GN Model of Scheduling
Patients' Medical Examinations

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1   Introduction

The primary aim of hospitals, as service providers, is to improve the health state of their patients. According to their illnesses, patients have to undergo several examinations and treatments during their stay in a hospital.

The nature of diagnostics is gaining additional information about the patients' diseases, that's way the necessary medical treatments are often not completely determined at the beginning of the treatment process.

Further, the sequence of execution of those actions does partially not follow a given order. Due to medical reasons, there can be minimum and/or maximum delay requirements between two (or more) check-ups. Because these constraints can depend on the sequence of execution, a check up might have to start:

- immediately after;
- sometime after;
- minimum time after;
- maximum time after;
- between a minimum and maximum time after; or
- never after a check-up
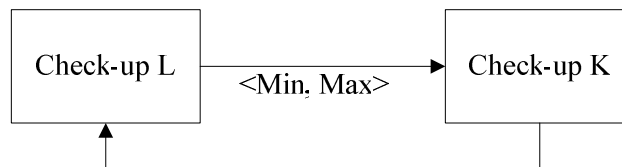
For the majority of the tasks, the patients have to attend physically. As the patient is an exclusive resource, those tasks can only be performed sequentially. Examples for those patient-requiring tasks are taking x-rays and drawing blood. However, some tasks do not require the patient to be present, like the evaluation of laboratory blood tests. Due to the individuality of the patients, the duration of the medical actions are stochastic. The treatments and examinations assigned to the patients and the relations between them, build the pathway for these patients through the hospital.

In the present paper we will construct a GN-model [1] that describes the process of scheduling the patients' medical examinations hours at a given healthcare unit.

2 GN Modelling of Scheduling Patients' Medical Examinations

The GN has three different types of tokens that represent respectively:
- α - patients (in principle, the α-tokens must be numbered, e.g., by α_i, where i is the identifier of the ith patient, but for brevity we will omit the index);
- β - database (DB), containing information about the physicians and patients of the unit, and information about assigned to a particular patient general practitioner;
- γ - DB with information about already reserved hours for medical examinations.

Every α-token enters the net with an initial characteristic "Patient's name and personal data". The β-token initially stays and cycles during the time of the GN-functioning in place l_4 of the GN-model with initial and current characteristic "DB containing information about the physicians and patients of the unit, and information about the correspondence between patients and general practitioners". The γ-token initially stays and cycles during the time of the GN-functioning in place l_{10} of the GN-model with initial and current characteristic "DB with information about already reserved slots for medical examinations".

The GN consists of three transitions and ten places. Below, we will describe the transitions of the nets.

Figure 1: GN-model of scheduling patients' medical examinations

Transition Z_1 represents patient's need to visit one or more physicians and has the following form:

$$Z_1 = <\{l_1, l_4, l_9\}, \{l_2, l_3, l_4\}, r_1>,$$

where

$$r_1 = \begin{array}{c|ccc} & l_2 & l_3 & l_4 \\ \hline l_1 & \textit{true} & \textit{false} & \textit{false} \\ l_4 & \textit{false} & \textit{false} & \textit{true} \\ l_9 & \textit{false} & \textit{true} & \textit{false} \end{array}$$

The α-tokens enter into the GN from place l_1 with the above described initial characteristic. They pass through transition Z_1 at the time of its activation and enter into place l_2, where extend their characteristics with "List of physicians whom the patient intends to visit". The sense of the token's characteristic in place l_3 will be discussed below. Token γ cycles in place l_4 at the time of transition Z_1 functioning without obtaining new characteristic.

Transition Z_2 represents the process of an hour reservation. If more than one visitation hour has to be reserved, the patients make reservations consecutively, waiting for a confirmation or rejection of the chosen hour. The transition has the following form:

$$Z_2 = <\{l_2, l_3, l_5, l_8\}, \{l_5, l_6, l_7, l_8\}, r_2>,$$

where

$$r_2 = \begin{array}{c|cccc} & l_5 & l_6 & l_7 & l_8 \\ \hline l_2 & W_{2,5} & \textit{true} & \textit{false} & \textit{false} \\ l_3 & \textit{false} & \textit{false} & \textit{false} & \textit{true} \\ l_5 & W_{5,5} & \textit{true} & \textit{false} & \textit{false} \\ l_8 & \textit{false} & \textit{false} & W_{8,7} & W_{8,8} \end{array}$$

and
- $W_{2,5} = W_{5,5} = $ "The list of physicians that the patient intends to visit is not empty",
- $W_{8,7} = $ "The patient has obtained confirmation for all requested hours for medical investigation",
- $W_{8,8} = $ "The patient has not yet obtained confirmation for all requested hours for investigation".

When token α from place l_2 contains as its most recent characteristic only one name of a physician, the token transfers to place l_6 without obtaining any new characteristic. Otherwise, the token splits into two tokens, α^1 and α^2. Token α^1 moves to place l_6 with a characteristic "Name of the first physician in the list", while token α^2 moves to l_5 with a characteristic "The list of physicians from the previous token characteristic, without its first member". This procedure will be repeated for the considered token α_i, thus generating a new pair of tokens, α_i^k and α_i^{k+1}, until the end of the physicians' list. On each of these steps the α_i^k-token will move to place l_6, while the α_i^{k+1}-token will remain in place l_5, $k \geq 2$.

When there are two tokens in the transition inputs, token γ entering place l_{10} obtains the characteristic "List of the possible hours for medical investigation", while token ε returns in place l_6 without a new characteristic.

When there is no token in place l_3, but there is a token in place l_7, then token ε returns in place l_6 with the characteristic "DB with information about already reserved hours for medical examination, taking in consideration the newly obtained visiting hours".

Transition Z_3 represents the process of confirmation / rejection of an hour, reserved for medical examination with a specified physician. It has the following form:

$$Z_3 = \langle \{l_6, l_{10}\}, \{l_9, l_{10}\}, r_3 \rangle,$$

where

$$r_3 = \frac{\begin{array}{c|cc} & l_9 & l_{10} \\ \hline l_6 & true & false \\ l_{10} & false & true \end{array}}{}$$

Token α transfers to place l_9 where it obtains the characteristic "Hour for examination, convenient for the current patient, as chosen among the vacant reception hours of the particular physician". Upon α-token movement to place l_9, and subsequent transfer to place l_3, passing through transition Z_1, the token will obtain the characteristic "Confirmation / rejection by the particular physician of the hour requested by the patient".

The α_i^k-token transfers to place l_8, if the i-th patient has requested more than one visit to different physicians, and the token loops in this place until all other tokens generated by the α-token enters the place and merge with the original α-token. As the tokens merge, their characteristics are accumulated in one. When no more α_i^k-tokens exist outside place l_8, the so obtained united token transfers to place l_7. If an α-token enters place l_3 with a characteristic, containing the name and visit hour for only one physician, the token transfers directly to place l_7. In place l_7 tokens obtain their final characteristic "The final patient's schedule for visiting the physicians of the medical unit".

In the end, once the current α-token has left the net, token γ loops in place l_{10}, obtaining as a characteristic "The updated list of the physicians' vacant visiting hours".

3   Conclusions

For a generic patient scheduling, a generic model needs to be derived in which the patients and resources are identified as the relevant co-ordination objects. Based on their individualism, those co-ordination objects are modelled as autonomous agents, where each of those agents is in possession of its own schedule and goals.

References

[1]   Atanassov, K. On Generalized Nets Theory. "Prof. Marin Drinov" Academic Publishing House, Sofia, 2007.