

# Simulation of the behavior of a system with social structure by means of generalized nets

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**Abstract:** The article presents an idea for simulating the behavior of a system with a social structure (SSS) by means of applying generalized nets (GNs). A brief introduction to SSS and the approaches to modeling them are given. Based on these, a formal model of SSS is described for the simplest case of a homogenous system with individuals as elements.

**Keywords:** Generalized nets, Social structures, Social systems.

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## 1 Introduction

A social system is defined in sociology as a set of elements (different social groups, communities) which maintain particular relationships and interrelations, and represent a given whole [12]. A number of problematic areas, such as economy, ecology, biology, medicine, political studies, etc., determine object systems with a structure similar to the one of a social system. These subject areas feature a high level of complexity stemming from: a huge number of elements and relations; heterogeneity of elements and relations; their dynamic nature; the undetermined (stochastic) behavior of the system; the unstable behavior of the system. Furthermore, in addition to the complexity of these object systems, the complexity of the tasks related to them must be considered as well. The latter is determined by: incomplete available information; outdated available information; partial contradiction of the available information; decentralized and distribution of the sources of information; the tendency the information to change during the process of solving the task; the very nature of the task; the multiple criteria for quality evaluation of the solution; the changing nature of these criteria in the process of task solving; the multidimensionality of the solution under investigation, etc., [3].

One of the most commonly applied approaches to researching the SSS behavior is modeling. The following mathematical models of social systems have been described and investigated: field [5], statistical [4, 5], stochastic [5], mental [4], descriptive [4], and system dynamics [4]. The potentials of Agent Based modeling for social systems are analyzed in [8], while [10] presents an application of Multi-agent systems to achieve the same goal. An

approach called processing, described in [11], realizes the model system via the means of interaction of sequence of processes. An application of this approach is presented in [9]. The design of computer SSS models and testing them in a lab do not completely guarantee flawless SSS; however, they support finding a significant number of flaws which to be corrected before real-life application of the SSS.

This article describes an SSS model, which can be classified as a computer one. A modeling tool in it is the generalized nets [1, 2]. GNs are complex and well organized environments for modeling. They provide an opportunity to perform equally well the two main groups of model activities:

- *Designing* (developing, checking and optimization of the abstract model in the particular subject area);
- *Application* (formulating and modeling particular tasks in the researched problematic area, finding model solutions and interpreting these solutions within the framework of the terminology of the subject area).

NGs possess own complexity compatible to the one of the modeled object system. They are internally uncontroversial and with good internal constructability, which provides tools and opportunities for effective realization of the model activities described above. The GNs can be used successfully for both parallel and sequential processes. They are suitable for modeling SSS as they allow embedding at any level (GNs can be components of other GNs). The need for this requirement stems from the fact that SSS elements can not only be general individuals but also other systems with social structure.

## 2 Generalized net model of a system with a social structure

Figure 1 presents a GN-model of a homogeneous SSS, whose elements are individuals. The SSS individuals are modeled by the tokens of the GN.

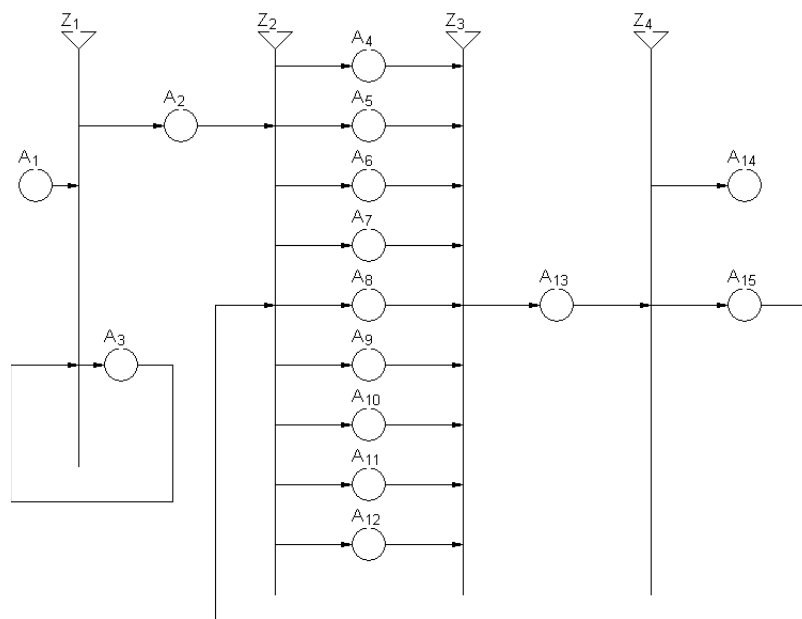


Figure 1: GN-model of a system with a social structure

We will first give the formal description of the four transitions, followed by the predicates used in the respective places of their index matrices, and will then discuss in details the behaviour of the tokens, transferring within the net.

The first transition has the form:

$$Z_1 = \langle \{A_1, A_3\}, \{A_2, A_3\}, r_1 \rangle,$$

where:

$$r_1 = \begin{array}{c|cc} & A_2 & A_3 \\ \hline A_1 & false & true \\ A_3 & \neg P_1 & P_1 \end{array}.$$

The second transition has the form:

$$Z_2 = \langle \{A_2, A_{15}\}, \{A_4, A_5, A_6, A_7, A_8, A_9, A_{10}, A_{11}, A_{12}\}, r_2 \rangle,$$

where:

$$r_2 = \begin{array}{c|cccccccccc} & A_4 & A_5 & A_6 & A_7 & A_8 & A_9 & A_{10} & A_{11} & A_{12} \\ \hline A_2 & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 & P_8 & P_9 & P_{10} \\ A_{15} & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 & P_8 & P_9 & P_{10} \end{array}.$$

The third transition has the form:

$$Z_3 = \langle \{A_4, A_5, A_6, A_7, A_8, A_9, A_{10}, A_{11}, A_{12}\}, \{A_{13}\}, r_3 \rangle.$$

This transition is unconditional, i.e. all values of the indexed matrix  $r_3$  are true.

The fourth transition has the form:

$$Z_4 = \langle \{A_{13}\}, \{A_{14}, A_{15}\}, r_4 \rangle,$$

where:

$$r_4 = \begin{array}{c|cc} & A_{14} & A_{15} \\ \hline A_{13} & P_{11} & \neg P_{11} \end{array}.$$

The respective predicates in all the transitions' index matrices of predicates are, as follows:

- $P_1$  = Creating a new individual.
- $P_2$  = Execution of a procedural action.
- $P_3$  = Execution of a perceptive action.
- $P_4$  = Execution of effector action.
- $P_5$  = Execution of a communicative action.
- $P_6$  = Execution of a modeling action.
- $P_7$  = Execution of a resolution-based action.
- $P_8$  = Execution of a population action.
- $P_9$  = Execution of a perfecting action.
- $P_{10} = \neg P_2 \wedge \neg P_3 \wedge \neg P_4 \wedge \neg P_5 \wedge \neg P_6 \wedge \neg P_7 \wedge \neg P_8 \wedge \neg P_9$ .
- $P_{11} = c(A_{13}) < MinCap$ ,

where  $MinCap$  is the minimal number of individuals needed in order for the set of individuals to establish an SSS, and  $c(A_{13})$  is the capacity of place  $A_{13}$ .

Now, we will describe the four transitions in further details.

Transition  $Z_1$  of the GN models the creation of the individuals in the SSS at the moment of the start of its functioning. To this end, the identifying characteristics and knowledge are defined, which will be attached to each individual at the beginning of SSS functioning. In the input place  $A_1$  there is a token with characteristic of the type (1).

At the first execution of  $Z_1$ , the token moves to place  $A_3$  and splits. Thus a new token is generated, which presents a new individual of the system, with characteristics containing information about the newly created individual. While condition  $P_1$  holds, the transition  $Z_1$  is executed. As a result, one or more tokens in place  $A_3$  split and create new tokens. The latter present newly created individuals and have characteristics with the respective information about these individuals. The true state of the condition  $P_1$  can be related to the duration of the  $Z_1$  transition active status. In case condition  $P_1$  does not hold, all tokens move from place  $A_3$  to place  $A_2$  and the execution of the transition  $Z_1$  is over. As a result, place  $A_2$  contains all tokens of the net which present the SSS individuals from the beginning of its functioning.

The characteristics of modeling an individual token are conveniently presented via a heterogeneous structure with a linear container and elements of the type:

$$\langle id, def\_prop, inf\_model, predecessors, inheritors, func\_action, behav\_action, other \rangle \quad (1)$$

where:

- *id* is an identifier defining the individual's name, which refers to the token. A suitable data structure for its realization is a symbol string.
- *def\_prop* presents the defining features of the individual: involuntary (perceptual, conservatism, inductivity) and voluntary (selectivity, interpretation, creativity). It can be realized by a compound dynamic data structure.
- *inf\_model* represents an information model, defining a system of individual's knowledge and the social and non-social components of their environment. The individual forms and maintains this model on their own; therefore it is characterized by subjectivity. A suitable realization tool is a GN.
- *predecessors* presents the predecessors of the individual. A tree data structure is most appropriate for its realization.
- *inheritors* presents the individual's inheritors. A tree data structure is most appropriate for its realization.
- *func\_action* defines the functional action which the individual, modeled by the token, is about to take. The data structure which is most appropriate for its realization is a symbol string.
- *behav\_action* defines the behavior action which the individual, modeled by the token, is about to take. The data structure which is most appropriate for its realization is a symbol string.
- other (depend on the particular SSS).

For some of the individuals, functional or/and behavioral actions, as well inheritors and predecessors, may not be defined. In this case the respective strings and trees must be empty.

Transition  $Z_2$  of the net models the functional actions of the individuals: procedural, perceptual, effector, communicative, modeling, resolution-based, population, perfecting. The terminology is consistent with the one suggested in [3]. These actions have to be specified and completed at the realization of each particular SSS. In brief, the procedural actions include: evaluation of the situation; goal formulation; choice, generation, actualization and execution of a behavioral schemata. The perceptual actions form perceptions about the social and non-social environment of the individual modeled by the token. The effector actions allow the individual to accomplish direct impact on elements of their respective social and non-social environment. The communicative actions support the information exchange with other individuals of the SSS. The modeling actions allow the individual to update the models of the different types of knowledge they possess. The resolution-based actions allow the individual to apply the methods and tools of the problem area to solving tasks related to the same area. The population actions allow creating and destroying individuals. The perfection actions support the improvement and development of the knowledge in the models maintained by the individual. The transition is first executed by parallel move of the GN tokens from place  $A_2$  to places  $A_4, A_5, A_6, A_7, A_8, A_9, A_{10}$  or  $A_{11}$ , according to the defined functional action for the individual, through the characteristics of the respective individual's token. If a token from  $A_2$  is characterized by a functional action which is an empty string, the token moves to place  $A_{12}$ . After the transition, some (or all) tokens change their characteristics according to the functional action performed. The characteristic function is specific for each particular application.

Generally, after a transition execution, it must make the following changes. At the execution of a procedural action, the current behavioral schemes of the respective tokens are executed and new such schemes are generated. This results in changes in the characteristic parameter *behav\_action* for each token, for which a procedural action has been performed. At the execution of a perceptual action, the *inf\_model* parameter changes: it reflects the formed perceptions regarding the social and non-social environment characteristics. The execution of an effector or communicative action changes elements of the information models of the interacting tokens. The execution of the modeling action changes the *inf\_model* of the token by updating the models of the different types of knowledge possessed. The execution of a population action changes *predecessors* and *inheritors* fields of the tokens connected to the token. A perfection action improves the knowledge in the models supported by the individual, i.e. changes *inf\_model* parameter by adding new components, by optimizing, etc.

Transition  $Z_3$  is executed unconditionally. All tokens in its input places move to place  $A_{13}$ . The characteristic function of this transition execution must initiate the execution of a behavioral action of each token at places  $A_4, A_5, A_6, A_7, A_8, A_9, A_{10}$  and  $A_{11}$ , if such are generated. It also causes the generation of new functional and behavioral actions in each token characteristics when the respective token falls in place  $A_{13}$ .

Transition  $Z_4$  realizes a condition to complete the GN functioning. This condition depends on the specifics of the particular SSS. In this case, a quantitative evaluation of the SSS individuals is performed. In case the number of individuals in place  $A_{13}$  is smaller than the required minimum number of individuals for forming an SSS, the latter dies. In this case, all tokens move to place  $A_{14}$ . Otherwise, the SSS continues functioning. Transition  $Z_4$  is followed by transition  $Z_2$ .

### 3 Conclusion

Current article presents a formal model of a homogeneous SSS of a simplest type: its elements are individuals. This model can be used in statistical research, in investigation the information activities in an SSS, etc. Generally, the SSS are heterogeneous. Their elements can be other SSS, SSS sub-systems and individuals. Defining a formal model in this case requires specification and more detailed development. GNs are suitable tools for modeling such SSS, as their tokens can have characteristics which are or contain other GNs. The idea currently described is at an initial stage of development. Next we envision developing particular SSS based on the designed general model, as well as applying the models to solving useful practical tasks. In addition, analyses of the model applicability and also researching the opportunities for more systematic generation of system requirements are to be conducted [6]. Our further plans include comparing the effectiveness of the suggested model in solving practical tasks with the effectiveness of some variations of the descriptive model (more specifically the one of SSS, described as respective core and/or domain ontologies [7]).

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### References

- [1] Atanassov, K., *Generalized Nets*, World Scientific, Singapore, 1991.
- [2] Atanassov, K., *On Generalized Nets Theory*, ‘Prof. Marin Drinov’ Academic Publishing House, Sofia, 2007.
- [3] Dobrev, D. Systems with Social Structure and Behavior – a Possible Paradigm in Computer Modeling, *Report of Contract 173/09 of Sofia University Research Fund*, Sofia, 2009.
- [4] Forrester, J. *Confidence in models of social behavior – with emphasis on system dynamics models*, MIT Press, 1973.
- [5] Guts, A., V. Korobitsin, A. Lapter, L. Pautova, J. Frolova. *Mathematical Models of Social Systems* (textbook), Omsk State University, 2000.
- [6] Kaloyanova, K. Design from data: how to use requirements for better information system analysis and design, *Proc. of the Int. Conference Informatics in Scientific Knowledge*, Varna, 26–29 June 2012, 189–197.
- [7] Nisheva-Pavlova, M. Providing and Maintaining Interoperability in Digital Library Systems. *Proc. of the Fourth International Conference on Information Systems and Grid Technologies*, Sofia, 28–29 May 2010, ‘St. Kliment Ohridski’ University Press, 2010, 200–208.

- [8] Pavon, J., C. Sansores, J. Gómez-Sanz. *Agent Based Modeling of Social Systems*, <http://biblioteca.coqcyt.gob.mx/bvic/Captura/upload/.../AGENT-BASED-MODELING-OF-ANACON.pdf>, 2006.
- [9] Theodosiev, T. An Application on Processing Approach in Modeling. In: *The Information Society, Proceedings of the 23rd ICT&P'1998*, Special Issues (2–5) of Volume 5 of *International Journal on Information Theories and Applications of "ICT&P'1998"*, Sofia, 1998, 169–174 (in Bulgarian).
- [10] Theodosiev, T., Multi-Agent System with Sociality, *Proc. of the 9th ECCAI Advanced Course on Artificial Intelligence (ACAI 2001) and the affiliated workshop "Adaptability and Embodiment Using Multi-Agent Systems" (AEMAS 2001)*, Prague, Czech Republic, 2001, 247–256.
- [11] Theodosiev, T. The Processing Approach in Realization of Model Environment with Social Structure. *Proc. of the 25th ICT&P'2000*, Sofia, 2000, 85–90 (In Bulgarian).
- [12] <http://sociology2015.ru/index/0-7> (Last visited: July 2012).