*	*false*	*false*	*false*	*false*	*true*

and

- $W_{28,22}$ = “the palm vein templates extraction is needed”;
- $W_{28,23}$ = “there are templates for preprocessing”;
- $W_{28,24}$ = “there are palm vein templates for comparison”;
- $W_{28,25}$ = “there are palm geometry templates for comparison”;
- $W_{28,26}$ = “there are password”;

- $W_{28,27}$ = “the palm geometry templates extraction is needed”;
- $W_{28,28} = \neg (W_{28,22} \wedge W_{28,23} \wedge W_{28,24} \wedge W_{28,25} \wedge W_{28,26} \wedge W_{28,27})$.

The α-tokens that enter places l_{22}, l_{23}, l_{24}, l_{25}, l_{26} and l_{27} have the following characteristics:

- “*demand of palm vein templates extraction*” in place l_{22},
- “*templates for preprocessing*” in place l_{23},
- “*palm vein templates for comparison*” in place l_{24},
- “*palm geometry templates for comparison*” in place l_{25},
- “*password*” in place l_{26} and
- “*demand of palm geometry templates extraction*” in place l_{27}.

The token β_6 enters the net via place l_{29} with initial characteristic: “*parameters for pattern matching*”.

The transition Z_7 has the form:

$$Z_7 = \langle \{l_{14}, l_{19}, l_{24}, l_{25}, l_{29}, l_{33}, l_{34}, l_{37}\}, \{l_{30}, l_{31}, l_{32}, l_{33}, l_{39}\}, R_7, \vee(\wedge(l_{14}, l_{19}, l_{24}, l_{25}, l_{29}, l_{34}, l_{37}), l_{33})\rangle,$$

where:

$R_7 =$

	l_{30}	l_{31}	l_{32}	l_{33}	l_{39}
l_{14}	*false*	*false*	*false*	*true*	*false*
l_{19}	*false*	*false*	*false*	*true*	*false*
l_{24}	*false*	*false*	*false*	*true*	*false*
l_{25}	*false*	*false*	*false*	*true*	*false*
l_{29}	*false*	*false*	*false*	*true*	*false*
l_{33}	$W_{33,30}$	$W_{33,31}$	$W_{33,32}$	$W_{33,33}$	$W_{33,39}$
l_{34}	*false*	*false*	*false*	*true*	*false*
l_{37}	*false*	*false*	*false*	*true*	*false*

and

- $W_{33,30}$ = “there are palm vein patterns for intuitionistic fuzzy estimation”;
- $W_{33,31}$ = “there are palm geometry patterns for intuitionistic fuzzy estimation”;
- $W_{33,32}$ = “there are password for intuitionistic fuzzy estimation”;
- $W_{33,39}$ = “there are result of pattern matching using intuitionistic fuzzy estimation”;
- $W_{33,39} = \neg (W_{33,30} \wedge W_{33,31} \wedge W_{33,32} \wedge W_{33,39})$.

The α-tokens that enter in the places l_{30}, l_{31}, l_{32} and l_{39} have the following characteristics:

- “*palm vein patterns for intuitionistic fuzzy estimation*” in place l_{30},
- “*palm geometry patterns for intuitionistic fuzzy estimation*” in place l_{31},
- “*password for intuitionistic fuzzy estimation*” in place l_{32} and
- “*result of pattern matching using intuitionistic fuzzy estimations*” in place l_{39}.

The intuitionistic fuzzy evaluations of the images of palm vein, palm geometry and passwords are calculated using the following sets:

- cardinality of the set of pixels is p;
- cardinality of the common set of pixels in the two images t;
- cardinality of the set containing the different pixels from the first image f.

Therefore, the intuitionistic fuzzy estimations have the following form:

– degree of membership

$$\mu_A(x) = \frac{t}{p},$$

– degree of non-membership

$$\nu_A(x) = \frac{f}{p},$$

– degree of uncertainty

$$\pi_A(x) = 1 - \frac{t}{p} - \frac{f}{p}.$$

The intuitionistic fuzzy evaluations are calculated for the palm geometry authentication, palm vein authentication and password identification.

The transition Z_8 has the form:

$$Z_8 = \langle \{l_3, l_{26}\}, \{l_{34}, l_{35}\}, R_8, \vee(l_3, l_{26}) \rangle,$$

where:

$$R_8 = \begin{array}{c|cc} & l_{34} & l_{35} \\ \hline l_3 & true & false \\ l_{26} & W_{26,34} & W_{26,35} \end{array}$$

and

- $W_{26,34}$ = "there are password";
- $W_{26,35} = \neg W_{26,34}$.

The α-token that enters place l_{34} has the following characteristics: "*password*".

The token β_6 enters the net via place l_{36} with initial characteristic: "*formulas for intuitionistic fuzzy evaluations*".

The transition Z_9 has the form:

$$Z_9 = \langle \{l_{30}, l_{31}, l_{32}, l_{36}, l_{38}\}, \{l_{37}, l_{38}\}, R_9, \vee(\wedge(l_{30}, l_{31}, l_{32}, l_{36}), l_{38}) \rangle,$$

where:

$$R_9 = \begin{array}{c|cc} & l_{37} & l_{38} \\ \hline l_{30} & false & true \\ l_{31} & false & true \\ l_{32} & false & true \\ l_{36} & false & true \\ l_{38} & W_{38,37} & W_{38,38} \end{array}$$

and

- $W_{38,37}$ = "there are intuitionistic fuzzy evaluations";
- $W_{38,38} = \neg W_{38,38}$.

The α-token that enters in the place l_{37} has the following characteristics: "*intuitionistic fuzzy evaluations*".

3 Conclusion

In the present research work, a generalized net model of biometric authentication system based on palm geometry and palm vein matching using intuitionistic fuzzy evaluations is constructed. Palm geometry identification and palm vein matching are two of the main methods in the area of biometrics authentication. They are used in access control systems. The calculated intuitionistic fuzzy evaluations are used in the pattern matching phase. The constructed generalized net model of biometric authentication system based on palm geometry and palm vein matching using intuitionistic fuzzy evaluations can be applied for simulation of the real access control processes.

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