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GENERALIZED NET REPRESENTATIONS OF CONTROL STRUCTURES IN SERVICE SYSTEMS THEORY

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Abstract. Generalized nets representations of often encountered elements of Service Systems Theory such as information feedback and feedforward and requests feedback are proposed. The proposed representations can be used in Generalized nets models of overall service systems. Only the simplest cases of information feedback and feedforward and requests feedbacks are considered but the proposed approach can be easily adapted to the cases of more complex types of control structures including information and requests flows.

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1. Introduction

The representation of control structures is a mandatory element of every system for modeling of service systems. In the present paper we consider the simplest cases of control structures consisting of information feedback and feedforward and requests feedback in systems for service of requests. Generalized Nets (GNs, see [4, 5]) are important and perspective approach to the conceptual modeling (see [14]) of service systems. Therefore, the study of the representations of the elements of real service systems through GNs is an important direction of research.

In [3] GNs representations of virtual device of the following types are proposed: generator, terminator, transportation, delay, server, information gathering, unifying transition, distributive transition, queue. Here, GNs representations of information feedback and feedforward [15] and requests feedback (repeated attempts in [8]) are proposed.

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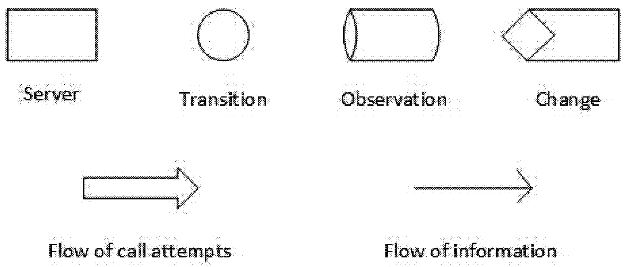

FIGURE 1. A graphical block representation of basic elements from Service Systems Theory.

The conceptual models of service systems are built of concepts on several levels. The lowest level consists of elementary (basic) concepts for which it is assumed that they do not contain other basic concepts. The defining of basic concepts is necessary in the process of comparison of different languages for informatical modeling, as well as for the design of new such languages.

Functional normalization is included, as in our models, we consider monofunctional idealized base virtual devices, shown in Fig.1.

Below is a functional description of the base virtual devices in Service Systems Theory, shown in Fig.1:

- *Server* - models the delay (service time, holding time) of requests in the corresponding device without their generation, elimination or modification. It models also intensity of the traffic [8]. The server has traffic capacity - the maximal number of simultaneously served requests;
- *Transition* - selects one of its possible exits for each request entered, thus determining the next device where this request shall go to;
- *Observation* - generates information, describing the state of the request entered. This information is used for taking decisions in the model (information feedback or feedforward). The information generated is placed in informational requests, different from the modeling ones. The observation device does not cause any changes in the requests' state, delay or path;
- *Change* - changes the characteristics of requests;
- *Flow of call attempts* - unconditionally points to the next device, which the request shall enter, but without transferring or delaying it;
- *Flow of information* - unconditionally points to the next device, which the informational request shall enter, but without transferring or delaying it. Flows of call attempts (modeling requests) and informational request (control flow) have different graphical presentations for better visual specification of the processes in the model.

One of the aims of the present paper is the development of GNs constructions (see [4]) for representation of control structures from the classical languages for computer modeling such as GPSS [6], SIMSCRIPT [9] and

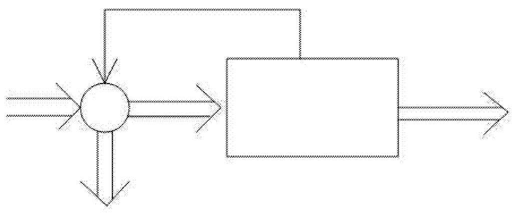

FIGURE 2. Graphical representation of information feedback.

their successers SLX [7] and SIMSCRIPT III [13], as well as and newer ones such as Ptolemy II [10].

In Section 2 of the present paper, a GN representation of information feedback is proposed. It is based on the representation of information feedback from Service Systems Theory. Construction of this type is used for example in the conceptual models of overall telecommunication system [11].

In Section 3, a graphical representation of information feedback and feedforward is given in terms of the Service Systems Theory. On the basis of this representation, two GNs representations of information feedback and feedforward are proposed – one using ordinary GNs and one using Generalized Nets with Characteristics of the Places (GNCP, [1]).

In Section 4, a Service Systems Theory representation of requests feedback is presented. Two GNs representations based on it are proposed.

Only the simplest cases of information feedback and feedforward and requests feedback are considered but the methods proposed here can be applied to more complex systems. The proposed GNs representations can be used in the conceptual modeling of overall service systems and, more specifically, in the modeling of overall telecommunication systems such as the ones studied in [12, 2].

2. GNs representation of information feedback

In Fig. 2 we have a construction which can be encountered for example in the conceptual modeling of an overall telecommunication system [11]. The Server represents a virtual device. The device has parameters such as occupancy, degree of occupancy, capacity. The call attempts occupy individual space within the device. When the device has reached its capacity the offered flow (requests) is blocked and sent to other device by the Switch before the Server. Otherwise, the requests are serviced. This is an example of Information feedback. A possible GN representation of such construction is shown in Fig. 3.

The parameters of the Server are kept in the form of characteristics of a token which stays in place l_5. The formal description of the two transitions may be as follows.

$$Z_1 = \langle \{l_1\}, \{l_2, l_3\}, r_1 \rangle ,$$

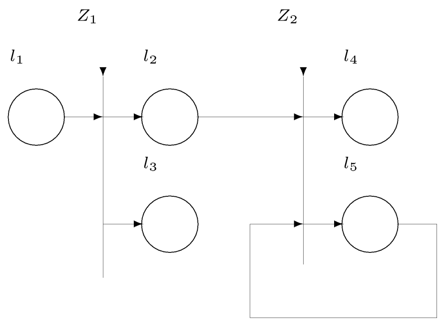

FIGURE 3. GN representation of information feedback.

where

$$r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & W_{1,2} & W_{1,3} \end{array}$$

and

- $W_{1,2} =$"The Server has not reached its capacity";
- $W_{1,3} =$"The Server has reached its capacity".

In place l_2 tokens do not obtain new characteristic. When the truth value of the predicate $W_{1,3}$ is "true" the token in place l_1 enters place l_3 with characteristic *"redirected call attempt"*.

$$Z_2 = \langle \{l_2, l_5\}, \{l_4, l_5\}, r_2 \rangle,$$

where

$$r_2 = \begin{array}{c|cc} & l_4 & l_5 \\ \hline l_2 & W_{2,4} & W_{2,5} \\ l_5 & W_{5,4} & W_{5,5} \end{array}$$

and

- $W_{2,4} = W_{5,5} =$ "true";
- $W_{2,5} = W_{5,4} =$"false".

The characteristic obtained by the tokens in l_5 is *"current values of the Server parameters"*. In place l_4 the token obtains the characteristic *"the call attempt has passed through the device"*.

3. Information feedback and feedforward

Graphical representation of information feedback and feedforward is presented in Fig. 4.

Its GN representation is shown in Fig. 5. Transition Z_2 represents some process or activity which is observed and controled. Copies of the tokens entering place l_3 and place l_7 are generated through splitting. They represent observation of the tokens before and after the process respectively. In place l_9 a token stays in the initial moment. It is used to store the observations before and after the process. In place l_5 a token stays in the initial moment with initial characteristic *"Initial rules for process control"*.

$$Z_1 = \langle \{l_1\}, \{l_2, l_3\}, r_1 \rangle,$$

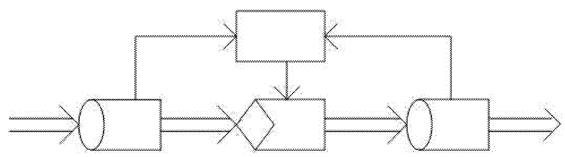

FIGURE 4. Graphical representation of information feedback and feedforward.

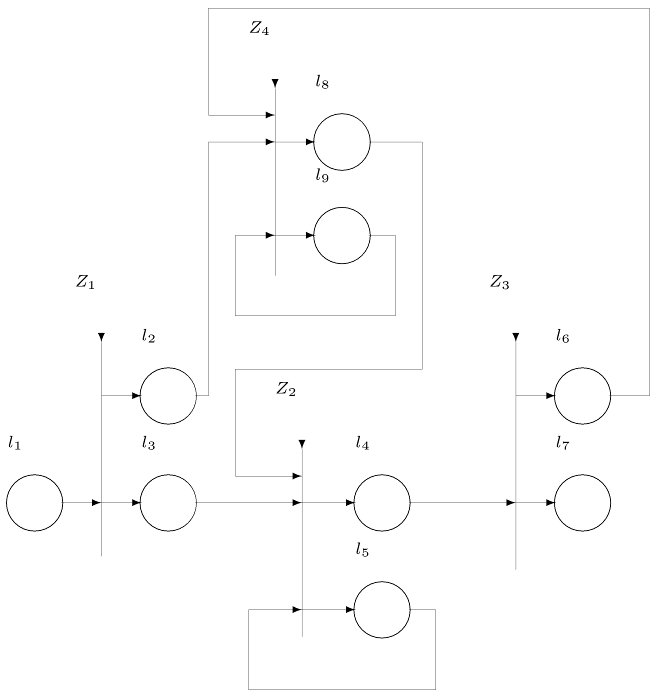

FIGURE 5. GN representation of information feedback and feedforward.

where

$$r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & W_{1,2} & W_{1,3} \end{array}$$

and

- $W_{1,2}$ =“The current token must be observed”;
- $W_{1,3}$ =“true”.

When the truth value of the predicate $W_{1,2}$ is “true” the current token in place l_1 splits into two identical tokens which are transfered to places l_2 and l_3 respectively without receiving characteristic.

$$Z_2 = \langle \{l_3, l_5, l_8\}, \{l_4, l_5\}, r_2 \rangle ,$$

where

$$r_2 = \begin{array}{c|cc} & l_4 & l_5 \\ \hline l_3 & W_{3,4} & W_{3,5} \\ l_5 & W_{5,4} & W_{5,5} \\ l_8 & W_{8,4} & W_{8,5} \end{array}$$

and

- $W_{3,5} = W_{5,4} = W_{8,4} =$“false”;
- $W_{5,5} = W_{8,5} = W_{3,4} =$“true”.

The token in place l_8 enters l_5 and merges with the token which stays permanently there. The new token obtains the characteristic *“New rules for process control”*. The token entering l_4 obtains the characteristic *“Results of the process”*.

$$Z_3 = \langle \{l_4\}, \{l_6, l_7\}, r_3 \rangle ,$$

where

$$r_3 = \begin{array}{c|cc} & l_6 & l_7 \\ \hline l_4 & W_{4,6} & W_{4,7} \end{array}$$

and

- $W_{4,6} =$“The current token is being observed”;
- $W_{4,7} =$“true”.

When the truth value of the predicate $W_{4,6}$ is “true”. The token in place l_4 splits into two identical tokens which enter places l_6 and l_7 respectively without obtaining new characteristics.

$$Z_4 = \langle \{l_2, l_6, l_9\}, \{l_8, l_9\}, r_4 \rangle ,$$

where

$$r_4 = \begin{array}{c|cc} & l_8 & l_9 \\ \hline l_2 & W_{2,8} & W_{2,9} \\ l_6 & W_{6,8} & W_{6,9} \\ l_9 & W_{9,8} & W_{9,9} \end{array}$$

and

- $W_{9,8} =$“New rules for process control are defined based on the observations”;
- $W_{2,9} = W_{6,9} = W_{9,9} =$“true”;
- $W_{2,8} = W_{6,8} =$ “false”.

The tokens from l_2 and l_6 enter place l_9 and merge with the token which stays permanently there. The token in place l_9 receives as characteristic a list of all oserved tokens characteristics before and after the process in the form:

“$\langle \alpha_1$, *observed characteristics of* α_1 *before, observed characteristics of* α_1 *after* $\rangle$, $\cdots$, $\langle \alpha_n$, *observed characteristics of* α_n *before, observed characteristics of* α_n *after* $\rangle$”.

When the truth value of the predicate $W_{9,8}$ is true the token in place l_9 splits into two tokens one of which remains in l_9 and the other one enters l_8 with characteristic *“New rules for process control”*.

A GNCP of the information feedback and feedforward allows for simpler graphical representation (see Fig. 6). Place l_7 does not have initial charac-

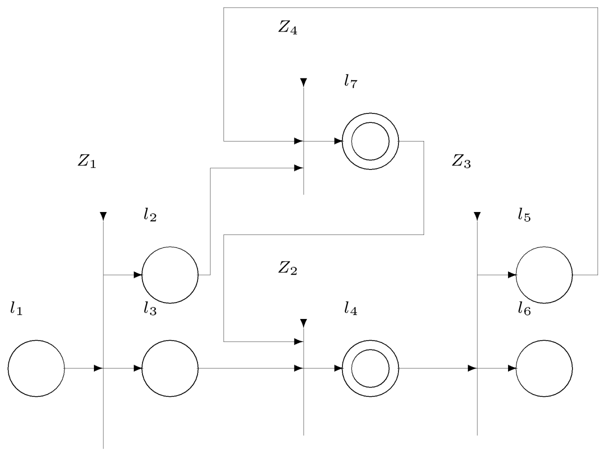

FIGURE 6. GNCP representation of information feedback and feedforward.

teristic. Place l_4 has initial characteristic *"Initial rules for process control"*.

$$Z_1 = \langle \{l_1\}, \{l_2, l_3\}, r_1 \rangle \,,$$

where

$$r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & W_{1,2} & W_{1,3} \end{array}$$

and

- $W_{1,2} =$"The current token must be observed";
- $W_{1,3} =$"true".

When the truth value of the predicate $W_{1,2}$ is "true" the current token in place l_1 splits into two identical tokens which are transfered to places l_2 and l_3 respectively without receiving characteristic.

$$Z_2 = \langle \{l_3, l_7\}, \{l_4\}, r_2 \rangle \,,$$

where

$$r_2 = \begin{array}{c|c} & l_4 \\ \hline l_3 & W_{3,4} \\ l_7 & W_{7,4} \end{array}$$

and

- $W_{3,4} = W_{7,4} =$"true".

The token in place l_7 enters l_4 and merges with the token coming from place l_3. The new token obtains the characteristic *"Results of the process"*. Place l_4 obtains the characteristic *"New rules for process control"*.

$$Z_3 = \langle \{l_4\}, \{l_5, l_6\}, r_3 \rangle \,,$$

where

$$r_3 = \begin{array}{c|cc} & l_5 & l_6 \\ \hline l_4 & W_{4,5} & W_{4,6} \end{array}$$

and

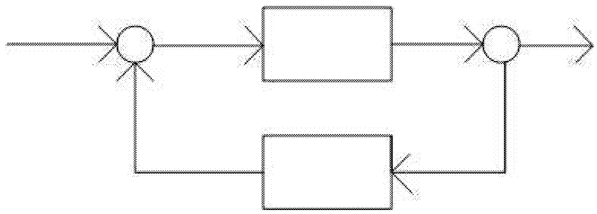

FIGURE 7. Requests feedback.

- $W_{4,5}$ = "The current token is being observed";
- $W_{4,6}$ = "true".

When the truth value of the predicate $W_{4,5}$ is "true". The token in place l_4 splits into two identical tokens which enter places l_5 and l_6 respectively without obtaining new characteristics.

$$Z_4 = \langle \{l_2, l_5\}, \{l_7\}, r_4 \rangle ,$$

where

$$r_4 = \begin{array}{c|c} & l_7 \\ \hline l_2 & W_{2,7} \\ l_5 & W_{5,7} \end{array}$$

and

- $W_{2,7} = W_{5,7}$ = "true".

The tokens from l_2 and l_5 enter place l_7 and merge into one token with characteristic *"New rules for process control"*. Place l_7 receives as characteristic a list of all oserved tokens characteristics before and after the process in the form:

"$\langle \alpha_1$, observed characteristics of α_1 before, observed characteristics of α_1 after $\rangle$, $\cdots$, $\langle \alpha_n$, observed characteristics of α_n before, observed characteristics of α_n after $\rangle$".

4. GNs representations of requests feedback

Here, we consider another type of feedback where the handling of the requests directed to the Server depends on the information obtained through observation of the requests that have been serviced (see Fig. 7). Its GN representation is shown in Fig. 8.

In place l_3 a token stays in the initial time moment with characteristic *"Initial rules for process control"*.

$$Z_1 = \langle \{l_1, l_3, l_4\}, \{l_2, l_3\}, r_1 \rangle ,$$

where

$$r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & W_{1,2} & W_{1,3} \\ l_3 & W_{3,2} & W_{3,3} \\ l_4 & W_{4,2} & W_{4,3} \end{array}$$

and

- $W_{1,2} = W_{4,2} = W_{3,3}$ = "true";
- $W_{1,3} = W_{3,2} = W_{4,3}$ = "false".

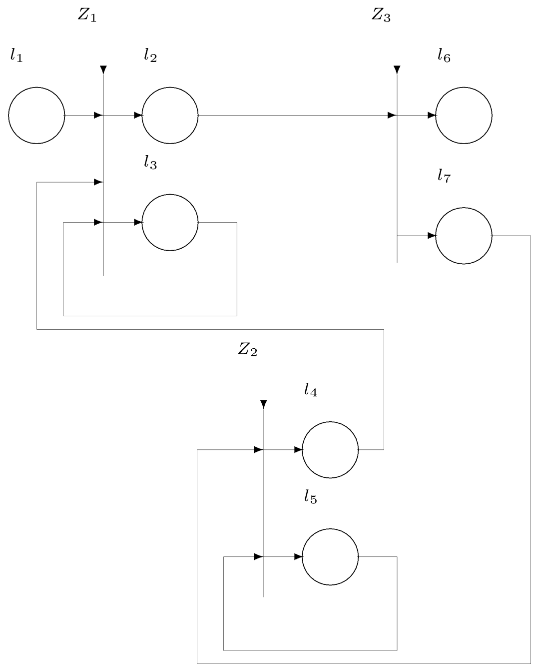

FIGURE 8. GN representation of requests feedback.

The tokens in places l_1 and l_4 representing call attempts enter place l_2 with characteristic *"Results of the process"*. The token in place l_3 obtains the characteristic *"New rules for process control"*.

$$Z_2 = \langle \{l_7, l_5\}, \{l_4, l_5\}, r_2 \rangle\,,$$

where

$$r_2 = \begin{array}{c|cc} & l_4 & l_5 \\ \hline l_5 & W_{5,4} & W_{5,5} \\ l_7 & W_{7,4} & W_{7,5} \end{array}$$

and

- $W_{5,4} =$"false";
- $W_{5,5} = W_{7,4} = W_{7,5} =$"true";

The token in l_7 splits into two identical tokens one of which enters l_4 without new characteristic and the other one enters l_5 where it merges with the token which stays permanently there. The token in place l_5 obtains as characteristic a list of all tokens that have been redirected to the server together with their observed characteristics in the form:

"$\langle\alpha_1$, *observed characteristics of* α_1 *after* $\rangle$, $\cdots$, $\langle\alpha_n$, *observed characteristics of* α_n *after* $\rangle$".

$$Z_3 = \langle \{l_2\}, \{l_6, l_7\}, r_3 \rangle\,,$$

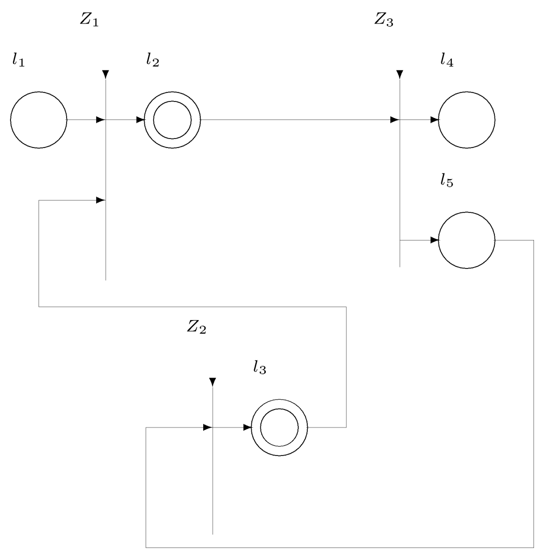

FIGURE 9. GNCP representation of requests feedback.

where

$$r_3 = \begin{array}{c|cc} & l_6 & l_7 \\ \hline l_2 & W_{2,6} & W_{2,7} \end{array}$$

and

- $W_{2,7} =$"The current token must be sent back";
- $W_{2,6} = \neg W_{2,7}$.

When the truth value of the predicate $W_{2,6}$ is "true". The token in place l_2 enters place l_6 without obtaining new characteristic. When the truth value of the predicate $W_{2,7}$ is "true" (with a predefined probability $0 \leq p \leq 1$) the token in place l_2 enters place l_7 with characteristic: *"Redirected request"*.

A GNCP describing the requests feedback leads to a simpler graphic representation (see Fig. 9). Place l_2 has initial characteristic *"Initial rules for process control"*. Place l_3 has no initial characteristic.

$$Z_1 = \langle \{l_1, l_3\}, \{l_2\}, r_1 \rangle ,$$

where

$$r_1 = \begin{array}{c|c} & l_2 \\ \hline l_1 & W_{1,2} \\ l_3 & W_{3,2} \end{array}$$

and

- $W_{1,2} = W_{3,2} =$"true".

$$Z_2 = \langle \{l_5\}, \{l_3\}, r_2 \rangle ,$$

where

$$r_2 = \begin{array}{c|c} & l_3 \\ \hline l_5 & W_{5,3} \\ & \end{array}$$

and

- $W_{5,3} =$"true";

The token in l_5 enters place l_3 without new characteristic. Place l_5 obtains as characteristic a list of all tokens that have been redirected to the server together with their observed characteristics in the form:

"$\langle \alpha_1$, observed characteristics of α_1 after $\rangle$, $\cdots$, $\langle \alpha_n$, observed characteristics of α_n after $\rangle$".

$$Z_3 = \langle \{l_2\}, \{l_4, l_5\}, r_3 \rangle \,,$$

where

$$r_3 = \begin{array}{c|cc} & l_4 & l_5 \\ \hline l_2 & W_{2,4} & W_{2,5} \end{array}$$

and

- $W_{2,5} =$"The current token must be sent back to the Server";
- $W_{2,4} = \neg W_{2,5}$.

When the truth value of the predicate $W_{2,4}$ is "true". The token in place l_2 enters places l_4 without obtaining new characteristic. When the truth value of the predicate $W_{2,5}$ is "true" the token in place l_2 enters place l_5 with characteristic: *"Redirected request"*.

5. Conclusion

The hereby proposed methodology allows for the often used elements of the service systems theory – information feedback and feedforward and requests feedback – to be included in the conceptual models of service systems using GNs.

For the first time, a GN representation of control structure consisting of information feedback and feedforward is proposed. Two representations are constructed: one using ordinary GNs and one using GNCP. The GNCP representation is more compact and consists of less places and arcs compared to the ordinary GN representation. Two GN representations of requests feedback are proposed – one using ordinary GNs and one using GNCP. The GNCP representation uses less places and arcs compared to the ordinary GN representation. The GNs representation of information feedback is simple enough as it consists of only two transitions and five places. That is why an alternative (simpler) representation using GNCP is not given.

GNs are one of the approaches used in the conceptual modeling of overall telecommunication systems. The GN representation of information feedback and feedforward and requests feedback allows for a GN model of overall telecommunication system as well as other service systems and human-cyber-physical systems to be constructed.

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