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Generalized Net Model of an Intelligent Agent Broker

Veselka Petrova-Dimitrova[1,a)], Dilyana Budakova[1,b)] and Lyudmil G. Dakovski[2,c)]

[1]*Department of Computer Systems and Technologies, Technical University of Sofia, Branch Plovdiv, Plovdiv, Bulgaria*
[2]*Department of Communication & Computer Technologies, European Polytechnic University, Pernik, Bulgaria*

[a)]vesi_s_petrova@yahoo.com
[b)]dilyana_budakova@yahoo.com
[c)]lyudmil.dakovski@epu.bg

Abstract. This article examines the possibility of using the mathematical apparatus of generalized networks to model and study the behavior of an intelligent agent - broker in a virtual environment. In the proposed model the agent-broker is presented with a generalized net model. The transitions cover the broker's knowledge of the sequence of stages of buying a property. Conditions describe its knowledge of the opportunities and risks that exist at every step of this process. The tokens represent the consumers who are looking for the most suitable way for them to buy a property. They are implemented with a knowledge base for their: financial status; for the risks they consider acceptable or unacceptable; for the compromises they may or may not make; for their preferences and goals. The transition of the tokens through the generalized net model allows to observe the process of interaction between the model of the expert broker and the models of the client agents.

INTRODUCTION

Generalized net models (GM) [1-5] are an established and widely used mathematical apparatus for modeling processes in many scientific and applied fields, which use discrete dynamical systems, modeling of parallel processes, real-time processes. Generalized net models have already been developed to address administrative services at the Digital University [6], to manage drone communication [7] for smart homes [8] to ensure their security, to monitor forest areas [9], to analyze the financing of small and medium enterprises [10], modeling of human physiology [11] and others.

In this article, a generalized net model is proposed and studied, which presents in detail the modeled processes for buying a property, the behavior of a smart agent-broker and the behavior of smart agents-consumers that want to get help buying a property.

The broker agent is presented with a generalized net model. The transitions cover the broker's knowledge of the sequence of stages of buying a property. The states describe its knowledge of the opportunities and risks that exist at every step of this process. Tokens are a model for consumers who are looking for the best way for them to buy a property. They are implemented with a generalized net model of thought process published in [12] and knowledge base for their: financial status; for the risks they consider acceptable or unacceptable; for the compromises they may or may not make; for their preferences and goals. The use of the generalized net model of a thought process allows the token users: to apply a quick, thorough or in-depth analysis of the broker's agent proposal; receiving an emotional assessment and possibly a change in emotional state; and ultimately leads to a decision, a choice of action or a continuation of the analysis [12].

The model presented in this way allows the behavior of the broker agent and the agent agents to be observed in parallel in each position; the interrelationship between the individual capabilities and requirements of each user

model and the decisions to take a step to move to the next state in the model; one can see the change in the state of the agents, the assessment and analysis of events at any time.

DESCRIPTION OF THE PROPOSED MODEL

The virtual intelligent agent-broker is modeled with a generalized net model, with transitions and states, which are implemented with rules that cover everything necessary for the successful passing of each user, with his individual capabilities and understandings through the process of buying property. The modeled intelligent user agents are the tokens that move in this virtual world. Each token is presented with rules that describe their individual capabilities, requirements and understandings.

Each token will be presented by the triple $< X, \Phi, b >$, where:

- X is a set of initial characteristics of the token,
- Φ is a function (let us call it transforming one), which defines a new characteristic h_i* for each token *i* with characteristic h_i upon passing the token from the input into the output place of each transition *j* simultaneously with getting of the token *k* through this transition, with characteristic h_k:

$$h_i^* = \Phi(r_j, h_i, h_k)$$

- b is the maximum number of characteristics which one token can obtain during its transition in the net.

As a result of these considerations and according to [1], we receive the following generalized net:

$$E = <<A, \pi_A, \pi_L, c, f, \theta_1, \theta_2>, <K, \pi_K, \theta_K>, <T, t^0, t^*>, <X, \Phi, b>>$$

where the rest of the designations mean:

π_A: A→N, where N={0, 1, 2, …} ∪ {∞} priority of the transitions.

π_L: L→N, where L=pr_1A ∪ pr_2A and pr_iX denote the i-projection of the n-dimension set X, n∈N, n≥i , i≤k≤n (L is a set from all places of GN).

c - function, giving the capacity of the positions c: L → N

f - function which defines the trueness value of the predicates.

θ_1 is a function assigning the subsequent moment in time, in which a given transition can be activated. The value of this function is recalculated in moments, when the active condition of the transition is over: $\theta_1(t)=t'$, where t, t'∈[T, T + t*] t ≤ t'.

θ_2 is a function giving the duration of the active condition of the transition: $\theta_2(t) =t'$, where t∈[T, T+ t*] and t' ≥ 0. The value of the function is calculated when the transition starts functioning.

K is the set of the tokens of GN. It can be represented in the form:

$$K = \bigcup_{l \in Q^I} K_l$$

where:

K_1 is the set of the tokens of GN, which are waiting in front of place 1 and Q^I is a set of all input places for GN.

π_K is a function assigning the priorities of the tokens, i.e. π_K:K→N;

θ_K is a function assigning moments in time, in which a given token can enter the net, i.e. $\theta_K(\alpha) = t$, where α∈K, t∈[T, T + t*]

T - moment in time, in which GN begins to function.

T^0 - elementary time step.

t* - duration of the functioning of GN.

We will present the generalized net model (Fig.1) by net transitions set – A:A={r1, r2, r3, r4, r5}.

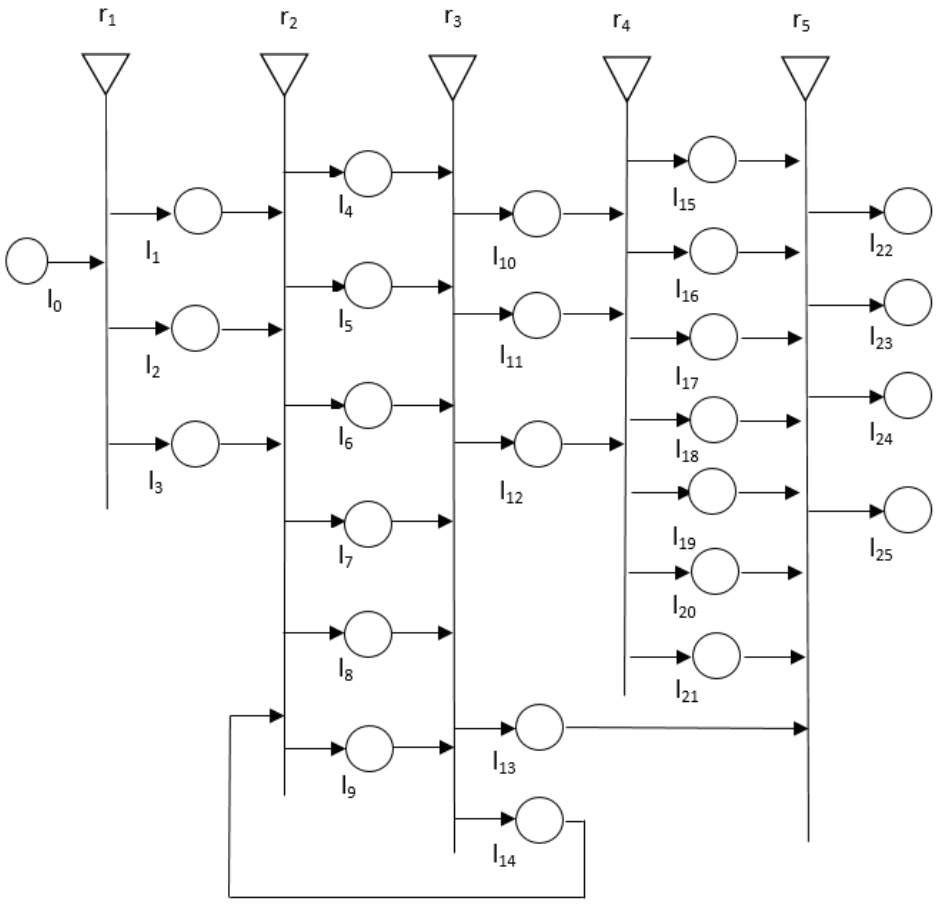

FIGURE 1. Generalized net model of the behavior of a smart agent - a smart broker

Transitions to the proposed Generalized Net Model. Indexed Transition Matrices.

The transitions in the generalized net model represent the steps that a user can go through when buying a property: (r_1) - determining what available properties and funds the user has; (r_2) - fundraising opportunities and trade-offs that are required; (r_3) - available percentage of funds from the value of the property to be purchased; (r_4) - opportunities for credit and sale of property to pay for the purchase of property; the risks to be taken; (r_5) - choice of residential property and trade-offs to be made.

The indexed transition matrices are given in Fig. 2.

$r_1 =$	l_1	l_2	l_3
l_0	w_{01}	w_{02}	w_{03}

(a)

$r_2 =$	l_4	l_5	l_6	l_7	l_8	l_9
l_1	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}
l_2	w_{24}	w_{25}	w_{26}	w_{27}	w_{28}	w_{29}
l_3	w_{34}	w_{35}	w_{36}	w_{37}	w_{38}	w_{39}
l_{14}	$w_{14\,4}$	$w_{14\,5}$	$w_{14\,6}$	$w_{14\,7}$	$w_{14\,8}$	$w_{14\,9}$

(b)

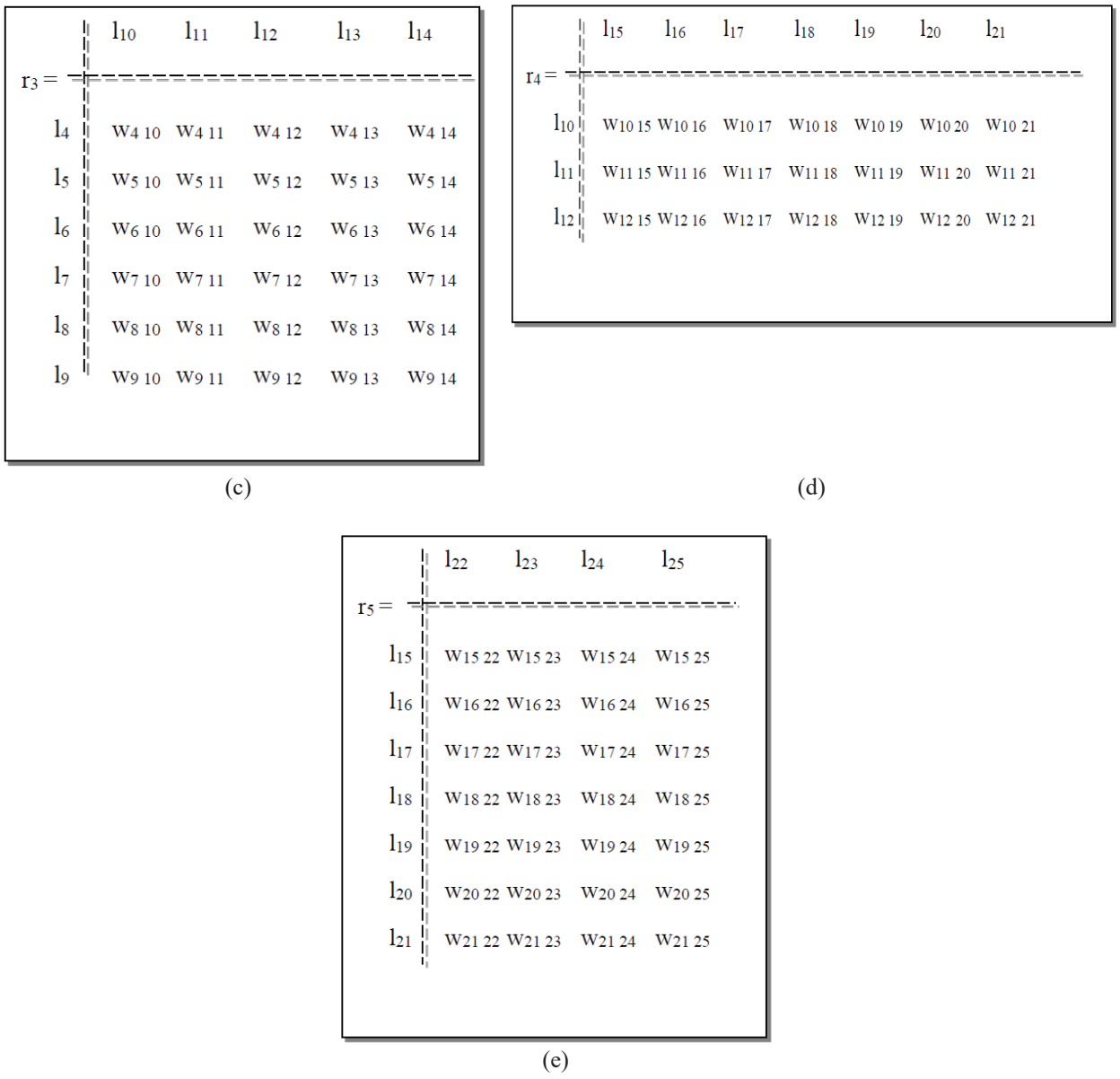

FIGURE 2. The indexed transition matrixes

Introduced Notations and Positions in the Generalized Model. Predicates for the Realization of the Transitions.

The following Boolean variables are introduced, which are used to compare the requirements for transition to the next state on the one hand and the capabilities and understandings of user tokens for their implementation on the other hand: $Bool_{\_have\_work}$; $Bool_{\_have\_prop}$; $Bool_{\_have\_accom}$; $Bool_{\_travel}$; $Bool_{\_repare}$; $Bool_{\_saves\_money}$; $Bool_{\_continue\_save\_money}$; $Bool_{\_mortgage}$; $Bool_{\_sell\_prop}$; $Bool_{\_have\_20per\_price}$; $Bool_{\_have\_40per\_price}$; $Bool_{\_sell\_prop\_for\_the\_rest\_pay}$; $Bool_{\_mortage\_60\_per}$; $Bool_{\_mortage\_80\_per}$; $Bool_{\_mortage\_30\_per}$; $Bool_{\_mortage\_50\_per}$; $Bool_{\_buy\_small\_old\_prop}$; $Bool_{\_buy\_small\_new\_prop}$; $Bool_{\_buy\_big\_old\_prop}$; $Bool_{\_buy\_big\_new\_prop}$.

Boolean variables are also used to determine the emotional state of user token in order to: examine it before and after taking certain actions; to determine their understandings; to determine whether or not to take action. These

variables are: $Bool_{\_emotion\_worry}$, $Bool_{\_emotion\_boring}$, $Bool_{\_emotion\_joy}$, $Bool_{\_emotion\_panic}$, $Bool_{\_emotion\_fear}$, $Bool_{\_emotion\_security}$, $Bool_{\_emotion\_enthusiasm}$.

Some of the methods used are: to determine the property status of the tokens-users M_{r1_prop}; for analysis of the situation and possibilities for action $M_{r\_analysis}$; to establish a new emotional state $M_{r\_emotion}$; to move to a new state $M_{r\_statie\_establish}$.

The predicates from transition r1 establish the initial property state and emotions of the user-token in the generalized net model:

$W_{01} = M_{r1\_prop}(Bool_{\_have\_work} \vee Bool_{\_have\_prop}) \vee M_{r\_analysis} \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{02} = M_{r1\_prop}(Bool_{\_have\_work} \vee \neg Bool_{\_have\_prop}) \vee M_{r\_analysis} \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{03} = M_{r1\_prop}(Bool_{\_have\_work} \vee Bool_{\_have\_more\_than\_one\_prop}) \vee M_{r\_analysis} \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

The consumer may not have property, may have one or more properties.

The predicates from transition r2 analyze the possibilities for the user to choose the way in which he could raise part of the necessary funds if he does not have enough. He could sell a property he has if he sees it as an acceptable compromise. If he finds this unacceptable, he can live in a flat or travel and raise money to buy the property he wants. Here, the methods of analysis include emotional analysis, which allows the broker agent to direct the token to take acceptable actions and move to acceptable states. Some of the predicates of transition r2 are the following:

$W_{14} = M_{r\_analysis}(Bool_{\_have\_accom} \vee Bool_{\_saves\_money} \vee \neg Bool_{\_sell\_prop} \vee \neg Bool_{\_emotion\_panic} \vee Bool_{\_emotion\_security}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{15} = M_{r\_analysis}(Bool_{\_travel} \vee Bool_{\_saves\_money} \vee \neg Bool_{\_sell\_prop} \vee \neg Bool_{\_emotion\_panic} \vee Bool_{\_emotion\_security}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{16} = M_{r\_analysis}(Bool_{\_repare} \vee Bool_{\_saves\_money} \vee \neg Bool_{\_sell\_prop} \vee \neg Bool_{\_emotion\_panic} \vee Bool_{\_emotion\_security}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{17} = M_{r\_analysis}(Bool_{\_mortgage} \vee \neg Bool_{\_emotion\_panic} \vee Bool_{\_emotion\_security})$

$W_{18} = Bool_{\_sell\_prop}$

$W_{19} = false$

For example, the following predicates belong to transition r3:

$W_{4\,10} = M_{r\_analysis}(Bool_{\_have\_20per\_price} \vee Bool_{\_emotion\_security} \vee \neg Bool_{\_emotion\_panic}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{4\,11} = M_{r\_analysis}(Bool_{\_have\_40per\_price} \vee Bool_{\_emotion\_security} \vee \neg Bool_{\_emotion\_panic}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{4\,12} = M_{r\_analysis}(Bool_{\_have\_60per\_price} \vee Bool_{\_emotion\_security} \vee \neg Bool_{\_emotion\_panic}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{4\,13} = M_{r\_analysis}(Bool_{\_have\_40per\_price} \vee Bool_{\_emotion\_security} \vee Bool_{\_sell\_prop} \vee \neg Bool_{\_emotion\_panic}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

According to them, the consumer has already saved 20%, 40% or 60% of the money required to buy the property. While according to $W_{4\,14} = Bool_{\_continue\_save\_money}$ there are not enough collected funds and their collection should continue.

The r_4 transition predicates cover the cases when the consumer has already collected an amount and is considering taking out a mortgage loan to pay off the remaining amount.

$W_{10\,15} = M_{r\_analysis}(Bool_{\_have\_20per\_price} \vee Bool_{\_mortage\_80\_per} \vee Bool_{\_emotion\_security} \vee \neg Bool_{\_emotion\_panic}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{10\,16} = W_{10\,17} = W_{10\,18} = W_{10\,19} = W_{10\,20} = false$

$W_{11\,16} = M_{r\_analysis}(Bool_{\_have\_40per\_price} \vee Bool_{\_mortage\_60\_per} \vee Bool_{\_emotion\_security} \vee \neg Bool_{\_emotion\_panic}) \vee M_{r\_statie\_establish} \vee M_{r\_emotion}$

$W_{11\,16} = W_{11\,17} = W_{11\,18} = W_{11\,19} = W_{11\,20} = W_{11\,21} = false$

The r_5 transition predicates define the purchase of the selected property. Some of them are the following:

$W_{15\,22} = M_{r\_analysis}(Bool_{\_buy\_small\_old\_prop} \vee Bool_{\_emotion\_joy})$

$W_{15,23} = M_{r\_analysis}(Bool_{\_buy\_small\_new\_prop} \vee Bool_{\_emotion\_joy})$

$W_{15,24} = W_{15,25} = false;$

CONCLUSION

This article examines the possibility of using the mathematical apparatus of generalized networks to model and study the behavior of an intelligent agent - broker in a virtual environment. In the proposed model the agent-broker is presented with a generalized net model. The transitions cover the broker's knowledge of the sequence of stages of buying a property. Conditions describe its knowledge of the opportunities and risks that exist at every step of this process. The tokens represent the consumers who are looking for the most suitable way for them to buy a property. They are implemented with a knowledge base for their: financial status; for the risks they consider acceptable or unacceptable; for the compromises they may or may not make; for their preferences and goals. The advantage of the proposed model is that it visualizes and standardizes the decision-making process for buying a property. Mathematical representation helps to unify this process; to facilitate its use in other mathematical models; to supplement and develop the model; to support the use of other methods for extracting and presenting knowledge in order to consider the modeled process from different points of view. The tokens route through the generalized net model shows visually (visualizes) and allows to observe the process of interaction between the model of the expert broker and the models of client agents.

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