A generalized net model of biometric access-control system

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Abstract: The Ceneralized Nets (GN) that are an extension of Petri Nets have been used for modeling of different processes, including intellectual ones. In this paper a CN model is developed for the description of the functioning of an biometrics based access-control system. The model gives the possibility for the investigation and practical realization of specific systems.

Key–Words: Generalized Net, Modeling, Biometrics, Access Control

1 Introduction

The rapid development of information and communication technologies gives the possibility to 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 for the prevention from non-authorized access that has been intensively developed during the last decades has used biomtric parameters the most popular of which were face, voice, fingerprints, hand, iris and signature [4, 5, 6, 7, 8]. However, the use of multi modal information requires different modalities to be merged. The simplest way to do this is of 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 this paper such a model, based on the theory of Generalized Nets (GNs, see [1]) is described. It includes the major stages of image, signature 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. The paper is extension of our previous research [3].

2 Short remarks on generalized nets

The concept of a *Generalized Net* (GN) is described in [1]. A given GN may not have some of the components, and such GNs give rise to special classes of GNs called "reduced GNs". For the needs of the present research we shall use (and describe) one of the reduced types of GNs.

Formally, every transition of a reduced GN is described by a four-tuple (Fig. 1):

$$Z = \langle L', L'', r, \rangle,$$

where:

(a) L' and L'' are finite, non-empty sets of places (the transition's input and output places, respectively); for the transition in Fig. 1 these are

$$L' = \{l'_1, l'_2, \dots, l'_m\}$$

and

$$L'' = \{l''_1, l''_2, \ldots, l''_n\};$$

(b) r is the transition's *condition* determining which tokens will pass (or *transfer*) from the transition's inputs to its outputs; it has the form of an Index Matrix (IM; see [1]):

$$r = \begin{array}{c|c} & l''_1 \ \ldots \ l''_j \ \ldots \ l''_n \\ \hline l'_1 & \\ \vdots & r_{i,j} \\ l'_i & (r_{i,j} \ - \ \text{predicate}\ ) \\ \vdots & (1 \le i \le m, 1 \le j \le n) \\ l'_m & \end{array};$$

$r_{i,j}$ is the predicate which corresponds to the i-th input and j-th output places. When its truth value is "*true*", a token from i-th input place can be transferred to j-th output place; otherwise, this is not possible.

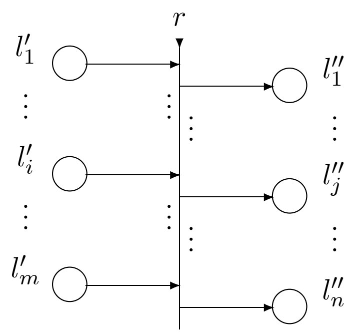

Fig. 1.

The ordered three-tuple

$$E = \langle A, K, X, \Phi \rangle$$

is called a *minimal reduced Generalized Net* if:

(a) A is a set of transitions;

(b) K is the set of the GN's tokens;

(c) X is the set of all initial characteristics the tokens can receive when they enter the net;

(d) Φ is a characteristic function which assigns new characteristics to every token when it makes a transfer from an input to an output place of a given transition.

3 GN model

Let us have n persons that are authorized to have access to a specific resource on the basis of some biometrical parameters like voice, face and signature. Let they be represented in the GN-model by tokens $\pi_1, ..., \pi_n$. These tokens are staying in place l_0. When some person wants to get access, its token does a circle from place l_0 to its transition Z_1 and simultaneously it splits into four tokens as follows: the same π-token and the new tokens β, φ and σ, where β corresponds to the voice, φ – to the face, and σ – to the signature. The latter three tokens enter places l_1, l_2 and l_3, respectively. The system may require additional data provided the submitted one is not sufficient for a reliable decision-making. The corresponding request will include one of the following: a new phrase among a few previously selected ones to be pronounced, a new face image of a different close-up to be captured, or a new writing to be done. Then the respective π-token does a new circle from place l_0 to its true transition Z_1 and simultaneously it splits into four tokens: the same π-token and the new tokens β', φ' and σ', that enter places l_4, l_5 and l_6 respectively (see Fig. 2).

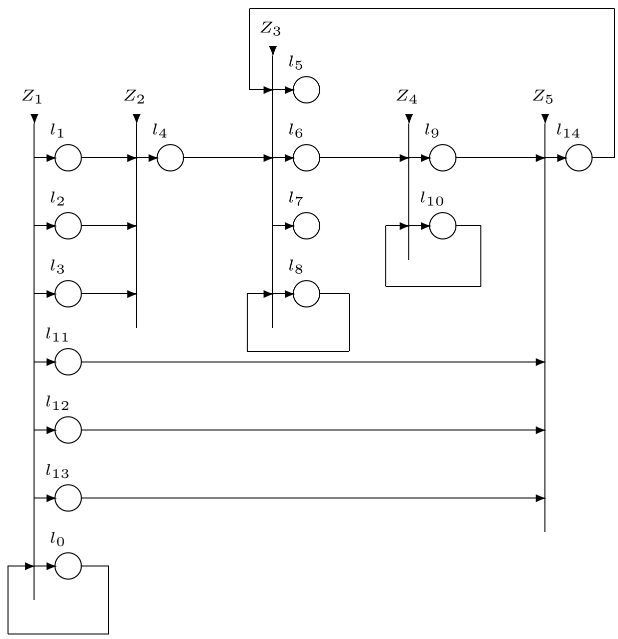

Fig. 2.

The form of transition Z_1 is

$$Z_1 =< \{l_0\}, \{l_0, l_1, l_2, l_3, l_4, l_5, l_6\},$$

	l_0	l_1	l_2	l_3	l_4	l_5	l_6
l_0	*true*	$W_{0,1}$	$W_{0,2}$	$W_{0,3}$	$W_{0,4}$	$W_{0,5}$	$W_{0,6}$

$>$,

where

$W_{0,1} =$ "the person must tell some phrase",

$W_{0,2}$ = "a face image is to be taken",
$W_{0,3}$ = "the person must sign",
$W_{0,4}$ = "the person must do the first additional request from x_{cu}^{α}",
$W_{0,5}$ = "the person must do the second additional request from x_{cu}^{α}",
$W_{0,6}$ = "the person must do the third additional request from x_{cu}^{α}",
where x_{cu}^{α} is the current characteristic of token α, described below.

Tokens β, φ and σ enter places l_1, l_2 and l_3, respectively with characteristics *"person's voice"*, *"person's face"*, *"person's signature"*. Tokens β', φ' and σ' enter places l_4, l_5 and l_6, respectively with characteristics *"first additional request"*, *"second additional request"*, *"third additional request"*.

The obtained person's information is normalized and collected in place l_7 of the second transition Z_2 that has the form

$$Z_2 = < \{l_1, l_2, l_3\}, \{l_7\},$$

$$\begin{array}{c|c} & l_7 \\ \hline l_1 & true \\ l_2 & true \\ l_3 & true \end{array} > .$$

Tokens β, φ and σ unite in place l_7 as one token – let us call it α with a characteristic *"person's identification parameters"*.

The token δ, representing the Data Base (DB) of the system, stays in place l_{11} with initial characteristic *"DB of persons' pattern"*.

The form of transition Z_3 is

$$Z_3 = < \{l_7, l_{11}, l_{14}\}, \{l_8, l_9, l_{10}, l_{11}\},$$

$$\begin{array}{c|cccc} & l_8 & l_9 & l_{10} & l_{11} \\ \hline l_7 & W_{7,8} & W_{7,9} & false & false \\ l_{11} & false & false & false & true \\ l_{14} & W_{14,8} & false & W_{14,10} & false \end{array} >,$$

where
$W_{7,8} = W_{14,8}$ = "the current person's biometric parameters coincide with these from the DB δ",
$W_{7,9} = W_{14,10} = \neg W_{7,8}$,
where $\neg P$ is the negation of predicate P.

Token α from place l_7 or from place l_{14} enters place l_8 with characteristic *"the person is authorised"*, if the biometric parameters of the current individual coincide with him/her parameters from the DB δ. In the opposite case α-token from place l_7 enters place l_9 with characteristic *"the person must be tested additionally if he/she likes to obtain access"* and α-token from place l_{14} enters place l_{10} with characteristic *"the person is not authorised"*.

During all the time of GN functioning token κ stays in place l_{13} with initial (and without next) characteristic *"criteria for generating of next test for estimation of the persons who like to obtain access"*.

When the person has to be tested additionally, the modelled system, using the respective criteria collected in the initial characteristic of token κ, will determine the next test for observation. For example, if the person has some face deformation (e.g., toothache) and articulation problems, then the system can ask him/her to write additional sentenses that are kept in the DB δ and/or to capture his/her profile without deformations (if exists), and/or to submit fingerprints, if possible.

The form of transition Z_4 is

$$Z_4 = < \{l_9, l_{13}\}, \{l_{12}, l_{13}\},$$

$$\begin{array}{c|cc} & l_{12} & l_{13} \\ \hline l_9 & true & false \\ l_{13} & false & true \end{array} > .$$

Token α from place l_9 enters place l_{12} with characteristic *"list of next admissible tests"*.

Finally, transition Z_5 has the form

$$Z_5 = < \{l_4, l_5, l_6, l_{12}\}, \{l_{14}\},$$

$$\begin{array}{c|c} & l_{14} \\ \hline l_4 & true \\ l_5 & true \\ l_6 & true \\ l_{12} & true \end{array} > .$$

Token α from place l_{12} and tokens β', φ' and σ' from places l_4, l_5, l_6, respectively, enter place l_{14}, where all they unite as α-token with characteristic *"new person's identification"*.

4 Conclusion

In this paper a GN-based model of a biometric access-control system is described. It covers all necessity processing steps irrespective to the number and character of modalities.

The model could be used for the development of a particular access-control system based on biometric parameters. Depending on the number of modalities some of the kernels and/or transitions could be ignored. Also, 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 like.

The future work will be aimed at the extension of the model in order to include the possibility to save the history of the system performance, i.e. to remember how many times an authorized person has accessed the system and the access time. Also, if the number of incorrect failures is registered, the system could be re-educated, using enlarged set of parameters involving those that have caused the failures.

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