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Generalized net model of the decision making process in the crisis management

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Abstract: The paper presents a common Generalized Net model (GN-model) of the decision-making process in crisis management using a five-transitions aggregate net. By verifying the feasibility of the solution in the last transition, the fact is taken into account that all crisis management solutions generated cannot be successfully implemented. When evaluating the parameters of the individual tokens, the possibility of using fuzzy and intuitionistic fuzzy values is envisaged.

Keywords: decision making, Generalized nets, modeling, crisis management

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AMS Classification: 03E72, 68Q85

1. Introduction

Crisis management is a complex and wide-ranging process related to the organization of multiple objects and resources, often performed in an unclear environment and influenced by many random factors. This process is analogous to the classic decision-making process, but is characterized by a great uncertainty about the information received such as „randomness” and „fuzzy”, as well as a lack of sufficiently accurate heuristic information about the correctness and feasibility of the proposed solutions. By organizing the content of the different stages of the crisis management process, the following main activities can be identified:

- clarification of the task, identification of the main moments for its accomplishment, evaluation of the crisis situation;
- analysis of the information at its disposal, updating it as needed;
- generating ideas and modeling different options for action;
- playing (simulating), evaluating and discussing (briefing) the solutions;

- preparation of an action plan and other accompanying documents related to the selected decision;
- updating the action plan and proposed solutions.

In modern conditions, crisis management is associated with the widespread use of information and communication technologies and software applications. They are used not only to process data and support decision-making, but also to protect information systems and resources. An interesting possibility for modeling information systems is presented in [13, 20] and for creating models in the field of cyber security [21, 22, 24] and communication environment [19, 23].

Generalized net (GN) theory can be used to model complex processes, such as the decision-making process in crises. The toolkit of the Generalized Nets Theory is defined in 1982 by K. Atanassov's in the article [1]. In the following years, it continued to evolve, with two varieties emerging – a special theory in the terms of Karl-Adam Petri on generalized nets and a general theory of generalized nets. The special theory of generalized nets [4], [6] deals with concepts such as the definition of generalized nets, functioning, conflict situations and their resolution, representation of Petri nets and their modifications through generalized nets [7, 11]. The general theory of generalized nets [2, 3] involves the compilation of algebraic, topological, functional, programmatic and logical aspects.

So far, generalized nets have found application in fields such as: medicine, economics, transport, industry, computer technology and various methods of database creation [9, 12, 14]. A number of models have been developed to analyze the processes of handling large volumes of data and extracting knowledge from them [5, 8], as well as GNs representing the elements of neural nets [15] and [16] and expert systems [10]. There are also some generalized net models that describe the decision-making process for water quality management [17, 18] (written by the one of authors)

2. GN-MODEL DESCRIPTION FOR CRISIS MANAGEMENT DECISION MAKING

The decision-making process in crisis management is related to the analysis of the crisis situation (evaluation of the individual states through which the crisis evaluation, of external and internal influencing factors, etc.), generating alternatives to the possible actions for managing the crisis (decisions), choosing the best alternative (solution), executing the decision and checking (controlling) the result. The schematic diagram of the Crisis management decision making GN-model is shown in Fig. 1.

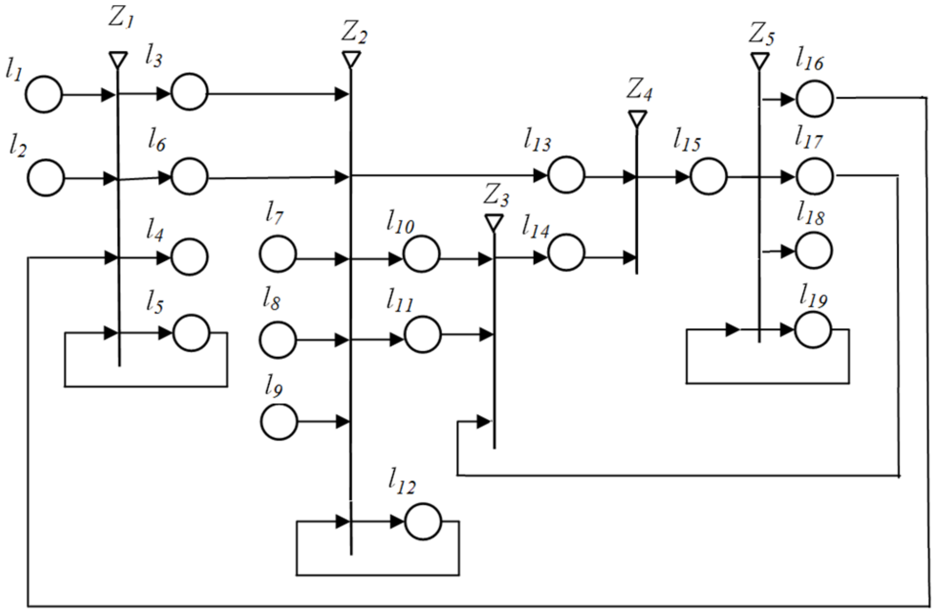

Figure 1. GN-model of the decision-making process in crisis management.

The GN model, represented by five generalized net transitions, is the following:

$$E_1 = \{Z_1, Z_2, Z_3, Z_4, Z_5\}, \text{ where}$$

Z_1 – evaluation of the parameters of the crisis situation
Z_2 – generation of alternatives to solutions
Z_3 – choice of solution
Z_4 – implementation of the decision (result)
Z_5 – check of the decision feasibility (control)
Tokens, using in generalized net E, are:
α – the object that has been managed – state of target system (setting parameters)
β – resources (materials, technical tools, staff and more)
γ – target states of the object (system, environment)
ι – information (data bases and knowledge of the objects in the scope of the crisis situation, decision-making processes for crisis management, etc.)
δ – evaluation of the situation (environmental factors influencing the managed object /system/)
φ – alternative solutions regarding the management of the target object (system)

The description of the transactions is following:

$$Z_1 = \langle\{l_1, l_2, l_5, l_{16}\}, \{l_3, l_4, l_5, l_6\}, r_1, M_1, ((l_1 \wedge l_2) \vee l_5 \vee l_{16},)\rangle, \text{ where}$$

l_1 – place into which the managed object (system) is represented by tokens α, with characteristics X_α ($e^\alpha_{p,1}$, $e^\alpha_{p,2}$, …, $e^\alpha_{p,i}$, …, $e^\alpha_{p,k}$), where $e^\alpha_{p,i}$ is the evaluation of the i-th parameter from k_i ($i \le k$) defining (significant) evaluation parameters of the current state

l_2 – place where the token γ (the target parameters of the managed object /system/) enters, with characteristics X_γ ($e^\gamma_{p,1}$, $e^\gamma_{p,2}$, …, $e^\gamma_{p,i}$, …, $e^\gamma_{p,q}$), where $e^\gamma_{p,i}$ is the state of the i-th parameter from p_i ($i \le q$) defining (essential) evaluation parameters of the target state of the object (desired system parameters, environment)

l_3 – place of the target state in which the token enters after changing (adjusting) their parameters

l_4 – place when adjustments cannot be made or they do not meet the target values

l_5 – place for activation of the evaluation of the object parameters

l_6 – place for the state of the object (its token) when its parameters differ from the target ones

l_{16} – place of the object (token α) after checking the feasibility of the solution and the need for updating

r_1 =

	l_3	l_4	l_5	l_6
l_1	$W_{1,3}$	F	$W_{1,5}$	$W_{1,6}$
l_2	F	F	$W_{2,5}$	F
l_5	F	F	T	$W_{5,6}$
l_{16}	$W_{16,3}$	$W_{16,4}$	$W_{16,5}$	$W_{16,6}$

T – true (transfer is possible), F – false (transfer is not possible)

$W_{1,3}$ = „the state of the object (system) is in accordance with the norms"

$W_{1,5}$ = „there are evaluation parameters in place l_2"

$W_{2,5}$ = „there is an evaluation object in place l_1"

$W_{1,6}$ = „the state of the object (system) is not up to standard and is subject to correction"

$W_{5,6}$ = „a transition is made in the evaluation"

$W_{16,3}$ = „the solution to the crisis has been successful"

$W_{16,4}$ = „there is no solution after examining the alternatives"

$W_{16,5}$ = „there is an evaluation of the current alternative"

$W_{16,6}$ = „there is a failure of the current alternative"

M_1 =	l_3	l_4	l_5	l_6
l_1	$m_{1,3}$	$m_{1,4}$	$m_{1,5}$	$m_{1,6}$
l_2	$m_{2,3}$	$m_{2,4}$	$m_{2,5}$	$m_{2,6}$
l_5	$m_{5,3}$	$m_{5,4}$	$m_{5,5}$	$m_{5,6}$
l_{16}	$m_{16,3}$	$m_{16,4}$	$m_{16,5}$	$m_{16,6}$

$m_{1,3}=m_{1,4}=m_{1,6}=m_{2,3}=m_{2,4}=m_{2,6}=m_{5,3}=m_{5,3}=m_{5,4}=m_{5,6}=m_{16,3}=m_{16,4}=m_{16,6}$ – the maximum number of objects (system elements such as buildings, people, equipment, resources, etc.) to be examined
$m_{1,5}=m_{2,5}=m_{5,5}=m_{16,5}$ – the maximum number of objects that can be evaluated in parallel

$$Z_2=<\{l_3, l_6, l_7, l_8, l_9, l_{12}\},\{l_{13}, l_{10}, l_{12}, l_{12}\}, r_2, M_2, (\wedge(l_6, l_7, l_8, l_9) \vee l_3 \vee l_{12}) >, \text{ where}$$

l_7 – place for receiving necessary information – token ι, with characteristics X_ι ($e^{\iota}_{f,1}$, $e^{\iota}_{f,2}$, … $e^{\iota}_{f,i}$,…, $e^{\iota}_{f,n}$), where $e^{\iota}_{f,i}$ can be an evaluation of the risk degree, of the random factor or of a priori information about a process (a set of actions affecting the development of a crisis situation) f_i ($i \leq n$)
l_8 – state of the environment /environment/ – tokens δ, with characteristics X_δ ($e^{\delta}_{w,1}$, $e^{\delta}_{w,2}$, … $e^{\delta}_{w,i}$,…, $e^{\delta}_{w,h}$), where $e^{\delta}_{w,i}$ is the evaluation of the i-th parameter from w_i ($i \leq h$) environmental factors influencing the managed object (system)
l_9 – place for receiving the necessary resources – tokens β with characteristics X_β ($e^{\beta}_{r,1}$, $e^{\beta}_{r,2}$, …,$e^{\beta}_{r,i}$, …, $e^{\beta}_{r,s}$), where $e^{\beta}_{r,i}$ is the state of the i-th parameter from r_i ($i \leq s$) resources needed (for example, to build a defense facility to counteract the escalation of the crisis)
l_{10} – place for generating alternatives – tokens φ, with characteristics X_φ($e^{\varphi}_{g,1}$, $e^{\varphi}_{g,2}$, … $e^{\varphi}_{g,i}$,…, $e^{\varphi}_{g,d}$), where $e^{\varphi}_{g,i}$ is the state of i-parameter from g_i ($i \leq d$) alternative solutions regarding the management of the target site (system)
l_{11} – place for setting selection rules
l_{12} – place to activate the process of generating alternatives

r_2 =	l_{10}	l_{11}	l_{12}	l_{13}
l_3	F	F	$W_{3,12}$	F
l_6	F	F	$W_{6,12}$	$W_{6,13}$
l_7	$W_{7,10}$	$W_{7,11}$	$W_{7,12}$	F
l_8	$W_{8,10}$	F	$W_{8,12}$	F
l_9	$W_{9,10}$	F	$W_{9,12}$	F
l_{12}	$W_{12,10}$	F	F	F

$W_{3,12}$ = „has the necessary information from previous successful results”
$W_{6,12}$,$W_{7,12}$,$W_{8,12}$,$W_{9,12}$,$W_{7,12}$ = „the necessary procedures are in place to process alternative solutions”

$W_{7,10}, W_{8,10}, W_{9,10}, W_{12,10}$ = „the necessary data is available to generate solutions”

M_2 =

	l_{10}	l_{11}	l_{12}	l_{13}
l_3	$m_{3,10}$	$m_{3,11}$	$m_{3,12}$	$m_{3,13}$
l_6	$m_{6,10}$	$m_{6,11}$	$m_{6,12}$	$m_{6,13}$
l_7	$m_{7,10}$	$m_{7,11}$	$m_{7,12}$	$m_{7,13}$
l_8	$m_{8,10}$	$m_{8,11}$	$m_{8,12}$	$m_{8,13}$
l_9	$m_{9,10}$	$m_{9,11}$	$m_{9,12}$	$m_{9,13}$
l_{12}	$m_{12,10}$	$m_{12,11}$	$m_{12,12}$	$m_{12,13}$

$m_{3,10}=m_{3,11}=m_{3,12}=m_{3,13}=m_{6,10}=m_{6,11}=m_{6,12}=m_{6,13}=m_{7,10}=m_{7,11}=m_{7,12}=m_{7,13}=m_{8,10}= m_{8,11}=m_{8,12}=m_{8,13}=m_{9,10}=m_{9,11}=m_{9,12}=m_{9,13}= m_{12,10}=m_{12,11}=m_{12,12}=m_{12,13}$ – the maximum number of tokens entering in this transition

$$Z_3=<\{l_{10}, l_{11}, l_{17}\},\{l_{14}\}, r_3, M_3,(l_{10} \wedge l_{11} \wedge l_{17})>, \text{ where}$$

l_{14} – a place in which token arrives (the chosen solution / alternative /) with characteristics X_φ

l_{17} – place of the object (token α) after verification of the feasibility of the decision and the need for additional tests and evaluation

r_3 =

	l_{14}
l_{10}	$W_{10,14}$
l_{11}	$W_{11,14}$
l_{17}	$W_{17,14}$

$W_{10,14}$ = „there is a rule for choosing an alternative solution”
$W_{11,14}$ = „at least one solution is generated”
$W_{17,14}$ = „at least one solution needs additional testing and verification”

M_3 =

	l_{14}
l_{10}	$m_{10,14}$
l_{11}	$m_{11,14}$
l_{17}	$m_{17,14}$

$m_{10,14}$ – the maximum number of alternatives is generated
$m_{11,14}$ – set the number of active rules
$m_{17,14}$ – the maximum number of solutions needs additional testing

$$Z_4=<\{l_{13}, l_{14}\},\{l_{15}\}, r_4, M_4,(l_{13} \wedge l_{14})>, \text{ where}$$

l_{13} – place for the managed object (token α) with characteristics X_α

l_{15} – managed object place (token α) with changed (corrected) characteristics X_α

r_4 =

	l_{15}
l_{13}	$W_{13,15}$
l_{14}	$W_{14,15}$

$W_{13,15}$ = „the selected solution is executable on the parameters of the managed object (system)"
$W_{14,15}$ = „the managed object is governed by the decision chosen"

M_4 =

	l_{15}
l_{13}	$m_{13,15}$
l_{14}	$m_{14,15}$

$m_{13,15}$ =1 (selected object /α-token/)
$m_{14,15}$ =1 (alternative solution chosen /φ-token/)

Z_5=<{l_{15}, l_{19}},{l_{19}, l_{17}, l_{16}, l_{18}}, r_5, M_5,($l_{15} \wedge l_{19}$)>, where

l_{18} – end place of the managed object (token *α* after correction and verification)
l_{19} – place to check the enforceability of the decision

r_5 =

	l_{16}	l_{17}	l_{18}	l_{19}
l_{15}	F	F	F	T
l_{19}	$W_{19,16}$	$W_{19,17}$	$W_{19,18}$	$W_{19,19}$

$W_{15,19}$ = T (the chosen token is subject to a feasibility check)
$W_{19,16}$ = „there are tokens that need updating (decision)"
$W_{19,17}$ = „there are tokens that need for additional tests and evaluation"
$W_{19,18}$ = „the chosen token is feasible"
$W_{19,19}$ = „verification of the feasibility of the chosen token"

M_5 =

	l_{16}	l_{17}	l_{18}	l_{19}
l_{15}	0	0	0	$m_{15,19}$
l_{19}	$m_{19,16}$	$m_{19,17}$	1	$m_{19,19}$

$m_{15,19}$ = $m_{19,16}$ = $m_{19,17}$ $m_{19,19}$ – maximum number of tokens (solutions) for a given situation

The estimations e^{α}_{p}, e^{β}_{r}, e^{γ}_{p}, e^{ι}_{f} and e^{δ}_{w} of the characteristics of the tokens and predicates ($W_{i,j}$) can be represent in the generalized net with different values: {0,1} – for the classical case; [0,1] – for ordinary fuzziness, or [0,1] × [0,1] – for intuitionist fuzziness and uncertainty of both types (fuzziness and chance).

3. CONCLUSION

Finding efficient enough and grounded decisions in the crisis management is a very complex process, because decision making process is working with a large set of data, a big part of which is with fuzzy and non-precise characters. The person often makes decisions in limited conditions – time, resources, data, risk and others. The GN-model of the Decision making process, represented in this paper, is an attempt of using GN(s) for modelling crisic management processes.

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REFERENCES

[1] Atanassov K. Theory of Generalized nets (an algebric aspect). AMSE Review, 1, №2, 27-33, 1984.
[2] Atanassov, K. Advances in Modelling & Analysis. C. – AMSE Press, Vol. 46, No. 2, 1995.
[3] Atanassov, K. AMSE Review, 1, №3, 1984.
[4] Atanassov, K. AMSE Review, 3, №1, 1986.
[5] Atanassov K., P. Chountas, B. Kolev, E. Sotirova. Generalized net model of a self-developing expert system. Tenth Int. Conf. on IFSs, Sofia, 28-29 Oct. 2006 NIFS Vol. 12 (2006), No. 3, 35-40.
[6] Atanassov K. Conditions in generalized nets. Proc. of the XIII Spring Conf. of the Union of Bulg. Math., Sunny Beach, April 1984, 219-226.
[7] Atanassov, K., D. Dimitrov, V. Atanassova. Algorithms for Tokens Transfer in Different Types of Intuitionistic Fuzzy Generalized Nets. Journal of Cybernetics and Information Technologies, Vol. 10, 2010, No.4, 22–35.
[8] Atanassov, K., E. Sotirova, D. Orozova. Generalized Net Model of Expert Systems with Frame-Type Data Base. Jangjeon Mathematical Society, Vol. 9, No. 1, 2006.
[9] Atanassov, K.(ed.). Applications of Generalized nets. World Scientific, Singapore, New Jersey, London 1993.
[10] Atanassov, K. Generalized Nets in Artificial Intelligence. Vol. 1:Generalized nets and Expert Systems, „Prof. M. Drinov" AcademicPublishing House, Sofia, 1998.
[11] Atanassov K. On generalized nets theory. Prof. Marin Drinov Academic Publishing House, Sofia, 2007.
[12] Atanassova V. Generalized net model of an online submission system. 13th Int. Workshop on Generalized Nets London, 24–33, 29 October 2012

[13] Bozhilova M, A. Nachev. Modeling of an error monitoring and management system for a distributed software application. Annual of the Defence Advanced Research Institute, National Defence Academy, 2008, pp. 149-157. (in Bulgarian)

[14] Kolev B., E. Sotirova, K. Atanassov, P. Chountas. Generalized net model of multi-source database system with different access times. Seventh Int. Workshop on GNs, Sofia, 15-19, 14-15 July, 2006

[15] Krawczak, M. Generalized Nets Representation of Multilayer Neural Networks.Thesis, 2003

[16] Krawczak, M., S. Sotirov, K. Atanassov. Multilayer Neural Networks and Generalized Nets. Warsaw School of Information Technology, Warsaw, 2010.

[17] Iliev, R. Modeling of decision making process on the river water quality analysing by using generalized nets, Proceedings of the Sixth Int. Workshop on Generalized Nets, Sofia, 17 December 2005, pp. 7-13.

[18] Iliev, R. Generalized Model of Decision Making Processes in the Management's Systems with use of Intuitionistic Fuzzy Sets. Proc. of the Ninth International Conference on Intuitionistic Fuzzy Sets – part 3, Volume 11, Number 4, Sofia, Bulgaria, May 2005, pp. 146-150.

[19] Marinov S., A. Kolev, and I. Ivanov. Modelling a Managed Communication Environment. Jubilee Scientific Conference with International Participation "Modern Aviation Training Trends", Dolna Mitropolia, 2017, pp. 146-151 (in Bulgarian).

[20] Pavlov G. and A. Kolev. A Place for GIS Technologies in Information Systems for Crisis Prevention. 6th International Conference on Application of In-formation and Communication Technology and Statistics in Economy and Education (ICAICTSEE 2016), Sofia, 2016, pp. 452 -457.

[21] Stoianov, N., and M. Bozhilova. A Model of a Cyber Defence Awareness System of Campaigns with Malicious Information. Information & Security: An International Journal 46, no. 2 (2020): 182-197. https://doi.org/10.11610/isij.4613

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

[23] Gospodinova E., M. Angelov, T. Nikolov. Differential cryptoanalysis of data distributed transmission system. Proc. of Conference "MT&S-2013", Defence Institute, Sofia, pp. II-77 - II-86, 2014. (in Bulgarian)

[24] Gospodinova E., M. Angelov, T. Nikolov. Analysis of security system for distributed data transmission at voice. Proc. of Conference "MT&S-2013", Defence Institute, Sofia, pp. II-87 - II-100, 2014. (in Bulgarian)