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A GENERALIZED NET MODEL OF BIOMETRIC ACCESS CONTROL SYSTEM

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Abstract. In this paper, a generalized net model of a biometric access control system is described. It is an extension of the existing generalized net models of such systems.

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1. Introduction

In a series of papers, collected in the books [3, 4], different processes of pattern and speaker recognition, classification, verification and identification are described by Generalized Nets (GNs; see [1, 2]). In [4], our aim was to detail the estimations related to these processes, using the approach of the Intuitionistic Fuzzy Sets (IFSs).

The GNs are a suitable tool for describing of parallel processes flowing in real-time, because these nets give the possibility to represent both the analytical point of

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view (using GN-token characteristics) and the logical point of view of the processes (using the GN-transition condition predicates). Using ordinary GNs, we estimate these predicated in the frameworks of the ordinary first-order logic. If elements of intuitionistic fuzziness are added, we can estimate the predicates and the validity of the tokens characteristics in more detail: with degrees of validity (correctness, etc.) and of non-validity (incorrectness, etc.).

As an illustration, extending results from [3, 4], we describe a generalized net model of biometric access control system.

2. A generalized net model

The rapid development of information and communication technologies gives the possibility for an easy and fast access to data bases of important personal or institutional information which may cause considerable damage to individuals, firms or state security. This requires secure authentication of the individuals trying to get access to specific resources. One of the approaches to the prevention of non-authorized access that has been intensively developed during the last decades uses biometric parameters the most popular of which are face, voice, fingerprints, hand, iris and signature [5 - 9]. However, the use of multi-modal information requires different modalities to be merged. The simplest way to do this is by making classification consecutively, i.e. modality by modality, and draw a conclusion on the obtained classification results. This process has to be modeled in order to have a common design for the development of concrete access control systems. In the present paper, such a model, based on the theory of GNs is described. It includes the major stages of image and/or voice processing, feature measurement, evaluation and classification. It assumes a consecutive decision-making and includes the possibility for re-education of the decision rules, if necessary.

Let us have n persons some of who are authorized to have access to a specific resource on the basis of some biometric parameters like voice, face (full face, left and right profile), handwriting, iris, finger print, signature and others. Let these persons are represented in the GN-model by tokens $\pi_1, ..., \pi_n$. In place l_{14} (see Fig. 1) there is a token Δ that represents the database with information for the persons who have access to the specific resource. It stays permanently in place l_{14} and has as an initial and current characteristic

"list of the persons who have access to the specific resource and their

biometric parameters refer to the first patterns and to the dates of

the previous visits of the persons".

In the present GN-model, we will use only the above mentioned 8 types of biometric parameters.

Let the procedures for obtaining of these parameters be:

Procedure 1 - voice verification/identification;
Procedure 2 - full face verification/identification;
Procedure 3 - left profile verification/identification;
Procedure 4 - right profile verification/identification;
Procedure 5 - handwriting verification/identification;
Procedure 6 - iris verification/identification;
Procedure 7 - finger verification/identification;

Procedure 8 - signature verification/identification.

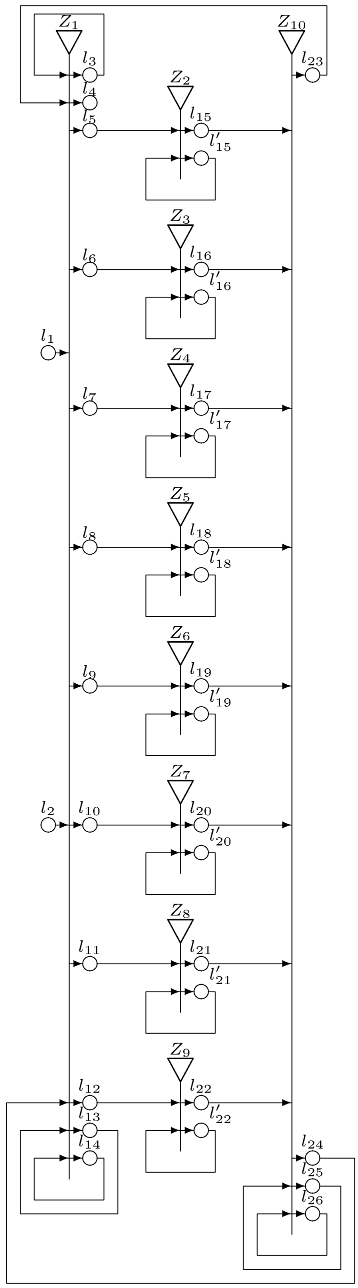

Fig. 1. GN-model of a biometric access control system.

The present GN-model has a more general form than the model from [4]. In it, in the first moment of the GN-functioning, a token ω enters place l_2 with initial characteristic:

"list of three biometric parameters that must be checked initially in the present simulation; way for evaluation of the results of comparison (e.g., optimistic, average, pessimistic); minimal admissible level α and maximal non-admissible level γ for evaluations".

For example, in [4], these three biometric parameters are: "person's voice", "person's face", "person's signature" and they are fixed, while here they are different for the separate simulations.

The system may work in two different ways, as follows:

1. The person claims his/her personality by entering his/her name or parole, and the system will verify it on the basis of his biometric parameters.
2. The person does not identify himself/herself and the system must identify him/her as belonging or not belonging to the group of authorised persons on the basis of his/her biometric parameters.

In the present paper we assume the first way of processing, i.e., verification procedure will be applied.

Tokens $\pi_1, ..., \pi_n$ enter the GN through place l_1. When i-th person wants to get access, its token splits into four tokens as follows: the same π_i-token that enters place l_3, where it will wait for the permission for access and the three new tokens. In the case from [4], these three tokens are β_i, φ_i and σ_i, that correspond to the voice, the face, and the signature, respectively.

Below, for brevity, we will omit index i for these tokens.

The form of transition Z_1 is (see Fig. 1):

$$Z_1 = \langle \{l_1, l_2, l_3, l_{13}, l_{14}, l_{23}, l_{24}\}, \{l_3, l_4, l_5, l_6, l_7, l_8, l_9, l_{10}, l_{11}, l_{12}, l_{13}, l_{14}\},$$

	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	l_{14}
l_1	T	F	$W_{1,5}$	$W_{1,6}$	$W_{1,7}$	$W_{1,8}$	$W_{1,9}$	$W_{1,10}$	$W_{1,11}$	$W_{1,12}$	F	F
l_2	F	F	F	F	F	F	F	F	F	F	T	F
l_3	T	$W_{3,4}$	$W_{3,5}$	$W_{3,6}$	$W_{3,7}$	$W_{3,8}$	$W_{3,9}$	$W_{3,10}$	$W_{3,11}$	$W_{3,12}$	F	F
l_{13}	F	F	F	F	F	F	F	F	F	F	T	F
l_{14}	F	F	F	F	F	F	F	F	F	F	F	T
l_{23}	$W_{23,3}$	$W_{23,4}$	F	F	F	F	F	F	F	F	F	T
l_{24}	F	F	F	F	F	F	F	F	F	F	F	T

$\rangle$

where F and T are abbreviations of $false$ and $true$, respectively, and for $j = 1, 2, \ldots, 8$:

$W_{1,j+4}$ = "the Procedure j determined in ω-characteristic must be realized for the i-th person",

$W_{23,3}$ = "the person must wait for additional checks",

$W_{23,4} = W_{3,4}$ = "the process of person's parameters checks is finished",

$W_{23,j+4}$ = "the Procedure j determined in the ψ-characteristic must be realized for the i-th person",

where ψ (short for ψ_i) is a token, generated in transition Z_{10} and it is described below. Three of the predicates $W_{1,j+4}$ must have truth-value true and the rest one - false; while the number of the predicates $W_{23,j+4}$, that must have truth-value true, is dependedent on the characteristic of token ψ, that we will describe in transition Z_{10}.

Token π from place l_1 splits to four tokens, as it was mentioned above. The original token π enters place l_3 without a new characteristic. It will stay in this place till the moment, when there is clearness for the coincidence of the current person's parameters and already existing ones in the data base Δ.

If predicate $W_{23,3}$ has truth-value "*true*", the φ_i-token (of for brevity φ) splits to one or two tokens in respect of its last characteristic, received in place l_{23}. In the opposite case, when predicate $W_{23,4}$ has truthg-value "*true*", token φ from place l_{23} enters place l_4 together with the π-token from place l_3 and both tokens are united with one of the characteristics:

"the i-th person obtains permission for access"

or

"the i-th person does not obtain permission for access"

depending on the previous φ-characteristic.

Token ω from place l_2 enters place l_{13}, where it stays permanently till the end of the GN-functioning and it determines the first checks of persons' biometric parameters.

In the case from [4], for the first predicate $j = 1, 2, 3$, and there, the tokens are marked by β, φ and σ. They enter places l_5, l_6 and l_7, respectively with characteristics:

"initial i-th person's voice parameters",

"initial i-th person's full face parameters",

"initial i-th person's signature parameters".

Transitions $Z_2, Z_3, \ldots, Z_9$ have equal forms. So, for $j = 2, 3, \ldots, 9$:

$$Z_j = \langle \{l_{j+4}\}, \{l_{j+14}\}, \begin{array}{c|cc} & l_{j+14} & l'_{j+14} \\ \hline l_{j+4} & false & true \\ l'_{j+14} & W_{j+14,j+14} & W'_{j+14,j+14} \end{array} \rangle,$$

where

$W_{j+14,j+14} =$"all patterns in the data base, related to Procedure j and the current pattern are checked",

$W'_{j+14,j+14} = \neg W_{j+14,j+14}$,

where $\neg P$ is the negation of predicate P.

Token from place l_{j+4} enters place l'_{j+14} with a characteristic:

"results of the use of Procedure j over i-th person's parameters;

the result of the comparison of the present research with the current pattern in the database, related to the i-th person's parameters".

When $W_{j+14,j+14} = true$, the token enters place l_{j+14} with a characteristic:

"list of all results of the use of Procedure j over i-th person's parameters;

list of all results of the comparison of the i-th person's parameters".

We must mention that the result of the comparison (the second part of the token's characteristic) can have the form of an IFP, i.e. $\langle \mu_{i,j,k}, \nu_{i,j,k} \rangle$, where

$$\mu_{i,j,k}, \nu_{i,j,k}, \mu_{i,j,k} + \nu_{i,j,k} \in [0, 1]$$

and $\mu_{i,j,k}$ is the degree of coincidence and $\nu_{i,j,k}$ - degree of non-coincidence of the i-th person's parameters evaluated by Procedure j with the k-th parameters of the i-th person memorized in the data base, where $k = 1, 2, \ldots, s_{i,j}$ and $s_{i,j}$ is the number of the patterns in the data base, related to the i-th person's parameters that must be evaluated by Procedure j.

Let us use here this more general form of the characteristic. Then, when $W'_{j+14,j+14} = true$, the token enters place $l_{j+14,j+14}$ with a characteristic:

$$\text{“}\langle \delta_{i,j}, \varepsilon_{i,j} \rangle = \langle \rho(\mu_{i,j,1}, ..., \mu_{i,j,s_{i,j}}), \sigma(\mu_{i,j,1}, ..., \mu_{i,j,s_{i,j}}) \rangle\text{”},$$

where the form of the pair (ρ, σ) is dependent on the second part of the initial characteristic of token β, i.e., they can determine optimistic, average or pessimistic evaluation for all results of the comparisons and $\langle \delta_{i,j}, \varepsilon_{i,j} \rangle$ is the aggregated evaluation of the i-th person's parameters evaluated by Procedure j.

These eight transitions can be changed by hierarchical operator H_3 with the respective GNs that represent the separate procedures. These GNs are described in [3, 4].

$$Z_{10} = \langle \{l_{15}, l_{16}, l_{17}, l_{18}, l_{19}, l_{20}, l_{21}, l_{22}, l_{25}, l_{26}\}, \{l_{23}, l_{24}, l_{25}, l_{26}\},$$

$$\begin{array}{c|cccc} & l_{23} & l_{24} & l_{25} & l_{26} \\ \hline l_{15} & false & false & false & true \\ l_{16} & false & false & false & true \\ l_{17} & false & false & false & true \\ l_{18} & false & false & false & true \\ l_{19} & false & false & false & true \\ l_{20} & false & false & false & true \\ l_{21} & false & false & false & true \\ l_{22} & false & false & false & true \\ l_{25} & false & true & false & true \\ l_{26} & true & W_{26,24} & W_{26,25} & false \end{array} \rangle,$$

where
$W_{26,24} =$ “there is a second check for token π”,
$W_{26,25} =$“not all first checks are positive or negative”.

The three, two or one token(s) from places $l_{15}, l_{16}, \ldots, l_{22}$ enter(s) place l_{26}, where they are united in a token χ with a characteristic:

$$\text{“}\langle \zeta_{i,j}, \eta_{i,j} \rangle = \langle \rho(\delta_{i,j}, ...), \sigma(\varepsilon_{i,j}, ...) \rangle\text{”},$$

where components of ρ and σ depend on the number of arrived tokens in place l_{26}.

We must mention that after the entering in the GN of token π, the tokens generated by it will be initially exactly three. If additional check is necessary, the new tokens, generated by π will be one or two. Obviously, when (in the second case) only one token enters place l_{26}, an aggregation procedure will be omitted and the token will not obtain any characteristic in place l_{26}.

The token χ from place l_{26} after the first splitting of token π (it is possible, this split to be unique) will split to two tokens - the same token χ that enters place l_{25} with a characteristic:

$$\text{“list of IFPs } \langle \delta_{i,j}, \varepsilon_{i,j} \rangle \text{ for which } \delta_{i,j} \geq \alpha, \varepsilon_{i,j} \leq \beta\text{”}$$

and token ψ that enters place l_{23} with characteristic:

$$\begin{cases} \text{all checks are positive,} & \text{if } \zeta_{i,j} > \alpha \text{ and } \eta_{i,j} < \beta \\ \text{no check is positive,} & \text{if } \zeta_{i,j} < \alpha \text{ or } \eta_{i,j} > \beta \\ \text{Procedure(s) } l \text{ (and } m\text{) must be realized,} & \text{otherwise} \end{cases},$$

where $l, m \in \{1, 2, \ldots, 8\}$ and they are different from the numbers of already realized procedures. If two of the first Procedures are finished positively, then only one new procedure must be realized; otherwise – two procedures must be realized. For example, if Procedure p gives negative result, it can be checked by Procedure q, where

value of p	value of q
1	5
2 with right deformation	3
2 with left deformation	4
2 with other deformation	6
3	4
4	3
5	1 or 7
6	1 or 7
7	1 or 6
8	1 or 7

The two or one token(s) from places $l_{15}, l_{16}, \ldots, l_{22}$ and the token χ from place l_{25} enter place l_{26}, where they are united in a token χ with a characteristic:

$$\text{“}\langle \zeta_{i,j}, \eta_{i,j} \rangle = \langle \rho(\delta_{i,j}, ...), \sigma(\varepsilon_{i,j}, ...) \rangle\text{”},$$

where components of ρ and σ depend on the number of arrived tokens in place l_{26}.

The token χ from place l_{26} after the second splitting of token π will split to two tokens - the same token χ that enters place l_{24} with a characteristic:

“set of all patterns of the i-th person, date”

and token ψ that enters place l_{23} with a characteristic:

$$\begin{cases} \text{the new checks are positive,} & \text{if } \zeta_{i,j} > \alpha \text{ and } \eta_{i,j} < \beta \\ \text{no check is positive,} & \text{otherwise} \end{cases}.$$

So, the database will be enriched with information for some changes of the i-th person's biometric parameters.

3. Conclusion

The described GN-model can be used for the development of a particular access control system based on biometric parameters. Different strategies could be implemented depending on the problem, e.g., access may be granted using only one of the modalities provided a high confidence result is obtained, or it may be denied after three failures, and likewise.

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