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Modeling the Process of Extracting Sensor Data from the Terrain Using Generalized Nets

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***Abstract* — The goal of the paper is to present an original Generalized Net model (GN-model) of the process of obtaining sensor data from the terrain, their analysis using artificial intelligence and their presentation in an operational center to support decision-making in crisis management. By using Generalized Nets, the aim is to create a general model of this process in order to achieve a better basis for research and future analyses of the complex relationships between subjects, objects and impacts in crisis management. To verify the presented GN-model, the simulation environment GN IDE was used, and some results from it are shown, related to the activation of transitions and movement between individual tokens in the net.**

Keywords* — *AI, GN-model, crisis management, modeling.

I. Introduction

Crisis management of various natures is a complex process requiring coordinated interaction between people, means and resources, which is usually carried out under complex working conditions and limited reaction time. The management team must have the necessary qualities and experience to make quick and efficient decisions in complex situations. However, it will need adequate information about the situation, the development of the crisis, the effect of the actions taken, etc. The more accurate and timely this information is, the closer the decisions made will be to the optimal ones for the given situation. Therefore, the process of obtaining sensor data from the area, photo and video images, etc. in real conditions, is of key importance for the successful analysis of the situation and making adequate decisions.

Recently, UAVs have been increasingly used to obtain data from the area. Their use has gained great popularity due to several main factors:

- they are easy to control and charge;
- they can carry equipment and cargo;
- they are relatively cheap.

With the improvement of electric batteries, which allow for a longer stay in the air, the miniaturization of electronic control components, as well as the development of artificial intelligence, it has become possible to create intelligent flying platforms that can choose the optimal route themselves, avoid obstacles, analyze the environment and make decisions in complex operating conditions. However, for transmitting data from the area using UAVs or ground (water) autonomous systems, good knowledge of the terrain is also required, which is essential for implementing stable communication for data transmission and remote control. Direct transmission of information from one point to another has a limited range, and the presence of obstacles and signal attenuation due to adverse passive or active effects greatly limits this distance and reduces it to several tens of kilometers. For this purpose, mobile stations can be used to relay data from drones and other sensor networks located in the area by connecting them to fixed networks, and from there to the crisis management operations center (see Fig. 1).

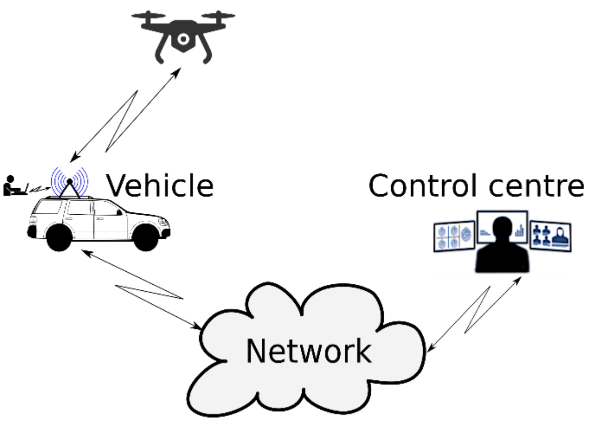

Fig. 1. Variant of using a field mobile station and a stationary network for transmitting sensor data [12].

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The data transmission system, located on a mobile vehicle, is a field mobile station, which also includes an operator. The operator can perform primary data processing or transmit them via a stationary or radio relay network to a remote operational center for analysis and decision-making. Such a system can be used mainly in the assessment and prevention of natural disasters, accidents, fires, explosions with explosives, etc. UAVs, equipped with specialized sensors for environmental assessment, IR-cameras and other sensors, are gaining increasing popularity for obtaining important information in real time and for transmitting it to an operational center for crisis management. A large part of the data obtained from the area can be processed even before being sent to the operational center - one part in the UAVs, and the other - in the field mobile station.

The process of obtaining sensor data from the area is an important element of the overall process of supporting decision-making by the management team in the crisis operations center. In order to study this complex process, an original Generalized Net model (GN-model) is presented below, suitable for use as a basis for future analyses of the complex interactions between participating entities (personnel, staff, teams, etc.), objects (means, equipment, resources, etc.) and processes (impacts of external and internal factors) in crisis management. Generalized nets are a very good toolkit for modeling complex processes, providing convenient means for describing the participating elements in a wide class of tasks, processes and phenomena. They are based on the Theory of Generalized Nets by K. Atanassov [1], [2], [3], which he defined in 1982. For modeling different tasks, other types of nets can also be used, such as N-nets (a type of Petri nets), which are used, for example, in [13]. Other studies related to modeling and analysis can be found in [5], [7], [8], [10], [11], [14], [15]. More information about the possibilities of obtaining sensor data from the area, such as meteorological data, pollution levels, photo and video recording, etc.), using unmanned aerial vehicles, can be found in another publication by one of the authors [12].

II. MATERIALS AND METHODS

The model for obtaining data from the area using sensors can be described by a generalized net E in the following way: E = {Z1, Z2, Z3, Z4, Z5}, where

Z1 – situation awareness and preparation;

Z2 – obtaining data from the area;

Z3 – processing data at a field station and sending them to an operations center;

Z4 – analysis of data at an operations center;

Z5 – decision making and management.

The scheme of the generalized net E is shown in Fig. 2.

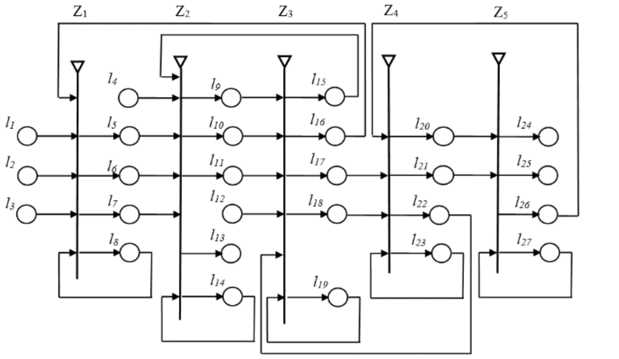


Fig. 2. Model of the process of obtaining sensor data from the area using a generalized net.

The tokens of the net E are:

α – subjects (personnel, experts, etc.), with the following characteristics: $X_\alpha(e^{\alpha}_{p1}, e^{\alpha}_{p2}, \ldots, e^{\alpha}_{pi}, \ldots, e^{\alpha}_{pk})$, where e^{α}_{pi} is the estimate of the i^{-th} parameter from k ($i \leq k$) basic estimate parameters characterizing the subjective factor;

β – objects (technique, equipment, resources, etc.), with the following characteristics: $X_\beta(e^{\beta}_{q1}, e^{\beta}_{q2}, \ldots,{}^{\beta}_{qi}, \ldots, e^{\beta}_{qn})$, where e^{β}_{qi} is the estimate of the i^{-th} object from n ($i \leq n$) necessary ones;

γ – procedures (sequence of actions, documentation, etc.), with the following characteristics: X_γ $(e^{\gamma}_{v1}, e^{\gamma}_{v2}, \ldots, e^{\gamma}_{vi}, \ldots, e^{\gamma}_{vs})$, where e^{γ}_{vi} is the estimate of the i^{-th} type of procedure from s ($i \leq s$);

λ – external factors (environmental impacts, escalation of the crisis, etc.), with the following characteristics: X_λ $(e^{\lambda}_{w1}, e^{\lambda}_{w2}, \ldots, e^{\lambda}_{wi}, \ldots, e^{\lambda}_{wt})$, where e^{λ}_{wi} is an estimate of the i^{-th} type of influencing external factor from t ($i \leq t$);

ι – data (data obtained from UAVs, sensor data from the area, intelligence data, etc.), with the following characteristics): $X\iota(e^{\iota}_{h1}, e^{\iota}_{h2}, \ldots e^{\iota}_{hi}, \ldots, e^{\iota}_{hm})$, where e^{ι}_{hi} is an estimate of the availability and transfer of the necessary data from m ($i \leq m$).

$\mathbf{e^{\alpha}_{p}, e^{\beta}_{q}, e^{\gamma}_{v}, e^{\lambda}_{w}}$ and $\mathbf{e^{\iota}_{h}}$ are functions of the generalized net, whose estimation parameters can include values in the following intervals: {0,1} – for integer values; [0,1] – for normal fuzziness, or [0,1] × [0,1] – for intuitionistic fuzziness.

By applying the Theory of Intuitionistic Fuzzy Sets of K. Atanassov [4], a more accurate estimation of the parameters of the individual tokens in the net can be achieved, using intuitionistic fuzzy estimates. For the generalized net model presented here, the estimates $\mathbf{e_k}^{\{\alpha, \beta, \gamma, \lambda, \iota\}}$ look like this:

$\mathbf{e_j}^{\{\alpha, \beta, \gamma, \lambda, \iota\}} = \{<\mu_j, \nu_j> (\mu_j, \nu_j \in R \ \& \ \mu_j \geq 0 \ \& \ \nu_j \geq 0 \ \& \ \mu_j + \nu_j \leq 1)\}$, for j=1, …, k,

where:

μ_j and ν_j are two functions: μ_j for membership and ν_j for non-membership, which belong to the real unit interval [0, 1] and whose sum belongs to the same interval, as well.

These functions can be used to express the degree of certainty /confidence/ (μ_j) or the degree of uncertainty (ν_j) regarding the estimate of a given parameter of the system;

$\pi_j = 1 - \mu_j - \nu_j$ – degree of uncertainty /ambiguity/ regarding the estimation of the values of a given parameter.

The description of the individual transitions is as follows:

$$Z_1 = <\{l_1, l_2, l_3, l_8, l_{16}\}, \{l_5, l_6, l_7, l_8\}, r_1, M_1, \vee(l_1, l_2, l_3, l_8, l_{16})>,$$

where

l_1 – initial input position, into which α-tokens (subjects - personnel, staff) enter, with characteristics $X_\alpha(e^\alpha_{p1}, e^\alpha_{p2}, \ldots, e^\alpha_{pi}, \ldots, e^\alpha_{pk})$;

l_2 – initial input position, into which β-token (objects - machinery, equipment, resources, etc.) enter, with characteristics $X_\beta(e^\beta_{q1}, e^\beta_{q2}, \ldots,^\beta_{qi}, \ldots, e^\beta_{qm})$, which initiate the individual elements of the objects and the environment;

l_3 – initial input position, into which γ-token (procedures) with characteristics enter X_γ ($e^\gamma_{v1}, e^\gamma_{v2}, \ldots, e^\gamma_{vi}, \ldots, e^\gamma_{vn}$), who initiate the individual rules of action, work guidance documents, etc.;

l_4 – transition position Z_2 (data acquisition from the terrain), which receives ι-tokens (data) obtained from various sources - from UAVs, from sensors located on the terrain (for movement, temperature, pressure, pollution, vibrations, etc.), from ground cameras in the visible and infrared range, from satellite images, etc.;

l_5 – position to transition Z_2 (data acquisition), where α-tokens (personnel, personnel) arrive;

l_6 – position where β-tokens arrive (technique, equipment, tools, resources, etc.);

l_7 – position where γ-tokens arrive (procedures, guidance documents, etc.);

l_8 – position where α-, β- and γ-tokens arrive, in the process of situation awareness and preparation for work).

r_1 =

	l_5	l_6	l_7	l_8
l_1	F	F	F	T
l_2	F	F	F	T
l_3	F	F	F	T
l_8	$W_{8,5}$	$W_{8,6}$	$W_{8,7}$	$W_{8,8}$
l_{16}	F	F	F	T

T – allowed transition (True), F – forbidden transition (False)

The predicates $W_{x,y}$ are the following:

$W_{8,5}$ – "there are suitable α-tokens (subjects – personnel, staff) after analyzing the situation (in position l_8), which are entering Z_2 (obtaining data from the area);

$W_{8,6}$ – "there are suitable β-tokens (objects – machinery, equipment, tools, resources, etc.), which are necessary for transition Z_2";

$W_{8,7}$ – "there are suitable γ-tokens tokens (procedures – sequence of actions, guiding documents, etc.), which are necessary for the functioning of transition Z_2";

$W_{8,8}$ – "there are tokens received for analysis and preparation".

M_1 =

	l_5	l_6	l_7	l_8
l_1	0	0	0	N
l_2	0	0	0	N
l_3	0	0	0	N
l_8	$m_{8,5}$	$m_{8,6}$	$m_{8,7}$	$m_{8,8}$
l_{16}	0	0	0	N

N – the maximum number of tokens specified for the transition;

$m_{8.5}$, $m_{8.6}$, $m_{8.7}$, $m_{8.8}$ – from 0 to the maximum allowed number of tokens for evaluation of the transition Z_1 ($m \le N$).

$$Z_2 = <\{l_4, l_5, l_6, l_7, l_{14}, l_{15}\}, \{l_9, l_{10}, l_{11}, l_{13}, l_{14}\}, r_2, M_2, \vee (l_4, l_5, l_6, l_7, l_{14}, l_{15})>,$$

where

l_4 – initial input position, where ι-tokens (data) arrive, with characteristics: $\iota(e^\iota_{h1}, e^\iota_{h2}, \ldots e^\iota_{hi}, \ldots, e^\iota_{hm})$, which are obtained from various sources – from UAVs, sensor data from the area, intelligence data, etc.;

l_9 – position to transition Z_3 (data processing in a field station), where ι-tokens (data carriers) arrive;

l_{10} – position to transition Z_3, where successful α-tokens (personnel, personnel, etc.) or β-tokens (equipment, equipment, resources, etc.) arrive;

l_{11} – position to transition Z_3, where successful γ-tokens (procedures, guidance documents, etc.) arrive;

l_{13} – position, where unsuccessful α-, β-, γ- or ι-tokens arrive;

l_{14} – position where the token participating in the transition enter, in waiting or processing mode.

l_{15} – position where α-, β-, γ- or ι- token coming from transition Z_3, requiring processing, enter.

r_2 =

	l_9	l_{10}	l_{11}	l_{13}	l_{14}
l_4	F	F	F	F	T
l_5	F	F	F	F	T
l_6	F	F	F	F	T
l_7	F	F	F	F	T
l_{14}	$W_{14,9}$	$W_{14,10}$	$W_{14,11}$	$W_{14,13}$	$W_{14,14}$
l_{15}	F	F	F	F	T

$W_{14.9}$ – "there are suitable (after analysis) α- and β-token that are needed for transition Z_2";

$W_{14.10}$ – “there are suitable γ-token that are needed for transition Z_3”;

$W_{14.11}$ – “there are suitable ι-token that go to transition Z_3”; after processing they return to transition Z_1”; and coming from Z_2;

$W_{14.13}$ – “there are unsuitable token after analysis of the situation” (they are discarded);

$W_{14.14}$ – “there are incoming token that need processing”.

M_2 =

	l_9	l_{10}	l_{11}	l_{13}	l_{14}
l_4	0	0	0	0	N
l_5	0	0	0	0	N
l_6	0	0	0	0	N
l_7	0	0	0	0	N
l_{14}	$m_{14,9}$	$m_{14,10}$	$m_{14,11}$	$m_{14,13}$	$m_{14,14}$
l_{15}	0	0	0	0	N

$m_{14,9}$, $m_{14,10}$, $m_{14,11}$ and $m_{14,13}$ are with values from 0 to the maximum allowed number of tokens for transition Z_2 ($m \leq N$);

$m_{14,14}$ – from 0 to the maximum allowed number of processed tokens for this transition.

$Z_3 = <\{l_9, l_{10}, l_{11}, l_{12}, l_{19}, l_{22}\},\{l_{15}, l_{16}, l_{17}, l_{18}, l_{19}\}, r_3, M_3, \vee(l_9, l_{10}, l_{11}, l_{12}, l_{19}, l_{22})>$,

where

l_{12} – position where λ-tokens (external factors – environmental impacts, escalation of the crisis, etc.) arrive, with the following characteristics: X_λ (e^λ_{w1}, e^λ_{w2}, …, e^λ_{wi}, …, e^λ_{wt});

l_{15} – position where ι-tokens (data) that require additional processing (analysis) in transition Z_2 arrive;

l_{16} – position where α-, β- and γ-tokens arrive, which return to transition Z_1, after successful work;

l_{17} – position where successful α-, β-, γ- or λ-tokens required for transition Z_4 arrive;

l_{18} – position where successful ι-tokens (data) required for transition Z_4 arrive;

l_{19} – position where tokens participating in the transition arrive, in waiting or processing mode;

l_{22} – position of returning tokens from transition Z_4 (data analysis in an operations center) that require additional processing (analysis) in transition Z_3.

r_3 =

	l_{15}	l_{16}	l_{17}	l_{18}	l_{19}
l_9	F	F	F	F	T
l_{10}	F	F	F	F	T
l_{11}	F	F	F	F	T
l_{12}	F	F	F	F	T
l_{19}	$W_{19,15}$	$W_{19,16}$	$W_{19,17}$	$W_{19,18}$	$W_{19,19}$
l_{22}	F	F	F	F	T

$W_{19,15}$ – „there are suitable ι-token that are needed for transition Z_2“.

$W_{19,16}$ – „there are suitable α-, β- or γ-token that are needed for transition Z_1“;

$W_{19,17}$ – „there are suitable α-, β-, γ- or λ-token that are needed for transition Z_4“;

$W_{19,18}$ – „there are suitable ι-token that are needed for transition Z_4“;

$W_{19,19}$ – „there are tokens that need processing“.

M_3 =

	l_{15}	l_{16}	l_{17}	l_{18}	l_{19}
l_9	0	0	0	0	T
l_{10}	0	0	0	0	T
l_{11}	0	0	0	0	T
l_{12}	0	0	0	0	T
l_{19}	$m_{19,15}$	$m_{19,16}$	$m_{19,17}$	$m_{19,18}$	$m_{19,19}$
l_{22}	0	0	0	0	T

$m_{19,15}$, $m_{19,16}$, $m_{19,17}$ and $m_{19,18}$ are with values from 0 to the maximum allowed number of tokens for transition Z_3 ($m \leq N$);

$m_{19,19}$ – from 0 to the maximum allowed number of processed tokens for this transition.

$Z_4 = <\{l_{17}, l_{18}, l_{23}, l_{26}\},\{l_{20}, l_{21}, l_{22}, l_{23}\}, r_4, M_4, l_{17} \vee l_{18} \vee l_{23} \vee l_{26}>$,

where

l_{20} – position to transition Z_5 (decision making and control), where successful α- or β- tokens enter;

l_{21} – position to transition Z_5 (decision making and control), where successful λ- or ι-tokens enter;

l_{23} – position where tokens participating in the transition enter, in waiting or processing mode.

r_4 =

	l_{20}	l_{21}	l_{22}	l_{23}
l_{17}	F	F	F	T
l_{18}	F	F	F	T
l_{23}	$W_{23,20}$	$W_{23,21}$	$W_{23,22}$	$W_{23,23}$
l_{26}	F	F	F	T

$W_{23,20}$ – „there are suitable α-, β-, γ- or λ-token that are needed for transition Z_5“;

$W_{23,21}$ – „there are suitable ι-token that are needed for transition Z_5“;

$W_{23,22}$ – „there are tokens that after processing return to transition Z_3“;

$W_{23,23}$ – „there are tokens received for processing and analysis“.

M_4 =

	l_{20}	l_{21}	l_{22}	l_{23}
l_{17}	0	0	0	$m_{17,23}$
l_{18}	0	0	0	$m_{18,23}$
l_{23}	$m_{23,20}$	$m_{23,21}$	$m_{23,22}$	$m_{23,23}$
l_{26}	0	0	0	$m_{26,23}$

$m_{23,20}$ and $m_{23,21}$ have values from 0 to the maximum allowed number of tokens for transition Z_5 ($m \leq N$);

$m_{23,22}$ – from 0 to the maximum allowed number of tokens returned to transition Z_3;

$m_{17,23}$, $m_{18,23}$, $m_{23,23}$, $m_{26,23}$ – from 0 to the maximum allowed number of tokens processed for this transition.

$Z_5 = <\{l_{20}, l_{21}, l_{27}\}, \{l_{24}, l_{25}, l_{26}, l_{27}\}, r_5, M_5, l_{20} \vee l_{21} \vee l_{27}>$,

where

l_{24} – position where failed tokens (those that do not correspond to the management decision made) enter;

l_{25} – position where successful tokens (those that correspond to the management decision made) enter;

l_{26} – position where tokens that return to transition Z_4 after successful operation enter;

l_{27} – position where tokens participating in the transition enter, in waiting or processing mode.

$r_5 =$

	l_{24}	l_{25}	l_{26}	l_{27}
l_{20}	F	F	F	T
l_{21}	F	F	F	T
l_{27}	$W_{27,24}$	$W_{27,25}$	$W_{27,26}$	T

$W_{27.24}$ – “there are tokens that do not correspond to the management decision and cannot be reused”;

$W_{27.25}$ – “there are suitable tokens that correspond to the decision and satisfy the set goal”;

$W_{27.26}$ – “there are tokens that, after processing, return to transition Z_4”.

$M_5 =$

	l_{24}	l_{25}	l_{26}	l_{27}
l_{20}	0	0	0	$m_{20,27}$
l_{21}	0	0	0	$m_{21,27}$
l_{27}	$m_{27,24}$	$m_{27,25}$	$m_{27,26}$	$m_{27,27}$

$m_{27,24}$ – from 0 to the maximum allowed number of token losses for this transition;

$m_{27,25}$ – from 0 to the maximum allowed number of target tokens;

$m_{27,26}$ – from 0 to the maximum allowed number of tokens returned to transition Z_4;

$m_{20,27}$, $m_{21,27}$, $m_{27,27}$ – from 0 to the maximum allowed number of tokens processed for this transition.

III. RESULTS AND DISCUSSION

A. GN-MODEL SUIMULATION

The presented GN-model was simulated in the GN IDE simulation environment [6], [9]. Some of the obtained results from the model simulation are shown in Fig. 3, 4 and 5.

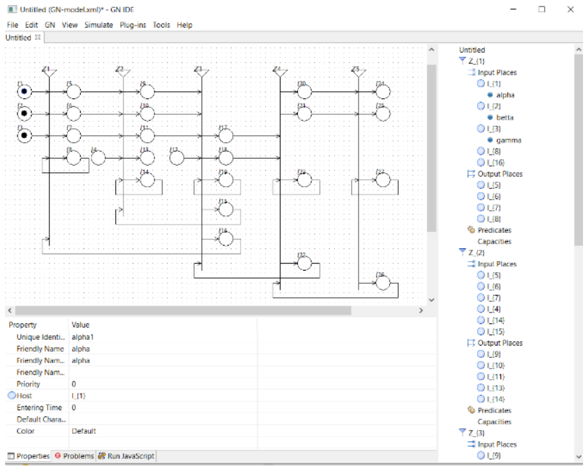
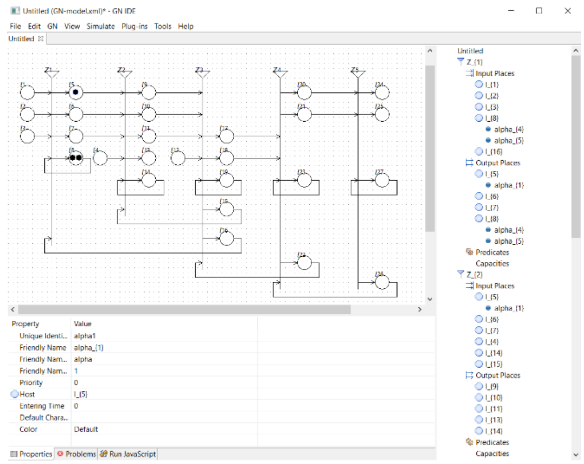
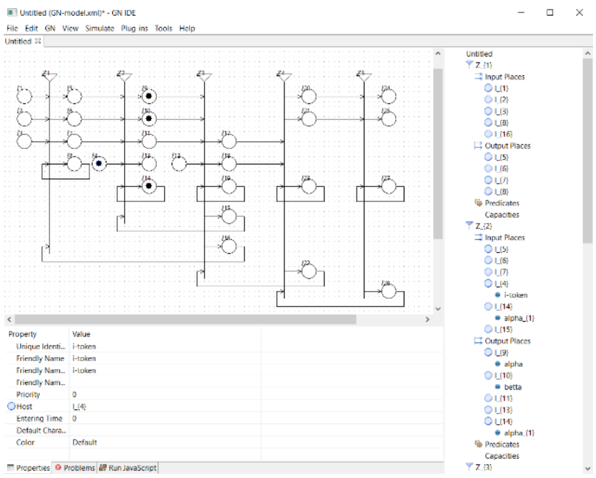


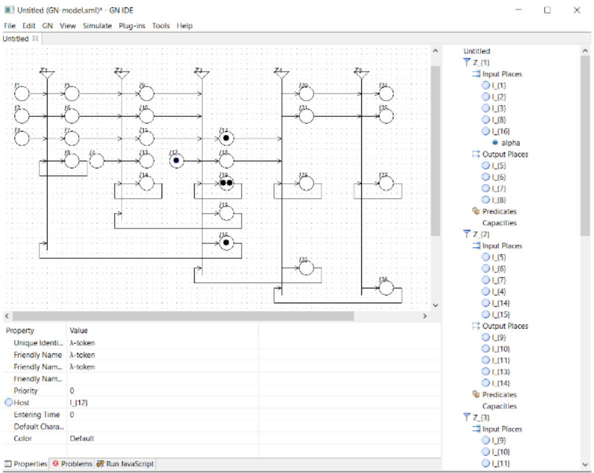
Fig. 3 Simulation of the GN-model of the process of obtaining sensor data from the terrain using the GN IDE simulation environment (initial state).



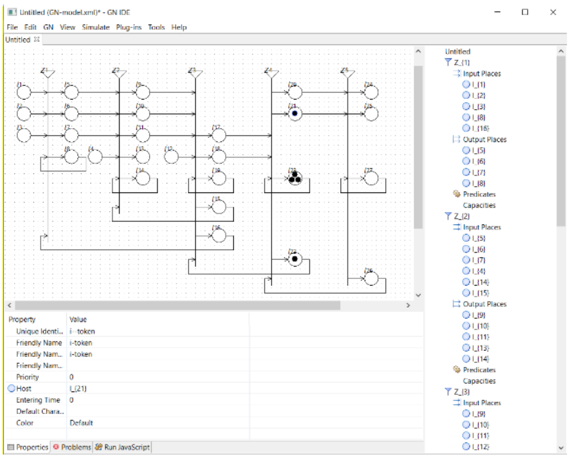
a) Step 1



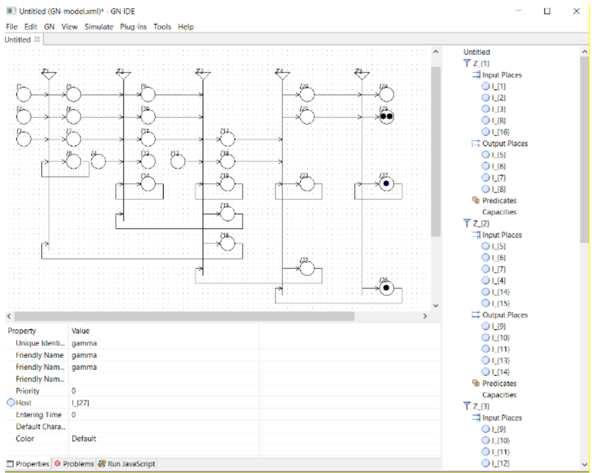
b) Step 2



c) Step 3



d) Step 4



e) Step 5

Fig. 4 Simulation of the GN-model of the process of obtaining sensor data from the terrain using the GN IDE simulation environment (steps 1 - 5)

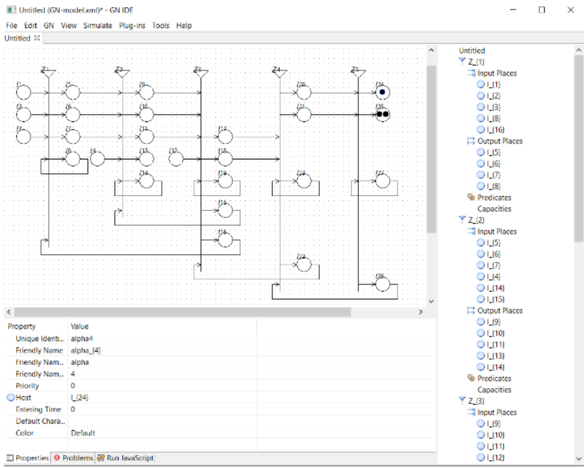


Fig. 5 Simulation of the GN-model of the process of obtaining sensor data from the terrain using the GN IDE simulation environment (final state).

B. *DISCUSSION*

By simulating the interaction between the main components (objects, subjects and processes) of the presented GN-model, it can be concluded that it is a flexible tool for studying and analyzing the complex interactions related to crisis management in terms of the process of obtaining sensor data from the area and transmitting them to an operational center for decision-making. The GN-model can simulate various variants of interactions, for example, by changing the individual characteristics of the used tokens circulating in the net, or by changing some predicates (Wx,y), it is possible to monitor what occurs at the output of individual transitions in the GN-model and simulate different situations. In this way, a more realistic idea of the impact of various input factors on the studied situation will be acquired, and this will significantly assist the process of managing a given crisis.

IV. CONCLUSION

The proposed GN-model of the process of receiving sensor data from the area of the crisis and transmitting them to an operational center is a basis for creating more detailed models for analyzing the complex interactions between the participating components in crisis management. By simulating different situations, the interdependencies between the participating subjects, objects and processes can be studied and effective ways to successfully manage the crisis while minimizing its adverse impact can be found.

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REFERENCES

[1] K. Atanassov.Theory of Generalized nets (an algebric aspect). AMSE Review, 1, №2, 27-33, 1984.

[2] K.Atanassov, (ed.). Applications of Generalized nets. World Scientific, Singapore, New Jersey, London 1993.

[3] K, Atanassov. Generalized Nets, World Scientific, Singapore, New Jersey, London 1991

[4] K., Atanassov, Intuitionistic Fuzzy Sets: Theory and Applications. Springer-Verlag, 1999

[5] K. Aleksandrova, I. Ivanov, Architecture of passive bistatic radar system based on DVB-T signals and software-defined platform, "Proc. of International scientific conference "Hemus 2016", pp. III-193 – III-201, ISSN 1312-2916, 2016

[6] N. Angelova, M. Todorova and K. Atanassov.(2016) GN IDE Implementation, improvements and algorithms. 69.411-420

[7] B. Genov, A. Bogdanov. Method for assessment of service life extension possibility of gyroscopic measurment apparatus. Scientific Notices of the Scientific and Technical Union of Mechanical Engineering, Defectoscopy 2002, Sozopol, ISSN 1310-3946, pp. 67-72

[8] B. Genov, G. Genov, D. Chervenkov, B. Botev, Methodology for logistic lifecycle assessment in an acquisition project. SCIENTIFIC session 2010, Shumen: collection of scientific papers. - Shumen: National Military University "Vasil Levski", Faculty of Artillery, Air Defence and CIS, 2011 1313-7433 (print) 1314-1953 (CD), pp. 261-270

[9] D.G. Dimitrov. GN IDE – A software tool for Simulation with generalized nets. Proceedings of Tenth International Workshop on Generallized nets, Sofia, 2009, 70-75.

[10] A. Kolev, and P. Nikolova, Instrumental Equipment for Cyber-attack Prevention, Information & Security: An International Journal 47, no. 3 (2020): 285-299. https://doi.org/10.11610/isij.4720

[11] S. Marinov, I. Ivanov, A. Kolev, Modeling of a controllable communication environment, Proceedings of the Scientific Conference "Modern Trends in Aviation Training", NMU "V. Levski", Faculty of "Aviation" - Dolna Mitropolia, ISBN 978-954-713-110-1, 2017

[12] R. Iliev, A. Genchev, Possibilities for Using Unmanned Aerial Vehicles to Obtain Sensory Information for Environmental Analysis., Information & Security: An International Journal, 46, no. 2, (2020), 127-140.

[13] V. Tselkov, and N. Stoianov. E-net models of a software system for web pages security. Mathematics and mathematical education, Sofia, Bulgaria, BAS, 2003.

[14] E. Petkova and M. Angelov. Key aspects of performing a “Brute Force” attack on encrypted voice streams in MATLAB environment, "Proc. of International conference on advanced research and technology for defence "ARTDef 2023", pp. II-128 – II-133, ISSN 2815-2581, 2023

[15] P. Nikolova and M. Angelov. Artificial Intelligence in cybersecurity on UAS networks, "Proc. of International conference on advanced research and technology for defence "ARTDef 2023", pp. II-87 – II-96, ISSN 2815-2581, 2023