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GENERALIZED NETS AS TOOLS FOR MODELLING OF INTELLIGENT SYSTEMS

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Abstract

It is shown that the way of functioning of a given intelligent system and the results of its work can be described by a generalized net. So, the generalized nets can play the role of a tool for modelling and simulating of the intelligent systems.

1 Introduction

During the recent years, the concept of *"Intelligent System" (IS)* becomes increasingly popular. One of its (non-formal) definitions is the following (see [17], cf. [11, 12]):

- It is a system.
- It learns during its existence. (In other words, it senses its environment and learns, for each situation, which action permits it to reach its objectives.)
- It continually acts, mentally and externally, and by acting reaches its objectives more often than pure chance indicates (normally much oftener).
- It consumes energy and uses it for its internal processes, and in order to act.

In the present paper we shall show that the Generalized nets (GN, [1, 5]) can be used as a tool for modelling of the behaviour, way of functioning and the results of the work of a given IS. Up to now, some research has been done in this direction. They started with the proof that the results of the work of each abstract system in the sense of M. Mesarovich and Y. Takahara [15, 16] can be described by an e-net (see [2]). This result was extended in a series of papers, collected in [2], where it was proved that the way of functioning and the results of the work of a given abstract system can be described by a GN. In [4, 6, 7, 14] GNs were constructed, that describe some complex systems, approaching to an IS in the sense of the above definition. But all these GN-models have other aims and the modelled objects are in some sense different that the ISs.

Here, we shall construct GN-models of a given IS.

2 GN-models of and IS

We shall start with the simplest GN-model, representing the functioning of a given IS, working and contacting with its Environment (EN) – see Fig. 1. Obviously, the IS ought to have sensors to receive information from the EN and effectors that will realize IS responses over the EN. The GN-model is shown on Fig. 2. It contains two transitions – Z_{EN}, Z_{IS} and two special tokens ε and σ that permanently stay in places l_{EN} and l_{IS} with initial and current characteristics *"current status of the EN"* and *"current status of the IS"*. In some moments token ε splits to two tokens – the same token ε and token α that enters place l_1 with characteristic *"signals from the EN to the IS, parameters of the signals"*. On the next time-step this token enters place l_{IS} and unites with token σ. If the "parameters of the signals" (second part of the α-characteristic) are higher than some (fixed, e.g., in the initial or current σ-characteristic) IS-parameters, token σ splits to two tokens – the same token σ and token β that enters place l_2 with characteristic *"effects of the IS over the EN, parameters of the effects"*. On the next time-step this token enters place l_{EN} and unites with token ε. If the "parameters of the effects" (second part of the β-characteristic) are higher than some (fixed, e.g., in the initial or current ε-characteristic) EN-parameters, token ε obtains a next characteristic and the process continues as above.

Below, this simple model will be essentially extended, adding to it separate components of the IS. Before this, we, following [17] will discuss some conditions that have to be valid as consequence of the above definition.

- *The system has to exist.*
- *An environment must exist, with which the system can interact.*
- *It must be able to receive communications from the environment, for its elaboration of the present situation. This is an abstracted summary of the communications received by the senses. By communications, in turn, we mean an interchange of matter or energy. If this communication is for the purpose of transmitting information, it is a variation of the flow of energy or a specific structuring of matter that the system perceives.*
- *The IS has to have an objective, it has to be able to check if its last action was favorable, if it resulted in getting nearer to its objective, or not.*
- *To reach its objective it has to select its response. A simple way to select a response is to select one that was favorable in a similar previous situation.*
- *It must be able to learn. Since the same response sometimes is favorable and sometimes fails, it has to be able to recall in which situation the response was favorable, and in which it was not. Therefore it stores situations, responses, and results.*
- *Finally, it must be able to act; to accomplish the selected response.*

As we saw from the above information from [17], the IS ought to contain as components tools for

- analysing, recognizing and identifying signals from the EN;

- prognostic, optimizing and decision making about the IS and/or EN behaviour;
- learning (and in particular - selflearning) of the IS;
- collection, organizing and memorizing of the information entering the IS.

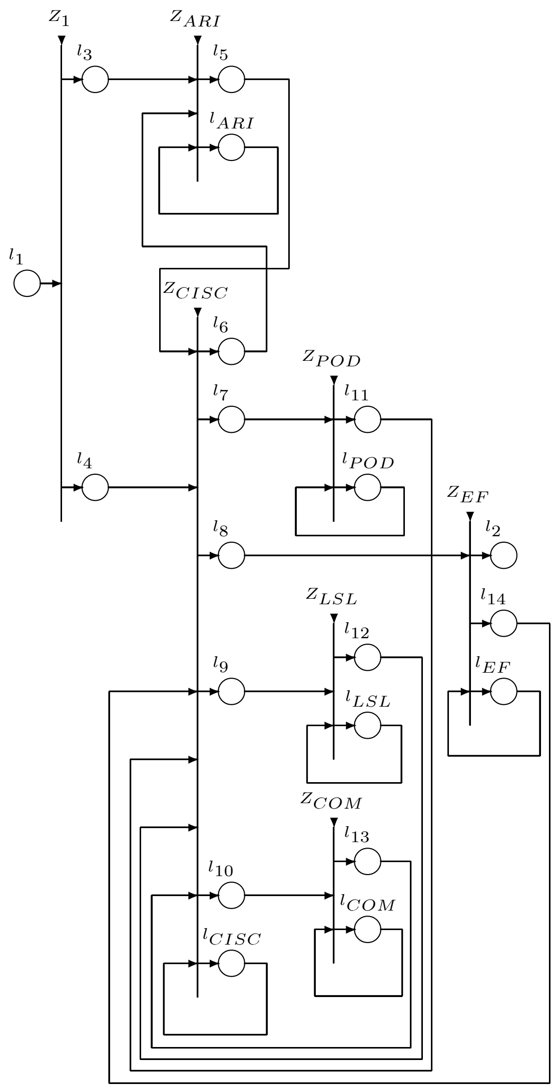

Fig. 1: GN-model

We shall represent these four tools by the GN-transitions $Z_{ARI}, Z_{POD}, Z_{LSL}, Z_{COM}$. In a next step of GN-detailization we can change each of these four transitions with a subnet describing in more details the work of the respective IS-component. For example, in [6] GN-models of processes of machine learning are constructed, in [8, 9] GN-models of pattern and speach recognition are described, in [1] GN-models of optimization processes are given. If we interprete the IS-component, related to collection, organizing and memorizing of the information by a some kind of a data base, we can use some of the GN-models from [13, 10].

The definition from [17] does not assume existence of a central IS-component to synchronize the functioning of the rest IS-components, but it seem, such one would be useful.

If we decide that this component is necessary in the GN-model, we will add a transition Z_{CISC}, representing the functioning of the central IS-component. If the modelled IS can function without such a component, transition Z_{CISC} can be omitted. Similar is the situation with IS-component, corresponding to the system effectors. We can interprete them by the GN-transition Z_{EF}, but in some cases this transition can be omitted. If we like to represent the situation in which the IS obtains information for the results of its effector activities, places l_{EF} and l_{14} will be added to this transition. In the first one token φ will stay permanently with initial and current characteristic *"current status of the IS-effectors"*. In some moment, after entering place l_{EF} of token that will be united with token f, two new tokens – let us mark them with ψ and β will be generated by token φ. The first of them will obtain characteristic *"effects of the IS over the EN, parameters of the effects"*, (as in the first GN-model), while the second token will obtain characteristic *"estimation (from IS-point of view) of the results of the effects of the IS over the EN"*.

Each of the transitions corresponding to IS-components will contain a special place (simultaneously input and output for the transition) in which one token will stay with initial and current characteristics, as follows:

- for place l_{ARI} of transition Z_{ARI} the token ρ has characteristic *"current status and current results of the work of the IS-tools for analysing, recognizing and identifying of signals from the EN"*,
- for place l_{CISC} of transition Z_{CISC} the token σ has characteristic *"current status and current results of the work of the central IS-component"*,
- for place l_{POD} of transition Z_{POD} the token δ has characteristic *"current status and current results of the work of the IS-tools for prognostic, optimizing and decision making about the IS and/or EN behaviour"*,
- for place l_{LSL} of transition Z_{LSL} the token λ has characteristic *"current status and current results of the work of the IS-tools for learning (and in particular - selflearning) of the IS"*,
- for place l_{COM} of transition Z_{COM} the token μ has characteristic *"current status and current results of the work of the IS-tools for collection, organizing and memorizyng of the information entering the IS"*.

The separate transitions have the following forms.

$$Z_1 = \langle \{l_1\}, \{l_3, l_4\}, r_1 \rangle,$$

where

$$r_1 = \begin{array}{c|cc} & l_3 & l_4 \\ \hline l_1 & W_{1,3} & W_{1,4} \end{array}.$$

For the two predicates there are two possibilities. If the model is not very detailed, we can assume that

$$W_{1,3} = W_{1,4} = true.$$

Therefore, each signal from the EN will be registered by the IS-component CISC and will be analysed in the IS-component ARI. Practically, this is not always valid. In reality there are some tresholds, so that only signals higher than the respective tresholds will be processed in the IS-components. Let for the two above components these tresholds be τ_{CISC} and τ_{ARI}, respectively. Then the above predicates will have the forms:

$$W_{1,3} = \text{“}\textit{current parameters of the EN are higher than } \tau_{ARI}\text{”}$$

and

$$W_{1,4} = \text{“}\textit{current parameters of the EN are higher than } \tau_{CISC}\text{”}.$$

In this case, we can add additional output place for transition Z_1 in which all token will enter if some of the above predicates has truth-value $false$. In the opposite case, token ε enters one of the places l_3 and l_4, or it splits to two tokens that enter both places. In all these cases the new token(s) do not have a new characteristic.

$$Z_{ARI} = \langle \{l_3, l_6, l_{ARI}\}, \{l_5, l_{ARI}\}, r_{ARI} \rangle,$$

where

$$r_{ARI} = \begin{array}{c|cc} & l_5 & l_{ARI} \\ \hline l_3 & false & true \\ l_6 & false & true \\ l_{ARI} & W_{ARI,5} & true \end{array}$$

and
$W_{ARI,5}$ = “the IS-component ARI finishes its work on EN-signals or it is ready with solution of some task of the IS-component CISC”.

When predicate $W_{ARI,5} = true$ token ρ splits to two tokens – the same token ρ and a new token ρ' that enters place l_5 with characteristic *“results of the work of the IS-component ARI”.*

$$Z_{CISC} =< \{l_4, l_5, l_{11}, l_{12}, l_{13}, l_{14}, l_{CISC}\}, \{l_6, l_7, l_8, l_9, l_{10}, l_{CISC}\}, r_{CISC} \rangle,$$

where

$$r_{CISC} = \begin{array}{c|cccccc} & l_6 & l_7 & l_8 & l_9 & l_{10} & l_{CISC} \\ \hline l_4 & false & false & false & false & false & true \\ l_5 & false & false & false & false & false & true \\ l_{11} & false & false & false & false & false & true \\ l_{12} & false & false & false & false & false & true \\ l_{13} & false & false & false & false & false & true \\ l_{14} & false & false & false & false & false & true \\ l_{CISC} & W_{CISC,6} & W_{CISC,7} & W_{CISC,8} & W_{CISC,9} & W_{CISC,10} & true \end{array},$$

where
$W_{CISC,6}$ = “there is a task from the IS-component CISC to the IS-component ARI”,
$W_{CISC,7}$ = “there is a task from the IS-component CISC to the IS-component POD”,
$W_{CISC,8}$ = “there is a task from the IS-component CISC to the IS-component EF”,
$W_{CISC,9}$ = “there is a task from the IS-component CISC to the IS-component LSL”,
$W_{CISC,10}$ = “there is a task from the IS-component CISC to the IS-component COM”.

All tokens from the input places of transition Z_{CISC} enter place l_{CISC} and unute with token σ. When some of the above predicates has truth-value *true*, token σ splits to two, three, ..., seven tokens – the same token σ that continues to stay only in its place and other tokens that enter places l_6 with characteristic *"a task from the IS-component CISC to the IS-component ARI"*, l_7 with characteristic *"a task from the IS-component CISC to the IS-component POD"*, l_8 with characteristic *"a task from the IS-component CISC to the IS-component EF"*, l_9 with characteristic *"a task from the IS-component CISC to the IS-component LSL"*, l_{10} with characteristic *"a task from the IS-component CISC to the IS-component COM"*.

$$Z_{POD} = \langle \{l_7, l_{POD}\}, \{l_{11}, l_{POD}\}, r_{POD} \rangle,$$

where

$$r_{POD} = \begin{array}{c|cc} & l_{11} & l_{POD} \\ \hline l_7 & false & true \\ l_{POD} & W_{POD,11} & true \end{array}$$

and
$W_{POD,11}$ = "the IS-component POD finishes its work on some task of the IS-component CISC".

When predicate $W_{POD,11} = true$, token δ splits to two tokens – the same token δ and a new token δ' that enters place l_{11} with characteristic *"results of the work of the IS-component POD"*.

$$Z_{LSL} = \langle \{l_9, l_{POD}\}, \{l_{11}, l_{POD}\}, r_{LSL} \rangle,$$

where

$$r_{LSL} = \begin{array}{c|cc} & l_{12} & l_{LSL} \\ \hline l_9 & false & true \\ l_{LSL} & W_{LSL,12} & true \end{array}$$

and
$W_{LSL,12}$ = "the IS-component LSL finishes its work on some task of the IS-component CISC".

When predicate $W_{LSL,12} = true$, token λ splits to two tokens – the same token λ and a new token λ' that enters place l_{12} with characteristic *"results of the work of the IS-component SLS"*.

$$Z_{COM} = \langle \{l_{10}, l_{COM}\}, \{l_{13}, l_{COM}\}, r_{COM} \rangle,$$

where

$$r_{COM} = \begin{array}{c|cc} & l_{13} & l_{COM} \\ \hline l_{10} & false & true \\ l_{COM} & W_{COM,13} & true \end{array}$$

and
$W_{COM,13}$ = "the IS-component COM finishes its work on some task of the IS-component CISC".

When predicate $W_{COM,13} = true$, token μ splits to two tokens – the same token μ and a new token μ' that enters place l_{13} with characteristic *"results of the work of the IS-component COM"*.

$$Z_{EF} = \langle \{l_8, l_{EF}\}, \{l_2, l_{14}, l_{EF}\}, r_{EF} \rangle,$$

where

$$r_{EF} = \begin{array}{c|ccc} & l_2 & l_{14} & l_{EF} \\ \hline l_8 & false & false & true \\ l_{EF} & W_{EF,2} & W_{EF,14} & true \end{array}$$

and
$W_{EF,2} = W_{EF,14} =$ "the IS-component EF prepared a reaction for the EN".

When predicate $W_{EF,2} = true$, token φ splits to three tokens – the same token φ and two new tokens φ' and φ'' that enter places l_2 and l_{14} with characteristics *"effects of the IS-component EF over the EN, parameters of the effects"* and *"information about the IS-component EF reaction over the EN".*

In some more detailed GN-model we, as above, can define some thresholds for the effects of the IS-component EF.

3 Conclusion

The so constructed GN-model shows that the GNs can be used as a tool for modelling of ISs. These models can be used for:

- simulation of the way of work of a given IS,
- control of the given IS,
- studying the behaviour of the given IS,
- obtaining solutions for changing the structure or the way of functioning of the given IS

and others. The above GN-model can be detailized, if we replace some (or all) above transitions with suitable subnets.

In the future we shall discuss GN-models of some particular ISs and will construct detailized models of these ISs.

The experience with the GN-models of, e.g., expert systems and processes of machine learning or genetic algorithm functioning, shows that the GN-models give ideas for generalizing of the modelled objects. For example, in [3] some extensions of the concept of an expert system are discussed. In a next research some ideas for generalizing of the ISs will be introduced.

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