Intuitionistic Fuzzy Generalized Net Model of the Process of Handwriting Analysis

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To Prof. Ivan Daskalov
for his 70-th birthday!

Abstract

Generalized Nets (GNs) are extensions and modifications of the ordinary Petri nets. The tokens enter the GN with initial characteristics and obtain new ones during their transfer in the net. Each GN-transition has input and output places (as in ordinary Petri nets), but it contains an index matrix (a matrix with indexed rows and columns) with elements - predicates that can be functions of the GN history up to the current moment (e.g., the tokens' characteristics). Intuitionistic Fuzzy General Nets, additionally, make it possible to describe imprecise information. We use this sort of nets in the process of handwriting analysis.

Keywords: General Nets, Intuitionistic Fuzzy General Nets, Handwriting analysis.

1 Introduction

Handwriting analysis is of primary importance in forensic science, development of access permission systems using biometric parameters, stress evaluation, evaluation of emotional condition of individuals, investigation of phsychiatric patients and others (see [1-4]). Despite the specific processing techniques stemming from handwriting peculiarities a theory for unified description of handwriting will be of great importance. The first attempt in this direction has been carried out with the application of Generalized Nets (GNs; see [5]). However, this approach assumes a deterministic evaluation, while, in practice, some innaccuracy is always present, concerning both parameter measurement and decision making. In particular, this concerns the so called general parameters that are of a qualitative nature. All these factors imply the insertion of imprecision in the analysis which could be done using the theory of Intuitionistic Fuzzy Sets (IFSs; see [6]) that are extensions of the ordinary fuzzy sets.

In 1985 there were defined the first two types of fuzzy Petri nets, called Intuitionistic Fuzzy GNs (IFGNs, see [5,7]) of first and of second types. They were extended to IFGSs of third and fourth types in [8].

All types of GNs can be ordinary (with all their components) or reduced (with only a part of their components). In Section 3 we shall use a reduced IFGN of the third type (IFGN3) and by this reason in Section 2 we shall give short description only of this type of nets.

2 Short remarks on IFGN3s

The concept of a *Generalized Net* (GN) is described in [5]. For the needs of the present research we shall use (and describe) one of the reduced types of GNs.

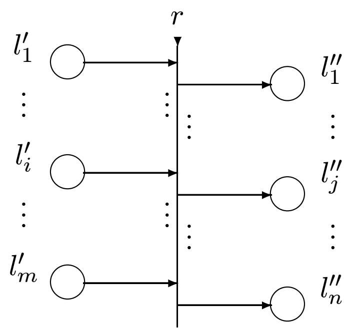

Fig. 1: GN-transition

Formally, every transition of this reduced class of GNs is described by (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 $L' = \{l'_1, l'_2, \ldots, l'_m\}$ 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 [5]):

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

$r_{i,j}$ 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 transfers to j-th output place; otherwise, this is not possible.

The ordered four-tuple

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

is called *the simplest reduced Generalized Net* (briefly, we shall use again "GN") 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 transfers from an input to an output place of a given transition.

Shortly, when each transition condition predicate $W_{i,j}$ is estimated not only by values $true$ and $false$ (1 and 0), but by a couple of real numbers $a_{i,j}, b_{i,j}$, such that $a_{i,j}, b_{i,j}, a_{i,j} + b_{i,j} \in [0, 1]$, then we obtain an IFGN of the first type (IFGN1). Here $a_{i,j}$ and $b_{i,j}$ are the degrees of validity and of non-validity of predicate $W_{i,j}$, respectively.

IFGN3s are extensions of IFGN1. Now, the token characteristics will be estimated in the intuitionistic fuzzy sense and only when their estimations (intuitionistic fuzzy couples) $\langle a_{i,j}, b_{i,j} \rangle$, satisfy conditions $a_{i,j} > t_l$ and $b_{i,j} < 1 - t_h$, where t_l and t_h ($t_l, t_h, t_l + t_h \in [0, 1]$) are two thresholds determined for the respective place.

3 The IFGN3-model

Following and extending [9,10], where a GN model of the same process has been described, we shall construct a reduced IFGN3 (see Figure 2) without temporal components, without transitions, places and tokens' priorities and without places and arcs' capacities. In this model the tokens keep all their history.

In order to ease the understanding of the actual formalism in use, we shall not describe the transition condition predicates fully formally.

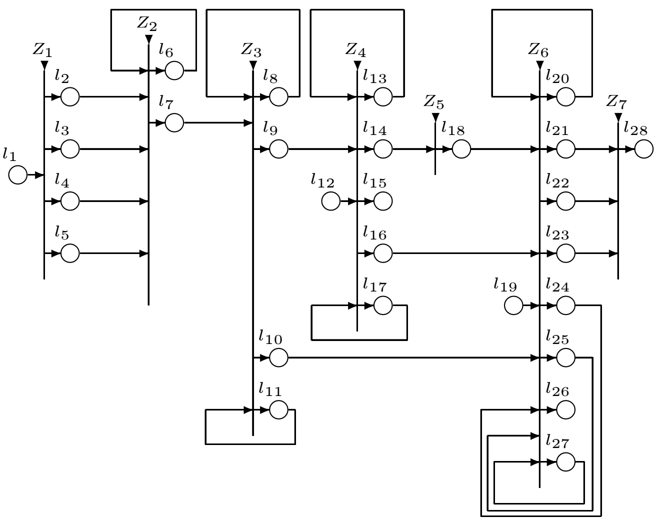

Figure 2: An IFGN3-model of the process of handwriting analysis

All transition condition predicates $W_{i,j}$ have degrees of validity ($\mu(W_{i,j})$) and non-validity ($\nu(W_{i,j})$). For each of these predicates we can determine two thresholds - lower ($t_l \in [0,1]$) and higher ($y_h \in [0,1]$), so that $t_l + t_h \leq 1$. The token from place l_i will go to place l_j if the following conditions hold:

$$\mu(W_{i,j}) > t_l \text{ and } \nu(W_{i,j}) < 1 - t_h.$$

Initially, token α enters place l_1 with the initial characteristic:

"digital matrix of the text image"

This ordinary GN-characteristic can be extended to an IFGN3-characteristic by adding intuituionistic fuzzy estimations of the image quality.

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

	l_2	l_3	l_4	l_5
l_1	$W_{1,2}$	$W_{1,3}$	$W_{1,4}$	$W_{1,5}$

where
$W_{1,2} =$ "noise reduction is necessary",
$W_{1,3} =$ "contrast enhancement is necessary",
$W_{1,4} =$ "background elimination is necessary",
$W_{1,5} = \neg W_{1,2} \& \neg W_{1,3} \& \neg W_{1,4}$.

The tokens obtain following characteristics:

- "digital matrix of the smoothed image" in place l_2,
- "digital matrix of the sharpened image" in place l_3,
- "digital matrix of the extracted text" in place l_4,
- and they do not obtain any characteristic in place l_5.

Each of these characteristics can obtain intuitionistic fuzzy degrees of goodness and badness.

Entering transition Z_1, token α can split into two or more tokens, if the original text needs to be processed by different procedures. Each of the new tokens will be interpreted as an α-token. All of them will transfer independently in the next transition and all of them will unite in place l_6 generating again only one α-token. Let us denote the current characteristic of each of α-tokens by x^{α}_{cu} and its characteristic obtained s steps ago – by x^{α}_{cu-s}.

$$Z_2 =< \{l_2, l_3, l_4, l_5\}, \{l_6, l_7\},$$

	l_6	l_7
l_2	$true$	$false$
l_3	$true$	$false$
l_4	$true$	$false$
l_5	$true$	$false$
l_6	$false$	$true$

The tokens obtain characteristic:

"segmented image" in place l_6, and they do not obtain any characteristic in place l_7.

This characteristic can be estimated as a degree of properly delineated strokes, characters, words and rows.

In place l_{11} there is a token β that loops only in this place while processing the α tokens in the transition, and it enters place l_{10} when the last α-token enters place l_9.

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

	l_8	l_9	l_{10}	l_{11}
l_7	$W_{7,8}$	$W_{7,9}$	$false$	$false$
l_8	$W_{8,8}$	$W_{8,9}$	$false$	$false$
l_{11}	$false$	$false$	$W_{11,10}$	$W_{11,11}$

,

where
$W_{7,8}$ = "the text contains more than one word",
$W_{7,9}$ = "the text contains exactly one word",
$W_{8,8}$ = "the text contains more than $s+1$ words, where s is the number of the cycles of the current token in place l_8",
$W_{8,9} = \neg W_{8,8}$,
$W_{11,10}$ = "there are no tokens in place l_8",
$W_{11,11} = \neg W_{11,10}$.

All these predicates can be estimated by their degrees of correctness and of non-correctness due to the distances between words.

The tokens obtain the characteristics:

- "current word in the text" in place l_8,
- "distance between the current word, found in place l_8 and its next word in the row; distance between the current row, where the word is placed and the next row; declination of the text; height of the letters; other formal parameters determined by the user before the simulation; degrees of validity and of non-validity for all mentioned parameters" in place l_{11},
- and they do not obtain any characteristics in places l_9 and l_{10}.

All these predicates can be estimated by their degrees of correctness and of non-correctness due to the handwriting conciseness.

Token β enters place l_{12} with an initial characteristic "user defined text and character features".

$$Z_4 =< \{l_9, l_{12}, l_{13}, l_{17}\}, \{l_{13}, l_{14}, l_{15}, l_{16}, l_{17}\},$$

	l_{13}	l_{14}	l_{15}	l_{16}	l_{17}
l_9	$W_{9,13}$	$W_{9,14}$	$false$	$false$	$false$
l_{12}	$false$	$false$	$true$	$false$	$false$
l_{13}	$W_{13,13}$	$W_{13,14}$	$false$	$false$	$false$
l_{17}	$false$	$false$	$false$	$W_{17,16}$	$W_{17,17}$

,

where
$W_{9,13}$ = "the word contains more than one letter",
$W_{9,14}$ = "the word contains exactly one letter",
$W_{13,13}$ = "the word contains more than $s+1$ letters, where s is the number of the cycles of the current token in place l_{13}",
$W_{13,14} = \neg W_{13,13}$,
$W_{17,16}$ = "there are not tokens in place l_{13}",
$W_{17,17} = \neg W_{17,16}$.

The tokens obtain the characteristics:

- "current letter in the word" in place l_{13},
- "values of the user-defined measurements of the parameters in the initial characteristic of token β" in place l_{17},
- and they do not obtain any characteristics in places l_{14} and l_{16}.

$$Z_5 =< \{l_{14}\}, \{l_{18}\}, \begin{array}{c|c} & l_{18} \\ \hline l_{14} & true \end{array}.$$

Token γ enters place l_{19} with an initial characteristic "data base of character parameters"

$$Z_6 =< \{l_{10}, l_{16}, l_{18}, l_{19}, l_{20}, l_{24}, l_{25}, l_{27}\},$$

$$\{l_{20}, l_{21}, l_{22}, l_{23}, l_{24}, l_{25}, l_{26}, l_{27}\},$$

	l_{20}	l_{21}	l_{22}	l_{23}	l_{24}	l_{25}	l_{26}	l_{27}
l_{10}	f	f	f	f	f	t	f	f
l_{16}	f	f	f	f	t	f	f	f
l_{18}	t	t	t	t	f	f	f	f
l_{19}	f	f	f	f	f	f	t	f
l_{20}	t	t	t	t	f	f	f	f
l_{24}	f	f	f	f	t	f	f	f
l_{25}	f	f	f	f	f	t	f	f
l_{27}	f	f	f	f	f	f	f	t

.

where t means "true", and f means "false".

The tokens have the characteristics:

- "a particular letter parameters" in place l_{20},
- "general parameters" in place l_{21},
- "specific feature parameters" in place l_{22},
- "formalized feature parameters" in place l_{23},
- "general parameters of the data base" in place l_{24},

- "specific parameters of the data base" in place l_{25},
- "data base search" in place l_{27},
- but they do not obtain any characteristic in place l_{26}.

Each of these characteristics can obtain intuitionistic fuzzy degrees of accurate measures and of non-accurate measures.

$$Z_7 =< \{l_{21}, l_{22}, l_{23}\}, \{l_{28}\}, \begin{array}{c|c} & l_{28} \\ \hline l_{21} & true \\ l_{22} & true \\ l_{23} & true \end{array}.$$

The tokens are given the characteristic "best match" in place l_{28}.

This characteristic can obtain intuitionistic fuzzy degrees of similarity and non-similarity.

4 Conclusions

In this paper a new approach to the description of handwriting analysis is introduced on the basis of the theory of IFSs. Now we use intuitionistic fuzzy estimations for all the activities in the framework of the process, as well as for the results of these activities. It allows us to take into account the inevitable inaccuracy at different stages at the investigation, thus making it more adequate. In this respect the details of the model are based on GNs.

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