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Generalized Net Model with Intuitionistic Fuzzy Estimations of Human Nervous System

Vihren E. Chakarov[1], Anthony G. Shannon[2,3] and Krassimir T. Atanassov[1,2]

[1] Centre for Biomedical Engineering - Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 105, Sofia-1113, Bulgaria
e-mails: *vihren@bio.bas.bg* and *krat@bas.bg*

[2] KvB Institute of Technology, North Sydney, 2060, Australia, e-mail: *tony@kvb.edu.au*

[3] Warrane College, University of New South Wales, Kensington, 1465, Australia email: *tony@warrane.unsw.edu.au*

Abstract: Generalized Nets (GNs) are extensions of Petri nets and their modifications. GNs are a suitable tool for modelling of parallel processes. In a series of papers the authors describe the ways of functioning of the different systems in the human body. In the present one a GN-model of the human nervous system is described. The model uses intuitionistic fuzzy estimations of the human body parameters.

1 Introduction

Multicellular animal organisms, unlike plants, develop in a dynamic and fast changing internal, as well as external environment. It is essential for them to constantly obtain quick and adequate information about environmental changes, so they can find favorable living conditions and adapt to them. The complex relationship with the environment requires perfect regulation. The information processing and regulatory functions are performed by the nervous and endocrine systems.

The nervous system receives the internal and/or external environment information, transforming its specific energy (light, sound, chemical substances etc.) into electric impulses, transmitted cablewise along the nerve cells specialized projections called dendrites and axons. The transmission of information between nerve cells, as well as between nerve cells and effector cells is performed by transformation of the electric impulse to a chemical signal and of the chemical signal back to electric. This process takes place in the cell membrane functional differentiations called synapses. They secrete specific substances - neuromediators, which act upon the effector cell. The incoming information is processed in the nervous system central departments (analyzers), where the most adequate behavior is determined and the effector organs and systems are involved for its performance (see, e.g., [5, 6]).

The endocrine system functions trough secretion of highly active substances (hormones) which enter the blood circulation, thus affecting the target cells along its way.

The basic functional unit trough which the nervous regulatory system operates is the reflex arc. It comprises either of a single or of multiple neurons, connected in a unidirectional chain, starting with a receptor (sensory), ending in an effector (performing) neuron, with one ore more analyzing (associative and integrative) neurons between them.

Anatomically the nervous system is divided into central, including the associative and integrative neurons, and peripheral, including the sensory neurons and the neurites of the reflex arc effector neurons.

The Central Nervous System (CNS) consists of brain and spinal cord. The brain includes the medulla oblongata, the hindbrain (metencephalon), consisting of the pons and cerebellum, the midbrain (mesencephalon), the inter-brain (diencephalons) and the forebrain (cerebral hemispheres). The peripheral nervous system consists of nerve cell clusters (ganglia), their cell projections forming nerves and nerve endings.

The neuro-regulatory system is functionally divided into somatic and autonomous nervous system.

The somatic nervous system regulates the relationships of the organism with the external environment, receiving incoming signals and performing voluntary movements.

The autonomous nervous system has two compartments: sympathetic and parasympathetic, which provide the innervations of the internal organs, blood vessels and glands, thus regulating metabolism. The autonomous nervous system is not subjected to voluntary control.

Here a Generalized Net (GN, see [1, 3]) model of the human nervous system is described. The model uses Intuitionistic Fuzzy Estimations (IFEs; for the concept of intuitionistic fuzzy set see [2]) of the human body parameters.

2 A generalized net model

Here we shall construct a GN-model of human nervous system (see Fig. 1). We shall use an extended GN, some of tokens of which have limited duration of life (see [3]). On the other hand, this GN will be reduced, because some of its components (e.g., its temporal components, conponents related to the place and arc capacities, and components repated to transition, place and token priorities) will be omitted.

The GN contains 9 transitions and 4 types of tokens:

μ-token that stays only in place l_5 with initial and current characteristic

"*current status of the human memory (sensory, short-term and long-term memory),*

m^{μ}- *and* n^{μ}-*parameters*",

α-tokens that enter place l_1 with initial characteristic

"*specific signals coming from the external environment (audio, visual,*

olfactory, etc.) reacting with the specialized sensory organs, m^{α}- *and* n^{α}-*parameters*"

and that will have duration of like 2 time-stepts, i.e., if the transition condition predicate $W_{1,2} = false$, these tokens will "die", χ-token that stays only in place l_{20} with initial and

current characteristic

"*status of the internal environment of the human body, m^{λ}- and n^{λ}-parameters*".

and that generates β-tokens with initial characteristic

"*information about changes in the internal environment of the human body m^{β}- and n^{β}-parameters*".

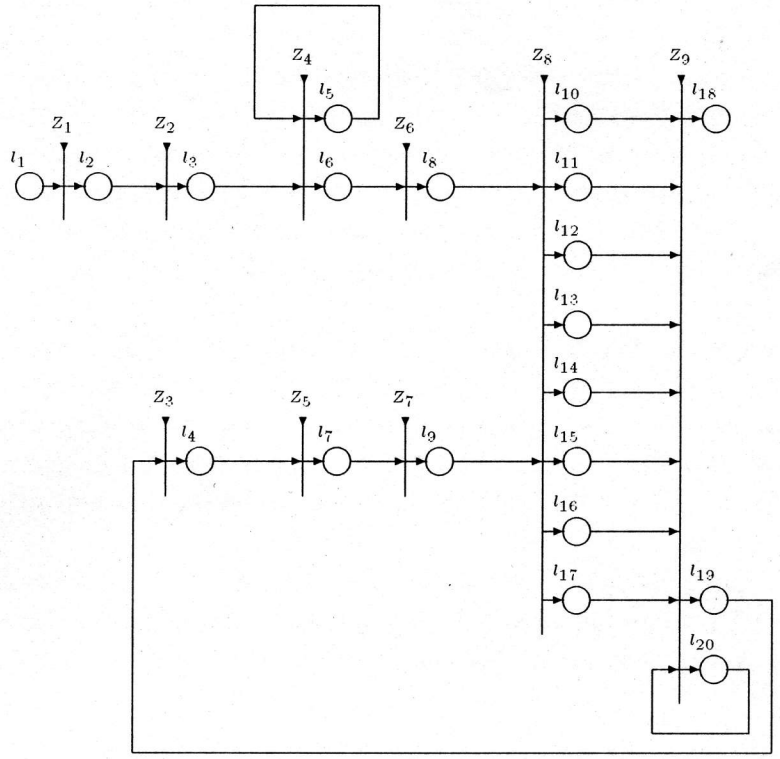

Fig. 1: A GN-model

The m^{μ}- and n^{μ}-parameters are the instrumentally measured values of the physical characteristics of the signal.

The m^{α}- and n^{α}-parameters are the psychologically measured values of the memory individual capacity.

The m^{λ}- and n^{λ}-parameters are the clinically measured values of the internal environment of the human body (temperature, blood pressure, urine, etc.).

The m^{β}- and n^{β}-parameters are the values of the changed parameters of the internal environment signals sent to the CNS.

Here, m^{ω}- and n^{ω}-parameters are the lower and upper bounds of the values of respective object, where $\omega \in \{\mu, \alpha, \lambda, \beta\}$ and

$$m^{\omega} + n^{\omega} \leq 1.$$

The GN-transitions have the following forms.

$$Z_1 = < \{l_1\}, \{l_2\}, \begin{array}{c|c} & l_2 \\ \hline l_1 & W_{1,2} \end{array} >,$$

where

$$W_{1,2} = \text{“}m^{\alpha} \geq M_1\text{”}\&\text{“}n^{\alpha} \leq N_1\text{”}$$

and M_1 and N_1 are lower and upper thresholds of the respective specialized sensor.

The current token α entering place l_2 obtains characteristic

“*current specialized sensory pathway for the signal coming from the external environment*”.

$$Z_2 =< \{l_2\}, \{l_3\}, \begin{array}{c|c} & l_3 \\ \hline l_2 & true \end{array} > .$$

Token α obtains characteristic

“*result of the processing of the specialized central analyser over the current signal from the external environment*”

in place l_3.

$$Z_3 =< \{l_{19}\}, \{l_4\}, \begin{array}{c|c} & l_4 \\ \hline l_{19} & true \end{array} > .$$

Token β obtains characteristic

“*result of the processing of the specialized central analyser over the current signal from the internal environment*”

in place l_4.

$$Z_4 =< \{l_3, l_5\}, \{l_5, l_6\}, \begin{array}{c|cc} & l_5 & l_6 \\ \hline l_3 & false & true \\ l_5 & true & false \end{array} > .$$

The current token α obtains in place l_6 characteristic

“*decision for adequate reaction based on the memory and past experience*”.

$$Z_5 =< \{l_4\}, \{l_7\}, \begin{array}{c|c} & l_7 \\ \hline l_4 & true \end{array} > .$$

The current token β obtains in place l_7 characteristic

“*adequate reaction of the autonomic nervous system for maintaining of needed level of the human body internal environment*”.

$$Z_6 =< \{l_6\}, \{l_8\}, \begin{array}{c|c} & l_8 \\ \hline l_6 & true \end{array} > .$$

The current token α obtains in place l_8 characteristic

“*current pathway for the execution of the generated adequate reaction of the somatic nervous system based on the signals coming from the external environment*”.

$$Z_7 =< \{l_7\}, \{l_9\}, \begin{array}{c|c} & l_9 \\ \hline l_7 & true \end{array} > .$$

The current token β obtains in place l_9 characteristic

"*current pathway for the execution of the generated adequate of the autonomic nervous system reaction based on the signals coming from the internal environment*".

$$Z_8 =< \{l_8, l_9\}, \{l_{10}, l_{11}, l_{12}, l_{13}, l_{14}, l_{15}, l_{16}, l_{17}\},$$

$$\begin{array}{c|cccccccc} & l_{10} & l_{11} & l_{12} & l_{13} & l_{14} & l_{15} & l_{16} & l_{17} \\ \hline l_8 & W_{8,10} & W_{8,11} & W_{8,12} & W_{8,13} & W_{8,14} & W_{8,15} & W_{8,16} & W_{8,17} \\ l_9 & W_{9,10} & W_{9,11} & W_{9,12} & W_{9,13} & W_{9,14} & W_{9,15} & W_{9,16} & W_{9,17} \end{array} >,$$

where

$W_{8,10}$ = "there is a specific command generated on the external environment based incoming signals directed to the central nervous system",

$W_{8,11}$ = "there is a specific command generated on the external environment based incoming signals directed to the cardiovascular and hematopoetic systems",

$W_{8,12}$ = "there is a specific command generated on the external environment based incoming signals directed to the respiratory system",

$W_{8,13}$ = "there is a specific command generated on the external environment based incoming signals directed to the gastrointestinal system",

$W_{8,14}$ = "there is a specific command generated on the external environment based incoming signals directed to the endocrine system",

$W_{8,15}$ = "there is a specific command generated on the external environment based incoming signals directed to the musculo-skeletal system",

$W_{8,16}$ = "there is a specific command generated on the based on the signals coming from the external environment and directed to the renal and urologic system",

$W_{8,17}$ = "there is a specific command generated on the external environment based incoming signals directed to the reproductive system",

$W_{9,10}$ = "there is a specific command generated on the internal environment based incoming signals directed to the central nervous system system",

$W_{9,11}$ = "there is a specific command generated on the internal environment based incoming signals directed to the cardiovascular and hematopoetic systems",

$W_{9,12}$ = "there is a specific command generated on the internal environment based incoming signals directed to the respiratory system",

$W_{9,13}$ = "there is a specific command generated on the internal environment based incoming signals directed to the gastrointestinal system",

$W_{9,14}$ = "there is a specific command generated on the internal environment based incoming signals directed to the endocrine system",

$W_{9,15}$ = "there is a specific command generated on the internal environment based incoming signals directed to the musculo-skeletal system",

$W_{9,16}$ = "there is a specific command generated on the internal environment based incoming signals directed to the renal and urologic system",

$W_{9,17}$ = "there is a specific command generated on the internal environment based incoming signals directed to the reproductive system".

Current α- and β-tokens obtain the following equal characteristics:

"*specific reaction of the central nervous system based on the current signal*"

in place l_{10},

"*specific reaction of the cardiovascular and hematopoetic systems based on the current signal*"

in place l_{11},

"*specific reaction of the respiratory system based on the current signal*"

in place l_{12},

"*specific reaction of the gastrointestinal system based on the current signal*"

in place l_{13},

"*specific reaction of the endocrine system based on the current signal*"

in place l_{14},

"*specific reaction of the musculo-skeletal system based on the current signal*"

in place l_{15},

"*specific reaction of the renal and urologic system based on the current signal*"

in place l_{16},

"*specific reaction of the reproductive system based on the current signal*"

in place l_{17}.

For each human body system we determine the lower and upper bounds of physiological m^{ω}- and n^{ω}-parameters (for $\omega \in \{\alpha, \beta, \lambda\}$ that can be measured by the means of special medical tools or instruments.

$$Z_9 =< \{l_{10}, l_{11}, l_{12}, l_{13}, l_{14}, l_{15}, l_{16}, l_{17}, l_{20}\}, \{l_{18}, l_{19}, l_{20}\}$$

	l_{18}	l_{19}	l_{20}
l_{10}	$false$	$false$	$true$
l_{11}	$false$	$false$	$true$
l_{12}	$false$	$false$	$true$
l_{13}	$false$	$false$	$true$
l_{14}	$false$	$false$	$true$
l_{15}	$false$	$false$	$true$
l_{16}	$false$	$false$	$true$
l_{17}	$false$	$false$	$true$
l_{20}	$W_{20,18}$	$W_{20,19}$	$true$

$>$,

where

$$W_{20,18} = \text{“}m^{\lambda} \geq M_2\text{”}\&\text{“}n^{\lambda} \leq N_2\text{”},$$

where M_2 and N_2 are lower and upper thresholds for the reaction of the human body, directed to the external environment, and

$$W_{20,19} = \text{“}m^{\lambda} \geq M_3\text{”}\&\text{“}n^{\lambda} \leq N_3\text{”},$$

where M_3 and N_3 are lower and upper thresholds for the reaction of the human body, directed to the internal environment.

Current α- and β-tokens obtain the following equal characteristics:

“*m^{α}- and n^{α}-parameters of the human body reaction directed to the external environment*”

in place l_{18} and

“*m^{α}- and n^{α}-parameters of the human body reaction directed to the internal environment*”

in place l_{19}.

3 Conclusion

The present GN-model can be used for the simulation of processes in human body nervous system. The current research is the first step in this direction. In future, the basic logical conditions that determine the way of functioning of the nervous system will be described in essential details. The role of the analytical research of the specialists who model the processes in the nervous system will be determined. Their theoretical results, prepared in systems theory form, will be represented as initial, current and final tokens characteristics of the extended GN-model. The modelled processes will be estimated by intuitionistic fuzzy values (see, [2]), following the ideas from [4, 7].

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