Generalized Net Model for Telecommunication Processes in Telecare Services

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Abstract: In a series of papers, Generalized Net (GN) models of processes, related to tracking changes in the health status of adult patients, have been presented. The contemporary state-ofthe- art of the telecommunications and navigation technologies allow these models to be further extended to the case of active and mobile patients. This requires the inclusion of patient's current location as a new and significant variable of the model. Various opportunities are considered for the retrieval of this information, with a specific focus on the optimal ones, and a refined GN model is herewith proposed.

Keywords: Generalized nets, Modelling, Telecare, Telecare services.

Received: July 10, 2021. Revised: December 14, 2021. Accepted: December 27, 2021. Published: January 20, 2022.

1. Introduction

In a series of papers, Generalized Net (GN, see the Appendix) models of processes, related to tracking the changes in health status of adult patients have been presented (see, e.g., [1, 2]). They are a continuation of the ideas for description of processes, taking place in hospital units, using the apparatus of GNs (see, e.g., [3–5]). The so constructed nets give the possibility to model the logical conditions for the realization of the processes, to simulate these processes, as well as search ways for their optimization.

In [1], the processes for generation of signals from sensors around adult patients and their transmission through different telecommunication tools to the respective hospital units, have been described. In [2], a GN-model of the telecommunication processes between the adult patients and hospital units, has been discussed. Below, a GN-model of the processes for signal classification and the reaction of the medical staff of the hospital units, is constructed. In the Appendix, short remarks of GNs are given.

2. The Generalized Net Model

The GN model (see Fig. 1) consists of.

- six transitions Z_1, Z_2, Z_3, Z_4, Z_5 and Z_6.
- sixteen places $l_1, l_2, \ldots, l_{16}$.
- four different types of tokens representing the patients, the dispatchers that monitor the signals from the sensors, the medical doctors who examine the patients and the medical specialists.

The tokens $\pi_1, \pi_2, ..., \pi_k$ which represent the patients enter the net in place l_4 with initial characteristic "patient; name of the patient; current health status".

The tokens $\delta_1, \delta_2, \ldots, \delta_l$ which represent dispatchers enter the net in place l_8 with initial characteristic: "dispatcher; name of the dispatcher; information about all received signals".

The tokens $\mu_1, \mu_2, ..., \mu_m$ which represent the medical doctors who examine the patients enter the net in place l_9 with initial characteristic: "medical doctor; name of the medical doctor; specialty".

The tokens $\sigma_1, \sigma_2, ..., \sigma_m$ which represent the medical specialists who examine the patients enter the net in place l_9 with initial characteristic: "medical doctor; name of the medical doctor; specialty".

The six transitions will be described in details below.

The first transition Z_1 has the form:

$$Z_1 = \langle \{l_4, l_{10}, l_{15}\}, \{l_1, l_2, l_3, l_4\}, R_1 \rangle,$$

where

$$R_1 = \begin{array}{c|cccc} & l_1 & l_2 & l_3 & l_4 \\ \hline l_4 & false & W_{4,2} & W_{4,3} & W_{4,4} \\ l_{10} & true & false & false & false \\ l_{15} & false & false & false & true \end{array},$$

and the predicates in the index matrix R_1 have the meanings:

- $W_{4,2}$ = "the sensor detected a change in patient's condition",
- $W_{4,3}$ = "the patient should be transported to hospital"
- $W_{4,4} = \neg W_{4,2}$,

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

When the truth-value of the predicate $W_{4,2}$ is *true*, the token π_i enters place l_2 with characteristic "signal of the sensor about the current patient".

When the truth-value of the predicate $W_{4,3}$ is *true*, the token π_i enters place l_3 with characteristic "name of the patient; current status".

In place l_4, the π-tokens receive the characteristic "current status of the patient".

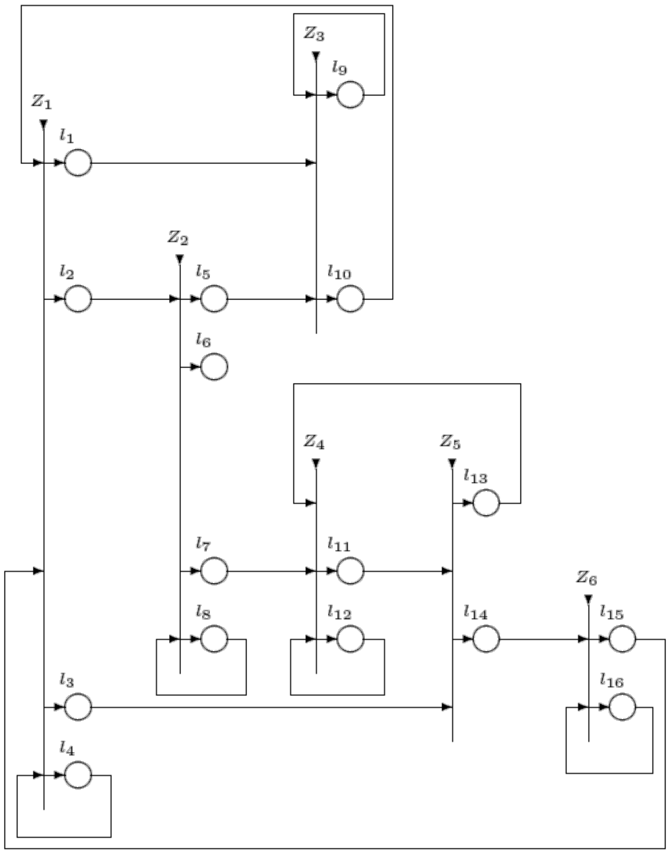

Fig. 1. GN model of the telecommunication processes, taking place in telecare services

The second transition Z_2 has the following form:

$$Z_2 = \langle \{l_2, l_8\}, \{l_5, l_6, l_7, l_8\}, R_2 \rangle,$$

where

$$R_2 = \begin{array}{c|cccc} & l_5 & l_6 & l_7 & l_8 \\ \hline l_2 & W_{2,5} & W_{2,6} & W_{2,7} & false \\ l_8 & false & false & false & true \end{array},$$

and the predicates in the index matrix R_2 have the meanings:

- $W_{2,5}$ = "medical doctor should be sent to perform examination of the patient at home",
- $W_{2,6}$ = "no action is necessary",
- $W_{2,7}$ = "the patient should be transported to a medical center".

When the truth-value of the predicate $W_{2,5}$ is *true*, the token π_i enters place l_5 with characteristic "a decision to visit the patient has been taken".

When the truth-value of the predicate $W_{2,6}$ is *true*, the token π_i enters place l_6 with characteristic "a decision to ignore the signal has been taken".

When the truth-value of the predicate $W_{2,7}$ is *true*, the token π_i enters place l_7 with characteristic "a decision to transport the patient to a medical center has been taken".

The third transition Z_3 has the form:

$$Z_3 = \langle \{l_1, l_5, l_9\}, \{l_9, l_{10}\}, R_3 \rangle,$$

where

$$R_3 = \begin{array}{c|cc} & l_9 & l_{10} \\ \hline l_1 & true & false \\ l_5 & true & false \\ l_9 & W_{9,9} & W_{9,10} \end{array},$$

and the predicates in the index matrix R_3 have the meanings

- $W_{9,10}$ = "a medical doctor should be sent to examine the patient",
- $W_{9,9} = \neg W_{9,10}$.

In place l_9, the μ-tokens do not obtain any new characteristics.

When the truth-value of the predicate $W_{9,10}$ is *true*, the corresponding μ_i token representing the medical doctor enters place l_{10} with characteristic "name of the medical doctor who will visit the patient".

The forth transition Z_4 has the following form:

$$Z_4 = \langle \{l_7, l_{12}, l_{13}\}, \{l_{11}, l_{12}\}, R_4 \rangle,$$

where

$$R_4 = \begin{array}{c|cc} & l_{11} & l_{12} \\ \hline l_7 & false & true \\ l_{12} & W_{12,11} & W_{12,12} \\ l_{13} & false & true \end{array},$$

and the predicates in the index matrix R_4 have the meanings

- $W_{12,11}$ = "specialists should be sent to bring the patient to the hospital";
- $W_{12,12} = \neg W_{12,11}$.

In place l_{11} the current token σ_i receives the characteristic "names of the specialists who will bring the patient to the hospital".

In place l_{12} the tokens receive the characteristic "names of the staff on duty".

The fourth transition Z_5 has the form:

$$Z_5 = \langle \{l_3, l_{11}\}, \{l_{13}, l_{14}\}, R_5 \rangle,$$

where

$$R_5 = \begin{array}{c|cc} & l_{13} & l_{14} \\ \hline l_3 & false & true \\ l_{11} & true & false \end{array}.$$

In place l_{13}, the tokens receive the characteristic "time for completing the transportation of the patient".

In place l_{14}, the tokens receive the characteristic "condition of the patient upon arrival at the hospital".

The sixth, final, transition Z_6 has the following form:

$$Z_6 = \langle \{l_{14}, l_{16}\}, \{l_{15}, l_{16}\}, R_6 \rangle,$$

where

$$R_6 = \begin{array}{c|cc} & l_{15} & l_{16} \\ \hline l_{14} & false & true \\ l_{16} & W_{16,15} & W_{16,16} \end{array},$$

and the predicates in the index matrix R_6 have the meanings

- $W_{16,15}$ = "all medical procedures are completed";
- $W_{16,16} = \neg W_{16,15}$.

In place l_{15}, the current π_i token receives the characteristic "condition of the patient upon discharge from hospital".

In place l_{16}, the current π_i token receives the characteristic "condition of the patient during the procedures".

Finally, we mention that place l_8 represents the processes, described by the GN from [3], while places l_{14}, l_{15} and l_{16} correspond to the processes, modeled by the GN from [4]. On the other hand, the present GN model elaborates into further details the basic idea presented in [5].

3. Conclusions

The so constructed GN model traces the logical stages of the final part of the process of communication between the sensors connecting mobile adult patients and the staff of the respective hospital unit. The developed model can be used for simulation of the processes of decision making of the appropriate specialists, who must either visit the respective adult patient or to transport him/her to the hospital unit. The model permits simulation of different scenarios e.g. the situation, in which many patients simultaneously require medical assistance.

Acknowledgment

This work was partly funded by the project FP7-PEOPLE-2009-IRSES-247541-MATSIQEL.

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Appendix: Short Remarks on Generalized Nets

Generalized Nets (GNs, see [6, 7] are extensions of the apparatus of mathematical modelling of Petri Nets and other modifications of theirs. GNs are a tool intended for the detailed modelling of parallel and concurrent processes.

A GN is a collection of *transitions* and *places* ordered according to some rules (see Fig. 2). The places are marked by circles. The set of places to the left of the vertical line (the transition) are called *input places*, and those to the right are called *output places*. For each transition, there is an index matrix with elements called *predicates*. Some GN-places contain *tokens* – dynamic elements entering the net with initial characteristics and getting new ones while moving within the net. Tokens proceed from an input to an output place of the transition if the predicate corresponding to this pair of places in the index matrix is evaluated as *"true"*. Every token has its own identifier and collects its own history that could influence the development of the whole process modelled by the GNs.

Two time-moments are specified for the GNs: for the beginning and the end of functioning, respectively.

A GN can have only a part of its components. In this case, it is called *reduced GN*. Here, we shall give the formal definition of a reduced GN without temporal components, place and arc capacities, and token, place and transition priorities.

Formally, every transition in the used below reduced GN is described by a triple: $Z = \langle L', L'', r\rangle$, where:

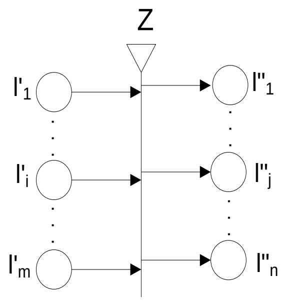

Fig. 2. A GN transition

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

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

(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):

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

where $r_{i,j}$ is the predicate that corresponds to the $i^{\text{-th}}$ input and $j^{\text{-th}}$ output place. When its truth value is "*true*", a token from the $i^{\text{-th}}$ input place transfers to the $j^{\text{-th}}$ output place; otherwise, this is not possible.

The ordered four-tuple

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

is called a *reduced Generalized Net* if:

(a) A is the set of transitions;

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

(c) X is the set of all initial characteristics which the tokens can obtain on entering the net;

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

Many mathematical operations (e.g., union, intersection and others), relations (e.g., inclusion, coincidence and others) and operators are defined over the GNs. Operators, being of six types (global, local, hierarchical, reducing, extending and dynamic operators) change the structure of the GN, the strategies of token transfer, etc.