

COMPUTER MODEL OF EMOTIONAL AGENTS

Dilyana Budakova¹, Lyudmil Dakovski²,

¹ Technical University-Plovdiv,
Sankt Peterburg Blvd. N:61,Plovdiv, Bulgaria
dilyana_budakova@yahoo.com

²Center of Biomedical Engineering Bulgarian Academy of Sciences,
Acad. G. Bonchev Str.,bl.105, 1113 Sofia, Bulgaria
seven_in@cablebg.net

Abstract. This article presents a computer model of intelligent agents inhabiting a virtual world. The agents combine the following basic components: necessities, knowledge of the world, knowledge of themselves, emotions, rules, meta-rules, actions, and characteristics. Some of characteristics are: energy, work, adaptation and inertia. The relations between the components are shown and the possibilities for their quantitative representation are suggested. In the software model we developed the agent parameters are stored in relational tables, which makes their effective modification possible. The agents based on this architecture can be visualized graphically. The agent's state and the reasons for this state are always known. Every state of the agent corresponds to an appropriate face, body, and gesture expression and behavior. The experiment and the obtained results are described.

Keywords: intelligent virtual agents, generalized nets, architecture, modeling

1 Introduction

In order the principles of intelligent behaviour to be shown and examined, there have been a number of models, introduced recently, that include virtual world and emotional software agents, inhabiting it [6, 8 17, 19]. The described models of worlds and agents combine emotion and learning [7]. Some of the more interesting decisions are connected to the possibility for the systems to acquire individual experience and to reveal their effectiveness [13]. In a number of models there has been shown how emotions are used as primary reasons and means of learning [11]. In others, the emotions are defined as an evaluating system, that works automatically on perceptive and cognitive level through measuring off importance and usefulness [14]. In the architectures of intelligent agents with clearly expressed emotional element, the components are grouped as follows: behavioral system, motive system, inner stimuli, generator of emotions [18]; meta-management subsystem, consultative subsystem, subsystem action [19]; synthesis of phrases in natural language, understanding phrases in natural language, sensations and conceptions, inductive conclusions, memory, emotions, social behavior and knowledge, physical state and face expression, generator of actions [17].

The cognitive cycle of IDA architecture [8,9,10] comprises nine steps: perception, summarized perception, local associations, competition for awareness, spreading the awareness, recovery of the resources, hierarchical aims defining, choosing an action, implementing an action. Emotions play a central part in the perception, memory, consciousness and choice of an action in the IDA architecture.

The development of intelligent agents and a number of computer models, that emulate features of intelligent behaviour, aims to creating practically useful systems with intelligent behaviour, and this could not happen without the active inclusion of emotions, as thought and feelings are partners in normal human life. A great amount of contemporary neurophysiological research confirms the main role of emotions in rational behaviour [5]. According to Turing, if a device that could “think” as the human brain does is to be designed, then it has to “feel” as well. Since 1979 this idea is the basis of the emotional computers and emotional intelligent agents. The software agents that know the interests, habits and priorities of the user will be able to actively assist him with work and information and, personalizing themselves, to take part in the activities in his leisure time [16].

Rational behavior is defined as intelligent, motivated and expressing behavior of agents. Its features are the perceive and interpretation of the information coming from the environment, including emotional information, decision making on the basis of analysis and emotional evaluation, action and emotional expression, change in the inner state as a result of cognitive and emotional preconditions, motivation of the agent, taking in mind the holistic theory [15] for motivated and expressing behaviour and [2] the degrees of autonomy, to which the agent controls its own behaviour. The purpose is to examine and show the primary principles of intelligent behaviour and this is why some basic according to us reasons are considered in the model. It is accented on the possibility for quantitative representation of the agent’s components and the relations between them. Another feature of the model is that none of the possible relations are ignored and it is open for new ideas. The experiment and the obtained results are described.

2 Architecture of Agent

The agent’s architecture includes the following components (fig.1): needs, emotions, actions, self-knowledge, knowledge of places and events, rules, meta-rules, characteristics. In the figure it is also shown the possibility components to influence each other. The basic agent’s needs are [15]: physiological (f), safety (s), love and belonging (l), evaluation and self-evaluation (o), self-actualization (sb), aesthetics (e).

The emotions include the following groups [12]: anger, sorrow, fear, joy, love, surprise, disgust and shame.

The agent’s characteristics are: energy, work, adaptation, and inertia.

Each statement, that has one or more antecedents and conclusion is called rule. Considering its own “principles”, when the agent acquires some new information, it is able to change its rules for behaviour. As pointed in [3,4], the meta-rules are conceived as the abstract “principles” or “consciousness” of the agent. They are applied to concrete rules for behaviour in each situation, that requires behaviour choice or reconsideration to be made. They are fewer than the behaviour rules, but

they require more time and knowledge. Rules and meta-rules for agent's behavior are stated dynamically in relational tables, which are interpreted as data by the program. Thus, changing only the table content easily does any modifications.

It will be assumed that there is a maximum value of satisfying some concrete need n_i (for example $x_i + C_i$), where x_i is the minimum value of i -th need, C_i is the appropriate constant chosen, and i is an element from the set $\{f, s, l, o, Sb, e\}$.

Let's assume that: $x_f + C_f < x_s$; $x_s + C_s < x_l$; $x_l + C_l < x_o$; $x_o + C_o < x_{Sb}$; $x_{Sb} + C_{Sb} < x_e$; $x_e + C_e = n_e$;

Each need is characterised by a weight K_i , where i is an element of the $\{f, s, l, o, Sb, e\}$ set.

The weights of the needs K_i increase and decrease with a value $\pm \Delta K_i$ from the minimum to the maximum value for each individual that is also characterised by an individual coefficient of increasing j :

$$K_i = K_i \pm j \cdot \Delta K_i. \quad (1)$$

In the normal "life" development of an agent, that has reached the highest degree of evolution, the weights of its needs are in the following sequence [15]:

$$K_e > K_{Sb} > K_o > K_l > K_s > K_f.$$

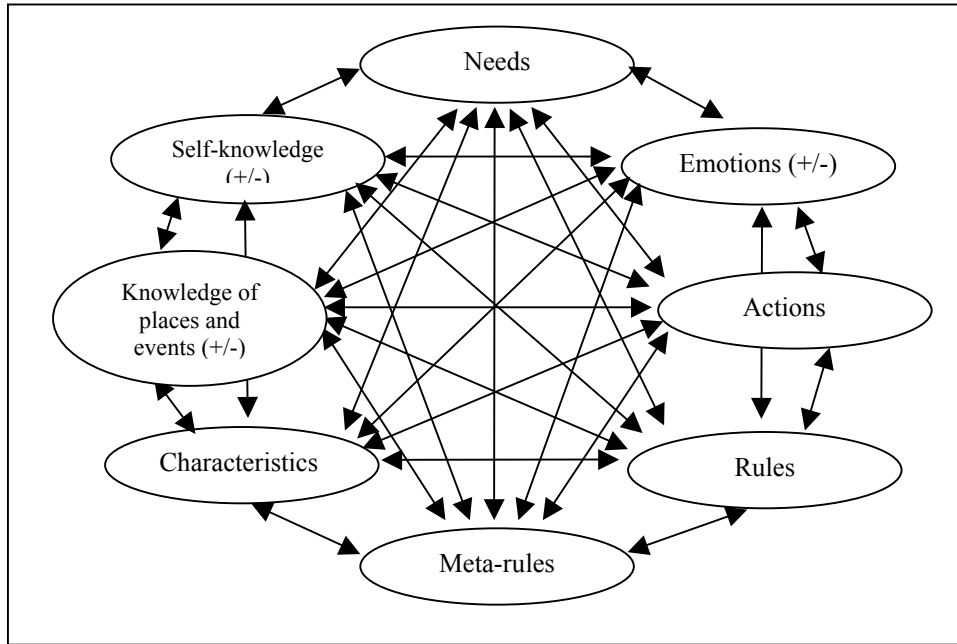


Fig. 1. Architecture of Agent

Let C_{pi} be the critical point of satisfaction of one need

$$C_{pi} = x_i + \left(\frac{C_i}{2} - 3 \div \frac{C_i}{2} + 3 \right). \quad (2)$$

Let P_i be a value of the basic needs of an agent. Then P_i is an element of the $\{ P_f, P_s, P_l, P_o, P_{Sb}, P_e \}$ set.

The need P_i is satisfied if: $C_{pi} < P_i < n_i$ and not satisfied if: $x_i < P_i < C_{pi}$.

Let Cr.coef. be the critical coefficient in satisfying a need.

$$\text{Cr.coef.} = K_{\text{on_the_highest_basic_agent_need}} + n_{\text{on_the_highest_basic_agent_need}} \quad (3)$$

In the normal life development, an agent evaluates most highly the highest basic need, which it has reached in its development. Therefore, to define the value of Cr.coef, the highest basic need which a given agent has reached in its development will be considered. If an agent has reached the highest development level, then the critical coefficient Cr.coef. is equal to the sum of the aesthetical need weight and its maximum value for the given agent. The aesthetical need weight is maximum and therefore it is considered in the value calculation of the critical coefficient. In this way, it is guaranteed that the unsatisfied need will acquire maximum weight.

When there is a crisis in the agent's life and the satisfaction of a need falls under the critical point, the weight of this unsatisfied need is defined as follows:

$$K_{\text{unsatisfied_need}} = K_{\text{unsatisfied_need}} \cdot \text{Cr.coef} \pm j \cdot \Delta K_{\text{unsatisfied_need}} \quad (4)$$

If the value of more than one need, falls under the critical point, then a specific order of the priorities of the agent may be achieved. In this way the behaviour and the principles of the agent may change in critical situations.

The emotions are represented by following indications:

- $q_i \in [1 \div b_i]$ – emotion in a group;
- b_i – maximum number of emotions in a given group;
- E_{pi,q_i} – emotions in a positive group;
- E_{oi,q_i} – emotions in a negative group;
- GrEoi – for the groups of negative emotions,
- Where $o_i \in [1 \div o_m]$ – number of negative groups of emotions,
- o_m – maximum number of negative groups of emotions;
- GrEpi – for groups of positive emotions,
- where $p_i \in [1 \div p_m]$ – number of positive groups of emotions,
- p_m is the maximum number of positive groups of emotions.

$$\begin{aligned} \text{GrEp1} &= \{E_{p1,1}, E_{p1,2}, \dots, E_{p1,q_i}, \dots, E_{p1,b1}\} \\ \text{GrEp2} &= \{E_{p2,1}, E_{p2,2}, \dots, E_{p2,q_i}, \dots, E_{p2,b2}\} \dots \\ \text{GrEpi} &= \{E_{pi,1}, E_{pi,2}, \dots, E_{pi,q_i}, \dots, E_{pi,b_i}\} \dots \\ \text{GrEpm} &= \{E_{pm,1}, E_{pm,2}, \dots, E_{pm,q_i}, \dots, E_{pm,bpm}\} \\ \text{GrEo1} &= \{E_{o1,1}, E_{o1,2}, \dots, E_{o1,q_i}, \dots, E_{o1,b1}\} \\ \text{GrEo2} &= \{E_{o2,1}, E_{o2,2}, \dots, E_{o2,q_i}, \dots, E_{o2,b2}\} \dots \\ \text{GrEoi} &= \{E_{oi,1}, E_{oi,2}, \dots, E_{oi,q_i}, \dots, E_{oi,b_i}\} \dots \\ \text{GrEom} &= \{E_{om,1}, E_{om,2}, \dots, E_{om,q_i}, \dots, E_{om,bom}\} \end{aligned} \quad (5)$$

The values of the dominant positive emotion and of the dominant negative emotion are respectively denoted by SE_{dpi,q_i} and SE_{doi,q_i} . They are defined by taking the emotion with the greatest value from the set of all groups of positive and respectively negative emotions. $SE_{dpi,q_i} = E_{pi,q_{i\max}}$, $SE_{doi,q_i} = E_{oi,q_{i\max}}$;

Let: M – be place in the world; D – be action; C – be state; S – be event; R – be rule;

AM, AD, AC, AS – are features or features of one place, action, state or an event.

AntR – are antecedents of a rule, Con – conclusions of a rule.

AM_{km} – are the features of the km-th place; km ∈ [1 ÷ brm], brm – the maximum number of places; kma ∈ [1 ÷ BrAM_{km}], BrAM_{km} – maximum number of features of the km place;

AD_{kd} – are features of the kd-th action; kd ∈ [1 ÷ brd], brd – maximum number of actions; kda ∈ [1 ÷ BrAD_{kd}], BrAD_{kd} – maximum number of features of the kd action;

AC_{kc} – are features of the kc-th state; kc ∈ [1 ÷ brc], brc – maximum number of states; kca ∈ [1 ÷ BrAC_{kc}], BrAC_{kc} – maximum number of features of the kc-th state;

AS_{ks} – are features of the ks-th event; ks ∈ [1 ÷ brs], brs – maximum number of events; ksa ∈ [1 ÷ BrAS_{ks}], BrAS_{ks} – maximum number of features of the ks-th event;

AntR_{kr} – are antecedents of the kr-th rule; kr ∈ [1 ÷ brr], brr – maximum number of rules; kra ∈ [1 ÷ BrAntR_{kr}], BrAntR_{kr} – maximum number of antecedents of the kr-th rule;

OM_{km} – denote the value of the km-th place.

OD_{kd} – denote the value of the kd-th action.

OC_{kc} – denote the value of the kc-th state;

OS_{ks} – denote the value of the ks-th event;

OR_{kr} – denote the value of the kr-th rule.

Every place, action, state, event or rule is described as a function of its features. Its value is calculated as a sum of the values of the features divided by their count.

$$M1 = f(AM1,1, AM1,2, \dots, AM1,kma, \dots, AM1,BrAM1), \dots$$

$$M_{km} = f(AM_{km},1, AM_{km},2, \dots, AM_{km},kma, \dots, AM_{km},BrAM_{km}) \dots \quad (6)$$

$$M_{brm} = f(AM_{brm},1, AM_{brm},2, \dots, AM_{brm},kma, \dots, AM_{brm},BrAM_{brm})$$

$$D1 = f(AD1,1, AD1,2, \dots, AD1,kda, \dots, AD1,BrAD1), \dots$$

$$D_{kd} = f(AD_{kd},1, AD_{kd},2, \dots, AD_{kd},kda, \dots, AD_{kd},BrAD_{kd}) \dots \quad (7)$$

$$D_{brd} = f(AD_{brd},1, AD_{brd},2, \dots, AD_{brd},kda, \dots, AD_{brd},BrAD_{brd})$$

$$C1 = f(AC1,1, AC1,2, \dots, AC1,kca, \dots, AC1,BrAC1), \dots$$

$$C_{kc} = f(AC_{kc},1, AC_{kc},2, \dots, AC_{kc},kca, \dots, AC_{kc},BrAC_{kc}) \dots \quad (8)$$

$$C_{brc} = f(AC_{brc},1, AC_{brc},2, \dots, AC_{brc},kca, \dots, AC_{brc},BrAC_{brc})$$

$$S1 = f(AS1,1, AS1,2, \dots, AS1,ksa, \dots, AS1,BrAS1) \dots$$

$$S_{ks} = f(AS_{ks},1, AS_{ks},2, \dots, AS_{ks},ksa, \dots, AS_{ks},BrAS_{ks}) \dots \quad (9)$$

$$S_{brs} = f(AS_{brs},1, AS_{brs},2, \dots, AS_{brs},ksa, \dots, AS_{brs},BrAS_{brs})$$

$$R1 = f(AntR1,1, AntR1,2, \dots, AntR1,kra, \dots, AntR1,BrAR1, Con1) \dots$$

$$R_{kr} = f(AntR_{kr},1, AntR_{kr},2, \dots, AntR_{kr},kra, \dots, AntR_{kr},BrAR_{kr}, Conkr) \dots \quad (10)$$

$$R_{brr} = f(AntR_{brr},1, AntR_{brr},2, \dots, AntR_{brr},kra, \dots, AntR_{brr},BrAR_{brr}, Conbr)$$

$$O_{M_{km}} = \frac{\sum_{kma=1}^{BrAM_{km}} OAM_{km,kma}}{BrAM_{km}} ; \quad O_{D_{kd}} = \frac{\sum_{kda=1}^{BrAD_{kd}} OAD_{kd,kda}}{BrAD_{kd}} ; \quad O_{C_{kc}} = \frac{\sum_{kca=1}^{BrAC_{kc}} OAC_{kc,kca}}{BrAC_{kc}} ; \quad (11)$$

$$O_{S_{ks}} = \frac{\sum_{ksa=1}^{BrAS_{ks}} OAS_{ks,ksa}}{BrAS_{ks}} ; \quad O_{R_{kr}} = \frac{\sum_{ksa=1}^{BrAntR_{kr}} OAntR_{kr,kra}}{BrAntR_{kr}} .$$

Every feature of M, D, C or EV or a rule antecedent is a function of its: emotions, emotions values, values and weights of the needs, and inertia.

$\forall Ai = f(Epi, qi, Eoi, qi, SEpi, qi, SEoi, qi, Pi, Ki, mi)$; they receive (+/-)sign of emotions. This means that every M, D, C, EV or R has many features related to different needs and emotions. The features related to the dominant emotion values and needs are the most significant.

Let: OAM_{km,kma} denote the value of the kma-th feature of the km-th place.

OAD_{kd,kda} denote the value of the kda-th feature of the kd-th action.

OAC_{kc,kca} denote the value of the kca-th feature of the kc-th state;

OAS_{ks,ksa} denote the value of the ksa-th feature of the ks-th event;

OAntR_{kr,kra} denote the value of the kra-th antecedent of the kr-th rule.

Let OAf_i, OAs_i, OAl_i, OAoi, OAsb_i, OAei denote the value of the features of different M, D, C, EV or R but associated only with one of the basic needs {f, s, l, o, Sb, e}.

bra_{fp} – the maximum number of features associated with the physical needs;

bra_{sp} – the maximum number of features associated with the need of security;

bra_{lp} – the maximum number of features associated with the need of love and belonging;

bra_{op} – the maximum number of features associated with the need of assessment and self-assessment;

bra_{sbp} – the maximum number of features associated with the need of self-actualization;

bra_{ep} – the maximum number of features associated with the aesthetical needs;

Let Op be the value of a need. $Op \in \{Ofp, Osp, Olp, Oop, OSbp, Oep\}$; The value of a need depends on the values of the features for different M, D, C, EV or R, but associated only to this need.

$$O_{fp} = \frac{\sum_{i=1}^{brafp} O_{Afi}}{brafp} ; O_{sp} = \frac{\sum_{i=1}^{brasp} O_{Asp}}{brasp} ; O_{lp} = \frac{\sum_{i=1}^{bralp} O_{Alp}}{bralp} \quad (12)$$

$$O_{op} = \frac{\sum_{i=1}^{braop} O_{Aop}}{braop} ; O_{sbp} = \frac{\sum_{i=1}^{brasbp} O_{ASbp}}{brasbp} ; O_{ep} = \frac{\sum_{i=1}^{braep} O_{Aep}}{braep}$$

General value of the agent's state $O_{generalized}$ is calculated as a sum of the values of the needs divided by their count.

$$O_{generalized} = \frac{O_{fp} + O_{sp} + O_{lp} + O_{op} + O_{sbp} + O_{ep}}{Need's\ count} \quad (13)$$

Let Z denote the knowledge of an agent of its own state, places, events, actions, rules and principles in the world. $\forall Zi$ is a function of its: emotions, emotions values, values and weights of the needs, and inertia:

$$\forall Zi = f(Epiq, Eoiq, SEpiq, SEoiq, Pi, Ki, mi) \quad (14)$$

The choice of actions, rules, principles and states depends on the knowledge of the agent.

$$\text{Choice (M, D, C, EV, R)} = f(Z1, Z2, \dots Zz); \quad (15)$$

$$(Z1, Z2, \dots Zz) = f(\text{Choice (M, D, C, EV, R)}) \quad (16)$$

The change in knowledge results in a change in the actions, rules, principles and states of the agent. They on their part lead to a change in knowledge.

The agent's state and the reasons for this state are always known. Every agent's state corresponds to an appropriate face, body, and gesture expression and behavior.

During his "life" the agent accumulates knowledge about himself, about his own needs, about the places in the world and their characteristics, on the events, that might be happening, on the states, under which one can fall into, about the emotions that they arise, on the possibilities for action and their consequences. This means that the agent acquires a potential φ . It is proportional to an accumulated amount of features Q for M, D, C, EV or R.

$\varphi = \frac{Q}{C}$ where the coefficient of proportionality C is called own capacity of the intelligent agent.

For building up its potential the intelligent agent must perform its work, in order to obtain all of these features and to evaluate and use them. Then, his potential energy will be equal to the work on collecting all features from the world.

Let us calculate it, drawing out of an elementary work for gathering one feature dQ . Assuming, that under this extremely small change of knowledge about the features, the alteration of the potential φ can be disregarded and the change in the potential energy of the intelligent agent will be equal to the potential energy of this feature dQ : $dA = dEp = \varphi dQ$. Then:

$$E_p = \int_0^Q \varphi dQ = \int_0^Q C \varphi d\varphi = \frac{C \varphi^2}{2} = \frac{Q^2}{2C} \quad (17)$$

We consider two intelligent agents with amount of features to M, D, C, EV or R, $+Q$ и $-Q$ and potentials φ_1 и φ_2 . Their potential energy is defined as for the system of features:

$$E_p = \sum_i \frac{Q_i \varphi_i}{2} = \frac{Q(\varphi_2 - \varphi_1)}{2} = \frac{QU}{2} \quad (18)$$

where $U = \varphi_2 - \varphi_1$ is the subtraction between the potentials or the tension between the two agents. By analogy with one virtual agent, we introduce: $C = \frac{Q}{U}$ which is called

reciprocal capacity of the two agents. Thus, the energy of the conflict between equal opponents can be examined. With agents, having an amount of features $+Q$ and $-Q$ pertaining to M, D, C, EV or R with equal signs, there is collaboration.

Purposeful collection and use of features with definite weights and signs aimed at one agent convincing another in a given cause is called Intelligent Impact and will be denoted by I . If necessary, the agent can disguise, ignore or increase the influence of

various features be, which could result in alteration in its behavior or in changing the conduct of other agents.

All features interact with each other, i.e., one feature can amplify or diminish the value of another feature and even change its sign.

The agent can search for and evaluate the features on his own or another agent can provide them together with the assessments made by him. Moreover, the agent can accept them in scale 1:1, with suspicion or with increased values depending on the degree of confidence and authority of the second agent. Many of the features of one event, thought or intended action will obtain a charge complying to the general rules in society, and not according to the impulse of behavior of the agent himself.

The work carried out by external forces F (events or other agents) is transformed into a potential energy of one intelligent agent. The potential energy can be positive or negative and its change can coincide by sign with the worked performed.

The elementary work done for an elementary change in the state of agent dx is:

$$dA = -Fdx = k \times dx$$

upon deformation of 0 to x we must integrate the equation in these limits:

$$A = \int_0^x dA = \int_0^x kx \cdot dx = \frac{kx^2}{2} \quad (19)$$

The inflexibility of the intelligent agents towards the alteration of their state is called inertia. The inertia is related to the degree of conviction of the agent in his behaviour and principles, in his belief in "life" generally and in particular in M , that it visits, D , C , S or R and the meta-rules, which applies. A quantitative measure of the inertia is the physical scalar quantity mass or rather the inertia mass, that is denoted by m_a . All features of M , D , C , S or R have their own inertia mass. Every agent defines individually according to his persuasions the inertia mass of the features that he recognises. The inertia mass of all features of M , D , C , S or R determines the inertia of the agent towards these M , D , C , S or R .

The inertia of the rules can be introduced, that the agent uses m_{rules} , as well as the inertia of meta-rules "principles" of the agent $m_{meta-rules}$, and the inertia of rules for construction and change of the agent's principles $m_{meta-meta-rules}$.

Then $m_{meta-meta-rules} > m_{meta-rules} > m_{rules}$.

m_a , m_{rules} , $m_{meta-rules}$, $m_{meta-meta-rules}$ of one intelligent agent depend on the Intelligent impact of the agent, on the Intelligent impact of the group of agents, which the agent belongs to, on the Intelligent impact of all other agents in the world and on the development of the situation facts and consequences.

Every intelligent agent keeps up its state at the usual behavior given by the programmer until the action of another event, agent or groups of agents gets him out of this state and the agent can change a rule for behavior. In this case a work has been carried out under the effect of a force. The elementary work performed for a change

in an agent's behavior is equal to: $E_{kp} = \frac{m_p dO_p^2}{2}$ i.e. of the inertia of the behavior m_p

by changes in the assessment of the behavior on square dO_p^2 , divided by two. The adaptation of the agent can be expressed with his power: $N = \frac{dA}{dt}$

3 Experiment and Experimental Results

For the purposes of the experiment the following simple scenario is suggested. Some agents visit a small, smoky restaurant1. The cigarette smoke is bad for their health and they are often ill. They recover in a hospital. They work in a firm to earn money, which they spend in the restaurant1. Some other agents visit a large, luxurious restaurant2 that has air conditioning. The fresh air is good for the health of the visitors and they are not often ill. On some of the agents meta-rules have been applied. When such agents meet, they can exchange information about the restaurants they visit and can change their rule for visiting a restaurant by using a meta-rule for making a decision.

Table 1. Rules for agent's 5 behavior.

N	Agent	Action	If action fact	If agent's need	If agent's emotion	If the generalized emotion value > agent's threshold
21	5	Hospital	Health	Physiological	Generalized	No
22	5	Restaurant 1	Money	Safety	Generalized	Yes
23	5	Restaurant 1	Health	Physiological	Generalized	Yes
24	5	Restaurant 1	Like to go to restaurant	Self-evaluation	Generalized	Yes
25	5	Firm	Money	Safety	Generalized	No

Table 2a,b. Positive and negative features upon choosing one or another action

Action Rejected	Fact	Related Needs
Reject visiting of Restaurant1	Smoky restaurant	Physiological
Reject visiting of Restaurant1	Mediocrity visitors	Self-evaluation
Reject visiting of Restaurant1	Cheap restaurant	Safety
Reject visiting of Restaurant2	Unknown staff	Belonging
Action Chosen	Fact	Related Needs
Going to a restaurant1	Friend with staff	Belonging
Going to a restaurant1	Delicious food	Aesthetics
Going to a restaurant2	Good ventilation	Physiological
Going to a restaurant2	Selected visitors	Self-evaluation
Going to a restaurant2	Accessible restaurant	Safety
Going to a restaurant2	Delicious food	Aesthetics

The state of the agents, the rules and meta-rules of behaviour are dynamically stored in relational tables. In this way it is easy to insert, delete or change features, characteristics, preconditions or even rules and meta-rules.

The usefulness of meta-rules of behaviour reveals itself in the fact that the agents are able to change the rules applied on them, they can change and choose their behaviour independently from the programmer. This may result in their better condition. Of course, the agents are dependent on the knowledge they have of the world and on the evaluations they give to each fact or event they learn.

As a suitable device for description of the models, a mathematical apparatus of generalised nets is selected, that has been increasingly established as a uniform mathematical device for modeling processes in different areas [1].

The advantage of generalized net models is the possibility of presenting and tracing back the evolvement of conditions, processes and conduct in the course of time; of attaining the compactness and unification of models; enabling the parallel function of predicates from each position; the observation of the mutual relationship between the agent and environment and among the agent themselves, etc.

According to the given scenario the program is started with the input of 10 token-agents that are to “live” in the modeled virtual world [3]. The positions of the generalized net-virtual world for the agents are built. The rules, according to which given action will influence the state of an agent not observing its knowledge and expectations are applied. These are the laws in the world. The initial states of the characteristics of the agents are applied. The rules for their behavior are applied as well. The agents with numbers from 1 to 5 visit restaurant 1 (Table 1), while the agents with numbers from 6 to 10 visit restaurant 2.

To two of the agents with numbers 5 and 9 the meta-rule is applied, in conformity with which, they can choose the better one out of two alternative actions. [4] These two agents can communicate with one another and on receiving new information or suggestion, they can change their behavior, transforming one of their behavior rules (in this case, which restaurant they visit). A detailed presentation of this meta-rule is the following: A predicate divides the positive and negative features upon choosing one or another action; the pluses and minuses are count down; the weight of each positive and negative features is determined depending on the basic need, which it is liked to; it is determined which need is the organizer of the agent’s behavior in the moment and which is the highest basic need and to the respective one is ascribed the largest weight. Another predicate presents the second part from the meta-rule that realizes the measurement itself and depending on the result, a decision is taken whether to change and in what way the already established rule for behavior. (Table 2 a,b).

Table 3. Behavior of Agent

Agent’s Behavior	Tact
going to a restaurant1	0
going to a restaurant1	2
going to a firm	4
gets recovered	6
gets recovered	8
going to a restaurant1	10
going to a firm	12
going to a firm	14
gets recovered	16
gets recovered	18
going to a restaurant2	20
going to a firm	22
going to a restaurant2	24
going to a firm	26
going to a firm	28
going to a restaurant2	30

Table 4. The agents explain why they do or why they do not do a specific action.

N	Agent	Reasons	Related Needs
5	5	I'm going to a restaurant because I have money, because I am healthy, because I want to visit a restaurant, and because I have enough positive emotion.	I associate going to a restaurant with the following necessities: safety; physiological need; self-evaluation; and enough positive emotion.
54	8	I'm going to a firm because I have not money and because I have not enough positive emotion.	My job is related to the following necessities: safety; and enough positive emotion.

The behavior of agent 5 throughout the time of the experiment is shown in Table 3. On tact 14 agents 5 and 9 meet and agent 5 actually changes its rule for visiting a restaurant according to our expectation. It is observed an increase in the positive attitude toward the bigger, more luxurious and cleaner restaurant²; toward the visitors there, betterment of its health, keeping good financial condition and aesthetical requirements of the agent. Considerably lower values of the agent toward the unknown staff in restaurant² are observed. So, it can be generalized that the state of the agent is better as result of its behavior change after the appliance of the meta-rule. The token-agents explain all the time why they do or why they do not do a specific action, with which their needs their choice is related and how they feel (Table 4). The tokens may read the table, in which their states are stored dynamically.

4 Conclusions

This article presents a computer model of intelligent agents inhabiting a virtual world. The agents combine the following basic components: needs, knowledge of the world, knowledge of themselves, emotions, rules, meta-rules, actions, and characteristics.

Some of agent's characteristics are: energy, work, adaptation and inertia. The relations between the components are shown and the possibilities for their quantitative representation are suggested. In the software model we developed the agent components are stored in relational tables, which makes their effective modification possible. Expressions for calculating various parameters of the model--including basic agent need weights and features of the places, actions, states, generalized agent states etc.--were presented and summarized. A coefficient used for reordering the basic needs was also introduced.

The agents based on this architecture can be visualized graphically. The agent's state and the reasons for this state are always known. Every agent's state corresponds to an appropriate face, body, and gesture expression and behavior.

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