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Generalized net model of the auto ferry traffic, using intuitionistic fuzzy estimations

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Abstract: The present paper describes the process of the auto ferry traffic The evaluations corresponding to the auto ferry traffic utilize the theory of intuitionistic fuzzy sets.

Keywords: Auto ferry traffic, Intuitionistic Fuzzy Sets, Generalized nets.

Introduction

Combined good transport is a high-efficiency technology aimed to the optimal use of all types of transport. Organization of the work performed at the terminals and auto ferries is the major factor influencing the efficiency of whole transport process [3, 4].

The auto ferry transport is a transport of vehicles, persons and goods a cross a river, lake or sea. This is a combined technology with horizontal transfer of transport. In this case the standard combined unit is a vehicle.

The characteristics of that combined transport result from the fact that the vehicles move in shorter intervals. This is due to the fact that there are a lot of means of transport.

In this research is created a model of process transportation of high automobile flow by water transport.

The number of vehicles which are transported by one auto ferry is known.

Practically the arrival of the vehicle that will be transported and the beginning of the loading of the auto ferry do not coincide. This leads to idle time of the vehicle. The auto ferry floats on schedule.

In the context of the present model we include some possibilities for the possible ways for evaluation of the auto ferry traffic. To do this we can apply estimations of the Intuitionistic Fuzzy Sets (IFS) [6] on the basis of which some amendments may be undertaken.

The estimations are represented by ordered pairs $<\mu, \nu>$ of real numbers from the set [0,1], where:

μ is the count of the transported and unloaded vehicles at the terminal divided by the total number of vehicles.

η is the count of vehicles on garage and on line for loading divided by the total number of vehicles.

The degree of uncertainty $\pi = 1 - \mu - \eta$ reflects the number of vehicles, which have already been loaded on ferry-boats, but haven't arrived in terminal yet divided by the total number.

A GN-model

The generalized net model constructed in Figure 1 describes the process of auto ferry floats.

The places in the generalized net fall into three categories:

- *T*-places standing for the separate vehicles;
- *F*-places describing the auto ferry; and
- *K*-places defining the criteria for estimating of the auto ferry traffic.

On the other hand the vehicles are interpreted in the auto ferry traffic by means of the α-tokens in the *T*-places. The auto ferry are described by β-tokens at *F*-places. The estimation criteria are interpreted by a γ-token at *K*-places.

Sequentially, α-tokens enter the net through place T_1 in some time-moments. These moments will be determined stochastically, when the model is simulated, or they will correspond to real events, when the GN is used for observation of real processes. These tokens have initial characteristic "vehicles *i*", $i = 1, 2, \ldots, n$.

Initially, there might be β-tokens located at places F_3 and F_5 with the characteristics "auto ferry *j*", $j = 1, 2, \ldots, m$.

The new auto ferry s described by β-tokens enter the net from place F_1 with initial characteristic "auto ferry *j*", $j = 1, 2, \ldots, m$.

The γ-tokens enter the net from place K_7 with characteristic "estimation criteria".

Initially there are a γ-tokens at places K_2, K_4 and K_6 with initially characteristics respectively:

"$S = 0$" in place K_2,
"$S_1 = 0$" in place K_4, and
"$S_2 = 0$" in place K_6,

where:
S is the number of vehicles at the current stage of the GN functioning,
S_1 is the number of vehicles, on auto ferries, but haven't arrived yet at the at the current stage of the GN functioning,
S_2 is the number of vehicles, that have already been unloaded at the terminal at the current stage of the GN functioning.

Every time when an α-token enter in places T_1, F_3 and T_6, the γ-tokens in places K_2, K_4 and K_6 respectively, obtain new current characteristic:

"$S = S+1$" in place K_2,
"$S_1 = S_1+1$" in place K_4, and
"$S_2 = S_2+1$" in place K_6.

The Generalized Net in Action

The Generalized Net [1, 2] contains the following set of transitions:

$$A = \{ Z_1, Z_2, Z_3, Z_4, Z_5 \},$$

where the following transitions represent:

- vehicles on garage and waiting on line for loading – transitions Z_1 and Z_2;
- the processes of the freighting and unshipping the vehicles on/from auto ferry – transitions Z_3 and Z_4; (processes for loading and unloading the auto ferry);
- defining the estimations, on the basis of preliminary set criteria – transitions Z_5.

The transitions have the following forms.

$$Z_1 = \langle \{T_1, T_3, K_2\}, \{ T_2, T_3, K_1, K_2\}, R_1, \vee (T_1, T_3, K_2) \rangle$$

The index matrix [5]of the transition conditions is:

$$R_1 = \begin{array}{c|cccc} & T_2 & T_3 & K_1 & K_2 \\ \hline T_1 & false & true & false & false \\ T_3 & W^T_{3,2} & W^T_{3,3} & false & false \\ K_2 & false & false & true & true \end{array},$$

where:

$W^T_{3,2}$ = " There is a vacant place in the parking lot",

$W^T_{3,3} = \neg W^T_{3,2}$.

The α–tokens, entering place T_2 do not obtain new characteristics.

On every activation on the transition Z_1 the γ-token, that is located in place K_2 is splits into two. One of them, let it be the original γ-token, will continue its stay in place K_2, while the other γ-token will enter place K_1.

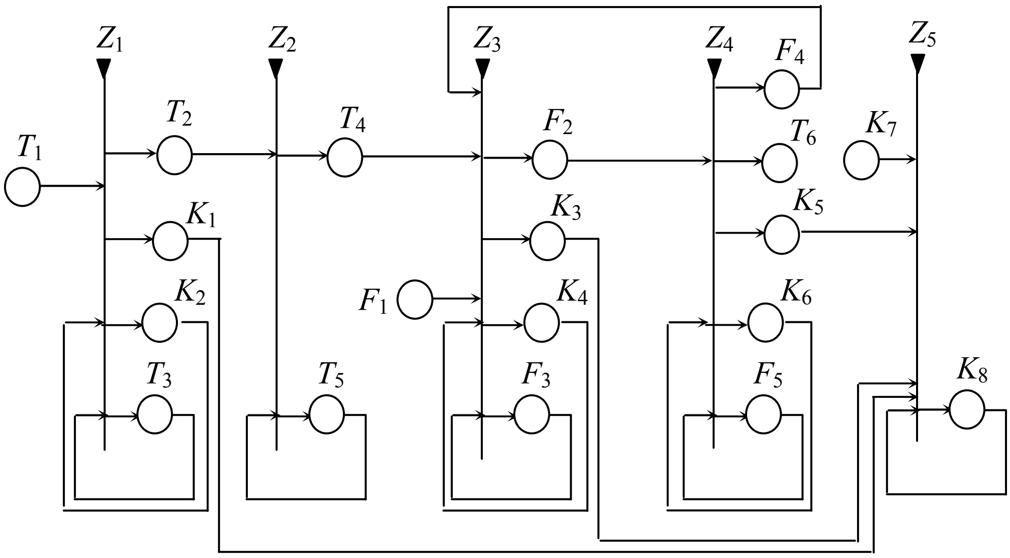

Figure 1: A GN-Model of the auto ferry traffic

$$Z_2 = <\{T_2, T_5\}, \{ T_4, T_5\}, R_2, \vee (T_2, T_5)>$$

The index matrix of the transition conditions is:

$$R_2 = \begin{array}{c|cc} & T_4 & T_5 \\ \hline T_2 & false & true \\ T_5 & W^T_{5,4} & W^T_{5,5} \end{array},$$

where:

$W^T_{5,4}$ = " There is a vacant place on the auto ferry",

$W^T_{5,5} = \neg W^T_{5,4}$.

The α–tokens, entering place T_4 do not obtain new characteristics.

$$Z_3 = <\{T_4, F_1, F_3, F_4, K_4\}, \{ F_2, F_3, K_3, K_4\}, R_3, \vee (T_4, F_1, F_3, F_4, K_4)>$$

The index matrix of the transition conditions is:

$$R_3 = \begin{array}{c|ccccc} & F_2 & F_3 & K_3 & K_4 & F_4 \\ \hline T_4 & false & true & false & false & false \\ F_1 & false & true & false & false & false \\ F_3 & W_{3,2}^F & W_{3,3}^F & true & true & true \\ K_4 & false & false & true & true & false \end{array},$$

where:

$W_{3,2}^F$ = " There is a vacant place on the auto ferry",

$W_{3,3}^F = \neg W_{3,2}^F$.

The β–tokens, entering place F_2 obtain characteristics:

"auto ferry j, vehicles i" $i = 1, 2, \ldots, n, j = 1, 2, \ldots, m$.

On every activation on the transition Z_3 the γ-token, that is located in place K_4 is splits into two. One of them, let it be the original γ-token, will continue its stay in place K_4, while the other γ-token will enter place K_3.

$$Z_4 = \langle\{F_2, F_5, K_6\}, \{F_4, F_5, T_6, K_5, K_6\}, R_4, \vee(F_2, F_5, K_6)\rangle$$

The index matrix of the transition conditions is:

$$R_4 = \begin{array}{c|ccccc} & F_4 & F_5 & T_6 & K_5 & K_6 \\ \hline F_2 & false & true & false & false & false \\ F_5 & W_{5,4}^F & W_{5,5}^F & W_{5,6}^F & false & false \\ K_6 & false & false & false & true & true \end{array},$$

where:

$W_{5,4}^F$ = "The auto ferry is unloaded",

$W_{5,5}^F = \neg W_{5,4}^F$,

$W_{5,6}^F$ = "There is a unloaded vehicle".

The α-tokens, entering place T_6 obtain characteristics:

" vehicle i", $i = 1, 2, \ldots, n$.

The β–tokens, entering place F_4 obtain characteristics:

"auto ferry j", $j = 1, 2, \ldots, m$.

On every activation on the transition Z_4 the -token, that is located in place K_6 is splits into two. One of them, let it be the original γ-token, will continue its stay in place K_6, while the other γ-token will enter place K_5.

$$Z_5 = \langle\{K_7, K_5, K_3, K_2, K_8\}, \{K_8\}, R_5, \vee(K_7, K_5, K_3, K_2, K_8)\rangle$$

The index matrix of the transition conditions is:

$$R_5 = \begin{array}{c|c} & K_8 \\ \hline K_7 & true \\ K_5 & true \\ K_3 & true \\ K_2 & true \\ K_8 & true \end{array}.$$

The token entering place K_8 obtain characteristic "estimations $<\mu_k, \nu_k>$".

Initially, when no information has been derived from places K_1, K_3 and K_4, all estimations take on initial values of <0,0>. When $k \geq 0$, the current (k+1)-st estimation is calculated on the basis of the previous estimations according to the recursive formula (as before):

$$<\mu_{k+1}, \nu_{k+1}> = < \frac{\mu_k k + \mu}{k+1}, \frac{\nu_k k + \nu}{k+1} >,$$

where $<\mu_k, \nu_k>$ is the previous estimation, and $<\mu, \nu>$ is the latest estimation of the ferry traffic , for $\mu, \nu \in [0, 1]$ and $\mu + \nu \leq 1$, and:

$$\mu = \frac{S_1}{S},$$

$$\nu = \frac{F(S-(S_1-S_2))}{S}.$$

Thus the γ-token in place K_8 forms the final estimation of the auto ferry traffic on the basis of the previous and the latest events.

Hence, on the basis of the characteristic of the γ-token at place K_8 the system is able to prepare statistical data about:

- are the vehicles transported and unloaded according to schedule;
- are the vehicles stick in a traffic jam before entering the parking lot.

As a result we may draw a conclusion about the insufficient number of the auto ferries.

Conclusion

The Generalized Net model described here is a possible model for the process of auto ferry traffic. The use of hierarchical operators, which could model the same transition at each place in more detail, would make the model more concrete.

Most of the model parameters can also be regarded as characteristics of tokens from an additional contour, thus achieving optimization with respect to our given aim. Statistical information would need to be collected in order to monitor the development of the process.

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