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Generalized net model of an oil refinery

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Abstract: A generalized net model of the proceesses related to oil refining is described and its applications are commended.
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1 Introduction

Among the economic sectors that produce consumer products, oil processing is considered as one of the most complex. In the oil industry, various products are produced simultaneously from one feedstock and the value of these products is of the same order. This complicates the direct calculation of the production costs of the different products, as it is possible for a production line manufacturing one major and several byproducts. The raw feed and the product flows to and from crude oil distillation units, conversion and upgrading units, followed by product blending, very much resemble a spider web in which there are many threads keeping the web in balance. The ability to process different kinds of oil, some of which require separate treatment, significantly increases the possible production options, thus complicating the economy of the oil company. The picture is further complicated when alongside the various options for processing the oil feedstock to final products risks are added in the supply chain, including operational risks and risks of business interruption due to accidents, spills, natural disasters, etc. Operational risks relate to inherent uncertainties such as demand (finding new customers and the loss of existing ones), the prices of oil and oil products, delays in the supply of raw materials, fluctuations in yields, production of non-standard products, etc.

Managers of today's oil refineries are under enormous pressure from both shareholders, which require steadily increasing profits and cost minimization, and by society, which requires satisfaction of its needs of high-grade environmentally friendly fuels to be produced in safe and healthy working conditions and offered at an affordable price. Achieving these requirements depends on the systems and tools that allow the right people / functions to make the right decisions at the right time. Decisions are often classified according to the time perspective (seconds, hours, days, weeks, quarters, years and longer periods) or with respect to the function/level in the organization hierarchy that must act (advanced process control; optimization real-time determination of schedules, raw material supply, strategy, etc.).

To create order in the chaos of possibilities and limitations, it is quite understandable to seek systematization and rely on the power of mathematical techniques. Such techniques are the generalized nets that are convenient for modelling and simulating complex objects and processes such as those occurring in oil processing enterprise, and represent a powerful tool to help today's management in real time modelling, simulation and prediction of various aspects of oil company activities.

Generalized Net (GN; see [1, 2, 3]) are a convenient tool for modelling complex objects featuring a wide variety of parallel processes. In general, it is not possible to analytically describe such systems by means of linear, polynomial, differential or integral equations. Then the only way for modelling them is the application of different simulation methods. GNs are one such tool. Due to existence of predicates, conditions and characteristics of cores, GN can incorporate elements of the analytical methods for description sake. For example, a characteristic function can be set as to assign a value to a core of the GN that is calculated by analytical functions, or is a solution of a system of equations or is a result of optimization procedures of type "linear programming", "transportation problem", "ant algorithm", etc. On the other hand, the presence of predicates in GN transitions allows for an adequate description of the logical patterns within the modeled processes.

By applying GN the processes in Lukoil Neftochim Burgas (LNB) can be modeled and based on such models these processes can be simulated. For building the models hierarchical GNs (see [2, 3]) will be used as well as GNs comprising already built simpler GNs. The models can be used for several different purposes:

1. At higher level of management: to make projections for the flow of processes in a long-term planning, to simulate emergency situations, such as in a plant (when the raw material should be redirected to other production units) or to simulate possible reconstruction and expansion of production capacity, if applicable.
2. At production process level of management: for optimal distribution of the resulting material.
3. At energy and resource level of management: to maximize profits, satisfaction and prioritization of received requests for finished goods taking into account the global situation.
4. At environmental level of management: to assess the level of contamination of the environment and supporting the decision to migrate to a cleaner and "green" manufacturing processes.

In [5, 4] the first GN models of LNB are described. Now, using and extending the GN-models from [5, 4], we construct a model corresponding to the present status of the LNB plant to Burgas, Bulgaria. All notations, related to the GNs are used by [2, 3].

2 The generalized net model

The GN-model (see Fig. 1), contains seven transitions and twenty places.

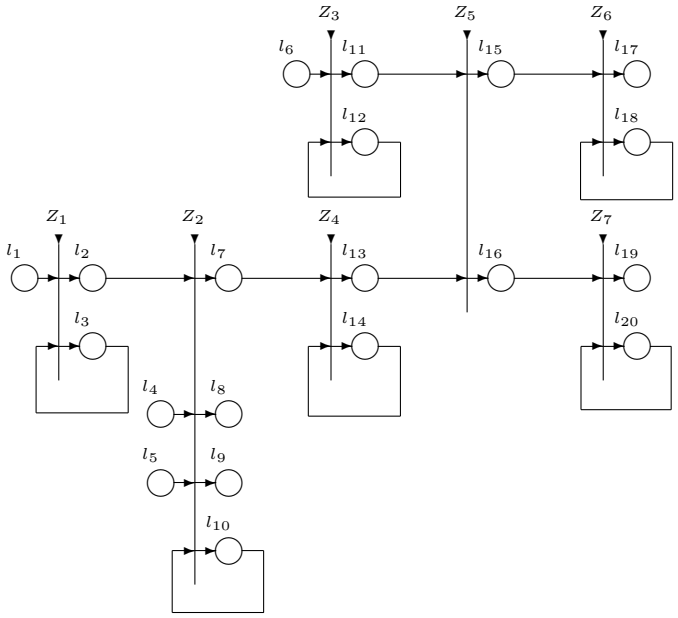

Figure 1: The GN model

In some moments, tokens ν_i enter place l_1 with initial characteristic

"crude oil, quantity, quality, price",

where $i = 1, 2, ...$ is the current number of the token, that corresponds to the number of the currently arrived crude oil. For brevity, below we will write ν instead of ν_i.

In some moments, tokens β_j enter place l_6 with initial characteristic

"biocompound for production of gasiline and diesel, quantity, quality, price, ...",

where $j = 1, 2, ...$ is the current number of the token, that corresponds to the number of the currently arrived biocompound. For brevity, below we will write β instead of β_j.

In some moments, tokens o_p enter place l_4 with initial characteristic

"order for final production, quantity, quality, agreed price",

where $p = 1, 2, ...$ is the current number of the token, that corresponds to the number of the currently arrived orders. For brevity, below we will write o instead of o_p.

In some moments, tokens ι_q enter place l_5 with initial characteristic

"informatiion about current international oil products, prices, supply and demand balance",

where $q = 1, 2, ...$ is the current number of the token, that corresponds to the number of the currently arrived information. For brevity, below we will write ι instead of ι_q.

Initially, tokens $\delta, \rho_1, \rho_2, \rho_3, \rho_4, \rho_5$, stay in places $l_{10}, l_3, l_{12}, l_{14}, l_{18}, l_{20}$, respectively, with initial characteristics
for δ: "history of the processes in the plant",
for ρ_1: "crude oil, quantity, quality in the tanks on the refinery port"
for ρ_2: "crude oil, quantity, quality in the tanks of the refinery"
for ρ_3: "biocompound, quantity, quality in the tanks before the blending plant"
for ρ_4: "fuel with biocompound, quantity, quality in the tanks with final production"
for ρ_5: "fuel without biocompound, quantity, quality in the tanks with final production".

The separate transitions of the GN-model have the following forms.

$$Z_1 = \langle \{l_1, l_3\}, \{l_2, l_3\}, \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & false & true \\ l_3 & W_{3,2} & true \end{array} \rangle,$$

where
$W_{3,2}$ = "there is a necessity to a crude oil for the production process".

Token ν from place l_1 enters place l_3 and unites with token ρ_1 that extend its currect characteristic with the information for the new crude oil.

When truth-value of predicate $W_{3,2} = true$, the token ρ_1, splits to two tokens - the original token ρ_1 that continues to stay in place l_3 with the above mentioned characteristic, but without for the quantity of crude oil that continue to stay in the tanks, and token ν that enters place l_2 with a characteristic

"crude oil, quantity, quality, price".

$$Z_2 = \langle \{l_2, l_4, l_5, l_{10}\}, \{l_7, l_8, l_9, l_{10}\}, \begin{array}{c|cccc} & l_7 & l_8 & l_9 & l_{10} \\ \hline l_2 & true & false & false & true \\ l_4 & false & false & false & true \\ l_5 & false & false & false & true \\ l_{10} & false & W_{10,8} & W_{10,9} & true \end{array} \rangle,$$

where
$W_{10,8}$ = "there is a solution for the order for a final production",
$W_{10,9}$ = "there is information and advertisement for supply of oil products".

The token ν enters place l_7 without a new characteristic. Tokens o and ι enter place l_{10} and unite with token δ, that permanently stays there and that obtains the above mentioned characteristic.

When predicates $W_{10,8}$ or/and $W_{10,9}$ have truth-values $true$, token δ splits to two or three tokens - the original tokens δ and/or tokens o and ι, that enter places l_8 and l_9, respectively, with

characteristics

"solution for satisfying/rejecting of a definite order for a final production",

"definite information or advertisement, addressed to supply of oil products",

$$Z_3 = \langle \{l_6, l_{12}\}, \{l_{11}, l_{12}\}, \begin{array}{c|cc} & l_{11} & l_{12} \\ \hline l_6 & false & true \\ l_{11} & W_{12,11} & true \end{array} \rangle,$$

where
$W_{12,11}$ = "there is a necessity to a biocompound for the production process".

Token β from place l_6 enters place l_{12} and unites with token ρ_2 that extend its current characteristic with the information for the new biocompound.

When truth-value of predicate $W_{12,11} = true$, the token ρ_2, splits to two tokens - the original token ρ_2 that continues to stay in place l_{12} with the above mentioned characteristic, but without the quantity of biocompound that continues to stay in the respective tanks, and token β that enters place l_{11} with a characteristic

"biocompound for the production process, quantity, quality".

$$Z_4 = \langle \{l_7, l_{14}\}, \{l_{13}, l_{14}\}, \begin{array}{c|cc} & l_{13} & l_{14} \\ \hline l_7 & false & true \\ l_{14} & W_{14,13} & true \end{array} \rangle,$$

where
$W_{14,13}$ = "there is a necessity to crude oil for the production process".

Token ν from place l_7 enters place l_{14} and unites with token ρ_3 that extend its current characteristic with the information for the new crude oil.

When truth-value of predicate $W_{14,13} = true$, the token ρ_3, splits to two tokens - the original token ρ_3 that continues to stay in place l_{14} with the above mentioned characteristic, but without the quantity of crude oil that continues to stay in the respective tanks, and token ν that enters place l_{13} with a characteristic

"crude oil for the production process, quantity, quality".

$$Z_5 = \langle \{l_{11}, l_{13}\}, \{l_{15}, l_{16}\}, \begin{array}{c|cc} & l_{15} & l_{16} \\ \hline l_{11} & true & true \\ l_{13} & true & true \end{array} \rangle.$$

Both tokens in the input places split to two tokens that enter output transition places, where they unite in two new tokens φ_1 and f_2 with characteristics
in place l_{15}: "fuel containing biocompound, quantity, quality",
in place l_{16}: "fuel not containing biocompound, quantity, quality",

$$Z_6 = \langle \{l_{15}, l_{18}\}, \{l_{17}, l_{18}\}, \begin{array}{c|cc} & l_{17} & l_{18} \\ \hline l_{15} & false & true \\ l_{18} & W_{18,17} & true \end{array} \rangle,$$

where

$W_{18,17}$ = "there is a necessity to a fuel containing biocompound for sale".

Token φ_1 enters place l_{18} and unites with token ρ_4 that obtains the initially mentioned characteristic.

When truth-value of predicate $W_{18,17} = true$, the token ρ_4, splits to two tokens - the original token ρ_4 that continues to stay in place l_{18} and token φ_1 that enters place l_{17} with a characteristic

"fuel containing biocompound for sale, quality, quantity, price".

$$Z_7 = \langle \{l_{16}, l_{20}\}, \{l_{19}, l_{20}\}, \begin{array}{c|cc} & l_{19} & l_{20} \\ \hline l_{16} & false & true \\ l_{20} & W_{20,19} & true \end{array} \rangle,$$

where

$W_{20,19}$ = "there is a necessity to a fuel not containing biocompound for sale".

Token φ_2 enters place l_{20} and unites with token ρ_5 that obtains the initially mentioned characteristic.

When truth-value of predicate $W_{20,19} = true$, the token ρ_5, splits to two tokens - the original token ρ_5 that continues to stay in place l_{20} and token φ_2 that enters place l_{19} with a characteristic

"fuel not containing biocompound for sale, quality, quantity, price".

The so-constructed GN model can become in future a subject of formal verification, using ideas from [2, 6].

3 Conclusion: On the possible applications of the generalized net model

The constructed model can be used for simulation of the processes in the oil refinery. The model is investigated following the ideas of hierarchical models and models based on the union and composition of simpler GN-models (see, [2, 3].

The general movement of fuels, petrochemicals products, produced and processed in the oil refinery can be observed by the first part of the GN, that contains places $l_1, l_2, l_3, l_6, l_7, l_{11}, ..., l_{20}$.

Besides, the GN has two other (not differentiated separately) parts.

The first one symbolizes the entry of orders of the demand of fuels and petrochemicals products (place l_4), workout of this information (orders) (place l_{10}) and report on the orders (place l_8) – whether they are satisfied or not.

The second one (place l_5) represents the influence of: 1) the global and local-area marketing situation, 2) the recent Customs and tax regulations in national and European legislations, 3) the

dynamics of crude oil prices, on the other side; and the advertisement of the refinery production (place l_9).

The described GN reflects only the most global connections existing between the different units of the refinery. When more details are required, some of its places and/or transitions may be substituted by whole new GNs. These nets will describe the separate subprocesses which are included in the most global ones.

The above constructed GN-model can be used for other purposes, too. For example, if we change the forms of the characteristic functions so that they determine the quantity of the products which go to the atmosphere, or down to the soil, then the GN can be used for modelling processes related to the ecological contamination of the environment.

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