Modeling of Emotional Influence in Multiagent System

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Abstract: Emotions are an integral part of human personality. That is why it is necessary to take them into account when modeling human behavior and to implement them appropriately with respect to the given objective. For simulation models, a so-called computational approach based on the emotional appraisal of the stimuli the individual is exposed to is usually used. The selection of criteria for this appraisal is not strictly given, just as the transformation of their values into the emotional space. It depends primarily on the purpose of the model and the environment in which the model exists. This paper describes a specific emotional appraisal setting for the modeling of social structures based on communication between individuals in a multi-agent environment. The experiments present simulations of several scenarios showing the development of selected model parameters over time, as well as the effect of the possible involvement of the emotional appraisal in the simulation of the authentic behavior of individuals in the network.

1 INTRODUCTION

Emotions are an integral part of human personality. It is, therefore, necessary to take them into account when modeling the human behavior (concerning given goal).

There are several approaches to describe emotions, more or less emphasizing the psychological or computational point of view. For modeling of emotions using IT, the so-called computational models of emotions are suitable. They are based on the emotional evaluation of the stimulus the individual is exposed to.

Many of these models with different methodologies of emotion appraisal are presented in the literature, but the critical parts of the model are rarely described, especially the transformation of the evaluation variables into their emotional impact. The paper focuses on this topic and presents one of the possible settings of the emotional appraisal process for use in multiagent social models and also on examples of agent's coping with appraisal results. The stress is also placed on the dynamics of the process of emotional appraisal.

This contribution is part of a larger research project aiming at simulation of the global behavior of humans in an environment based on events and communication.

The next sections of the paper are organized as follows. Section 2 focuses on a brief description of state of the art in the field of emotional appraisal. Section 3 then concentrates on the description of the proposed appraisal model, and Section 4 presents experiments with the model aimed primarily at testing the overall approach.

2 STATE OF THE ART

Study of emotions from multiagent systems view is a constant topic in which we can find different approaches. Current survey on this field can be found in (Bourgais et al., 2018). Our model can be assigned to a group of computational appraisal models of emotions, which are based on an emotional appraisal of all the influences or perceptions the individual can capture.

The example is a model based on valence and arousal of emotion (Russell, 1980). The emotion invoked here is represented by a point in 2D space, so it is possible to examine the whole range of emotions specified by different combinations of valence and arousal. However, it is clear that the use of only two variables is a little bit restrictive and minor differences in emotions can be hidden in other dimensions and cannot be captured. On the other

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hand, the significant question is if it is necessary from the point of coping with the emotions to work with more emotional dimensions. Sometimes we just want to know the overall mood of the individual to determine the emotional influence on agent's actions.

A cognitive theory of emotions usually works in the process of emotional appraisal of a given event with several input dimensions (e.g., Ellsworth and Scherer, 2003; Lazarus, 1991; Roseman et al., 1990; Scherer, 1999). The list of these dimensions typically includes (Siemer et al., 2007) the self-importance of the event for the agent, event expectancy, possibility to control the event (controllability) and responsibility for the event. The appraisal value is usually normalized, the discrete value scale (0; 10) is frequently used from 0 (strongly disagree) to 10 (strongly agree). All of these are factors capable of generating emotional excitation. The proposed model is based on this dimensional approach.

A description by (Bylsma et al., 2011) can also be used to describe the event which then has also other metadata as a type, global type, location and type of interaction.

If speaking about the selection of the appraisal dimensions (variables) there is no standard set of these variables; the specific choice depends on the particular purpose (Moors et al., 2013). However, a simple rule can be applied - the more degrees of freedom we have (i.e., variables and their possible values) the more types of emotions can be identified and modeled.

Our model is focused on event processing, so it necessary to use appraisal variables based on events and their relation to the individual's goals (more general interests):

- Agent's goal relevance
- Agent's goal congruence
- Event's certainty
- Event's causality
- Agent's potential for coping the event or control or influence on control
- Event's novelty or usefulness
- Event's expectancy
- Event's urgency
- Event's intentionality
- Event's legitimacy or fairness
- Compatibility with the agent's norms

The list taken from (Moors et al., 2013) is very diverse and unclosed and includes variables from which emotional reaction can arise. When determining the emotional impact of these variables, the interests of an individual (his or her desires or beliefs) should also be taken into account.

What is mentioned only marginally in the literature is the transformation of these variables' values into the emotional output or the specification of a particular emotion. An exception may be the approach used in the OCC model (Clore and Ortony, 2000) which partly describes used rule-based mechanism. More detailed information we can also find in (Courgeon et al., 2009), where the event appraisal transformation is nonlinear and is focused on selected emotions expressed on a human model. Our approach is similar to this one, but our goal is to obtain information about the actual emotional state in the form of mood.

Machine learning methods (with or without a teacher) are can also be used to generate emotional appraisal (e.g., Nakatsu et al., 1999). These methods need both computational power and (in case of supervised learning) also the annotated training set. That was the reason we tried to propose a more straightforward way of computing the appraisal.

Just a part of the researchers focuses on the dynamics of an individual's emotional state. The approach used in this paper is similar to that of (Schweitzer and Garcia, 2010) where continuous 2D space is used. Our model works with the continuous mood 1D space with no value limits.

However, the above event-based approach is currently considered by some scientists to be limited. This consideration is evident, for example, in the theory of (Gebhard et al., 2018), which denotes the emotions generated by the events as only a part of the emotional space (so-called situation emotions). Apart from these emotions, there are also defined the structural emotions (arising from the internal stimuli of the individual) and emotions expressed non-verbally (communication emotions). However, with a suitable event definition also covering both the latter categories, it is possible to convert them into events appraised according to the above dimensions.

From the multiagent point of view, we build on the previous work of the author focused on modeling of dynamics of multiagent social systems based on communication between agents (Jelínek, 2011) and aspects influencing this process (Jelínek, 2018).

3 PROPOSED MODEL

The presented approach aims to focus on determining the emotional impact of the given event, i.e., on the definition of R^m -> R^n, where R^m is the

input space of appraisal variables, and R^n the space of emotional output. Unlike the approach, where these variables are chosen to allow differentiation of emotions, the presented model focuses primarily on the variables that can cause any emotional excitation.

In the emotional output space R^n, specific types of emotions can be used as dimensions or computed from them. We use the set of six dimensions mentioned later in this paper. However, we think that the global level of emotional excitement is crucial to investigate the influence of emotions on the agent's behavior. Therefore the presented model transforms these dimensions to just a single one ($n = 1$), the mood of the agent. The possible output values of this dimension are then in (-1; 1), with negative values denoting negative emotions and vice versa.

The underlying environment model builds on the previous work of the author (Jelínek, 2018). The model is implemented in Java, and the social network is made up of agents communicating with each other in the form of messages. The message is here understood as an event and has to be emotionally appraised. In a broader look, we can say, that event is everything that the agent can register. It can be any stimulus from the environment (generated directly by the environment or as a result of communication between the agents) or a result of the agent's cognitive processes. In every simulation step, the incoming event is accepted by the agent with a certain probability, which is the agent's parameter.

The content of the event is some fact comparable with agent's knowledge base. Content can be further structured depending on the used form of data representation. The modeling of the agent's knowledge base can be simplified, and it may not have much to do with real problems. The essential thing is that the knowledge base allows the setting of the emotional appraisal for a given event.

In addition to content, each event is complemented by related metadata that can also be used to determine emotional variables:

- Event origin - who caused or triggered an event.
- Time and location of the event - when and where the event happened.
- The event type - determines the appearance of the event message (e.g., information, command or question).

Also, it is necessary to take into account the attributes of the message itself and also the agent attributes:

- Message sender - from whom we received the information.
- Priority - how urgent is the message marked.
- Form - determines the shape of the event message. Here we can choose for instance the transmission channel (audio, video, text, data or their combinations).
- The time and location of the agent at the time of receiving the event message - when and where the agent learned about it.

We accept the premise that emotions can arise only as a result of receiving an event message, which means only by a cognitive stimulus that the agent processes. However, emotion can occur even when we expect the event, but it does not occur or vice versa. Nevertheless, this situation can also be included under the concept of expectations and its comparison to reality (model uses for this situation a particular type of event).

The appraisal process is based on the fact that the rate of the emotional state change depends on the difference between the expectations or desires of an individual, and the reality. Expectations of an individual are based on an internal model of his / her knowledge about the world and the communication history and are constructed with the help of the metadata mentioned above (both message and event ones).

For example, for a specific agent location, the agent recalls events previously received at this location, and on their base, he/she defines the expectations for a new event. The same can be done for the specific sender and other metadata. The difference between the expectations and the given event is the basis for the emergence of the emotion — the bigger the difference, the stronger emotional excitation.

There are two possible ways to model and study emotions in the communication environment. The first way leads to a model in which the emotional appraise of the event is directly assigned to the event by the model controlling mechanism. The advantage of this approach is the simplification of the model and the possibility to focus on the influence of emotion on the individual's mood and behavior and not on the factors that cause it. The disadvantage is the absence of an appraisal process which cannot be studied. The second way is to create a more comprehensive model that will include emotional calculations from the values of input variables and appropriate expectations. Thus, the event must be described in the manner mentioned above (content and metadata).

The presented model is designed in a second way to enable the broader study of emotional influence on the agent's behavior.

3.1 Model Details

The presented model was created on the base of the text description of the event's content and message metadata (except for the time that is defined in simulation steps, and priorities which are also numeric). The randomly generated text was used to identify specific content. We use Levenshtein distance for comparing data and setting its similarity. The text is not the only way of data representation, an approach based on a numerical data can also be used. However, text representation was chosen for compatibility with other research projects.

The first step in the appraisal process is to determine emotional variables on message content and metadata and also on historical data. The values of all variables were normalized to the range of (0; 1). The following variables were selected, based on the nature and availability of the input data and the information about the computational models of emotions:

- Benefit for goal (b)
- Controllability, the possibility to control the event (c)
- The urgency (u)
- The popularity of the form of the message (f)
- The type popularity of the event (t)
- The popularity of the sender (s)

This way the message is transformed into a universal space that can be used for any content and type of message. The list does not intentionally mention the event expectancy. Its effect is reflected in its use in the setting of agent *x* expectations.

Next step is the emotional appraise of variable values to determine their emotional impact *e* in the emotional space R^1, in the model represented by a value in the range of (-1; 1). The value $e = 1$ corresponds to the maximum positive emotion and vice versa. The model uses a simple linear transformation to speed up the appraisal process, specific formulas for given variables are nearly the same and are presented at the end of the next paragraphs. However, it is also possible to select another type of function.

For determining benefit for goal *b*, it is necessary to define an agent's goal. In the considered model it is implicitly expressed as a widening the knowledge base. The key here is the relation between message content and the content of the agent's knowledge base that arises from all the hitherto taken and processed events. The degree of benefit is calculated from the minimal Levenshtein distance between event content and all contents from the agent's knowledge base. If the given event does not yet occur, its benefit is maximal ($b = 1$). Positive emotions arise when a beneficial message is received ($e_b = 2b - 1$).

Controllability *c* specifies the level to which an event can be influenced or controlled by an agent. The maximum value $c = 1$ is assigned if the agent is the origin of the event. In addition, if the event is caused by a known agent (our agent has already received a message from him) the value $c = 0.66$, if the origin is an unknown agent, the value $c = 0.33$ and if the source is an unknown circumstance given directly by the environment, the value is $c = 0$. The maximum positive emotion arises when our agent is the origin of the event and has the best conditions to control it ($e_c = 2c - 1$).

The urgency *u* of a message has a direct link to message priority, which is defined in the range of (0; 1) and therefore $u = priority$. Positive emotions here arise if the message is not urgent ($e_u = 1 - 2u$).

The popularity of the message form *f* depends on the form of the message and personal characteristics of the agent. Typical forms were selected (oral communication, letter, mail, SMS and telephone call) and for testing were assigned particular values of popularity *f*. The emotional appraisal is derived directly from this value ($e_f = 2f - 1$).

The popularity of the event type *t* is constructed similarly to the popularity values of a message form, the list of possible types is given, each of them evaluated. The emotional appraisal is derived directly from the value *t* ($e_t = 2t - 1$).

The popularity of the sender *s* is calculated as the average of the emotional appraisal of all messages received from this sender in the past. The emotional impact is then defined as $e_s = 2s - 1$.

For expectation calculation are collected the average values of emotional variables according to the following breakdown:

- Agent location in the simulation step in which the message is received (x_l)
- Message sender (x_s)

The resulting expectation values for each emotional variable $y \in \{b, c, u, f, t, s\}$ are then calculated as the average of the above values (Eq. 1).

$$x_y = (x_l - x_s)/2 \quad (1)$$

Simulation time and possible periodicity of events also could be taken into consideration.

However, this was not implemented in the model yet.

Now we proceed to the calculation of the emotional appraisal of the event concerning given expectation. For each variable y we can determine the difference between its expected x_y value and the value y for the given message (Eq. 2):

$$a_y = (y - x_y + 1)/2 \quad (2)$$

The difference of a_y in the range (0; 1) is the basis for calculating the emotional appraisal of the given variable. It is set according to the formulas presented for each emotional variable (e.g., for urgency $e_u = 1 - 2a_u$). The reality better than expectations generates positive emotions and vice versa. The impact of the event in the emotional space according to above-presented variables is in Figure 1.

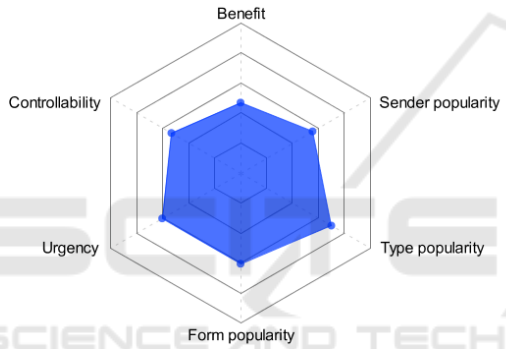

Figure 1: Event representation in the emotional space.

As we can see, the appraisal is determined according to exact algorithms, but using individual knowledge and individual history. Each dimension also can be of particular importance to the agent according to personal preferences. Therefore, specific individual weights are assigned to the variables and the resulting emotional excitation is given by the Eq. 3.

$$e = \sum_{n=1}^{N} e_y w_y \quad (3)$$

In the Eq. 3, e_y is the value of the emotional appraisal for a given variable, w_y weight assigned by the individual to the given dimension, and N the number of variables we work with (in our case $N = 6$). These weights are set in range (-1; 1), the negative allows to model agents with a reversed emotional perception. This approach makes it possible to work with the diversity of behaviors and preferences in the population.

The weighted appraisals of the emotional variables are in the model summed up, but other methods, such as the calculation of the Euclidean distance in the dimension space, are also applicable.

Emotional excitation e caused by the appraisal of one event (message) is not isolated during the simulation. Total excitation of the agent is given by the superposition of all excitations of events whose impact persists. The sum of these impacts can be described as the current mood of an agent in the range (-∞; ∞).

However, the event's influence on the mood during the time decreases. Forgetting parameter d from the interval (0; 1) models the speed of decay; it defines the decrease of event's impact on the agent in one simulation step. Thus the real mood arises from the superposition of emotions from all the events the agent has observed, concerning the forgetting (Eq. 4).

$$m = m_0 + \sum_{k=1}^{K} e_k d^{V - v_k} \quad (4)$$

In Eq. 4 the m_0 is the mood at the beginning of the simulation, K is the number of all recorded events to current simulation step V, e_k the emotional appraisal of the given event and the v_k simulation step in which the agent observed the event k.

4 EXPERIMENTS

Several preliminary experiments were conducted aimed at testing the overall approach. In all experiment were parameters of all agents set on values from Table 1.

Table 1: Agent's parameters in experiments.

Parameter	*Value*
Forgetting parameter d	0.9
Event acceptance probability in one step	0.5
Initial mood m_0	0.0
Weights of emotional variables w_y (for all variables randomly chosen from most likely range)	0.0 - 1.0

4.1 Standard Agent and Network

In the first experiment, we focus on a single agent standard behavior (all the weights of emotional

variables set to 1.0) and the behavior of the whole network. Figure 2 shows the mood of the agent with repeated receiving of the same message from the same agent. The figure shows the initial positive mood value due to the receiving messages about unknown events. The mood of the agent worsened as the communication continued and did not bring him new information. However, during the time, the incoming messages modify the agent expectation for the sender, so further acceptance of the same message generates the only minimal emotional response.

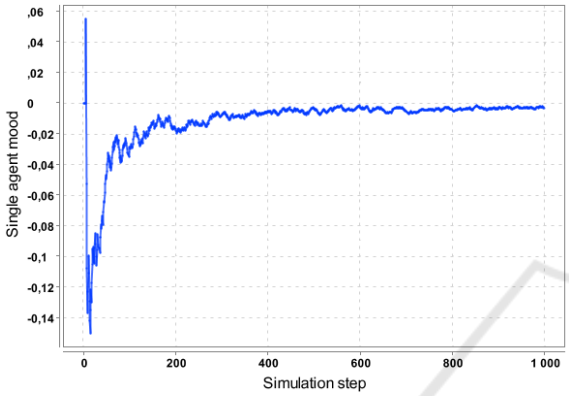

Figure 2: Single-agent mood change in time.

Receiving the same message frequently affects the speed of process dynamics only marginally, the main factor here is the factor of forgetting *d*.

The dynamics of a global mood in the network of 100 agents, 20 locations, and 15000 different randomly generated message contents copies the behavior of single agent (Figure 2).

4.2 Preferred Message Senders

Information about the emotional appraisal of messages from each sender can be stored and used for the selection of preferred communication partners (senders of positively appraised messages).

This mechanism is demonstrated in the following experiment where after the step *s = 2000* starts the preference of positively appraised message senders (Figure 3).

The significant change of global mood to positive values is caused by the better emotional rating of message senders, which is a part of the appraisal process. After some time the agents adapt their expectations and the global mood decreases to neutral zero value.

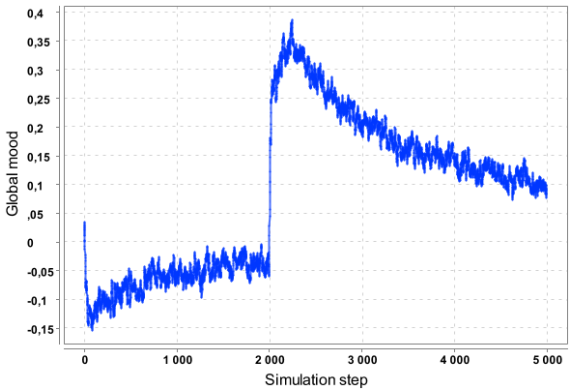

Figure 3: Global average mood change in time – a selection of best-rated partners from step 2000.

4.3 Modified Event Probability

The last experiment was based on a previous one and took into account the mood of an individual when setting his willingness to communicate. This influence was implemented by modifying the probability of message reception (event probability) of the agent in the given simulation step (Figure 4).

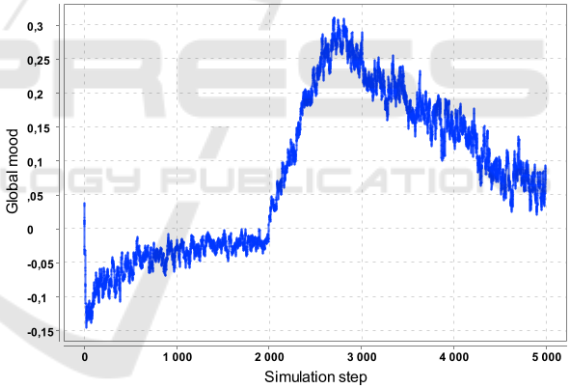

Figure 4: Global average mood change in time – modified agent's event probability, selection of best-rated partners from step 2000.

The global mood had similar progression as in the previous experiment, but the influence of reception probability modification (Figure 5) caused slower and not so high change.

With worsening agent's mood, the event probability has fallen. However, from step 2000 the mood started to increase and the willingness to communicate increased too, also due to the selective choice of message senders. The value on the y-axis approaches 1, so about step 4000 the agents wanted to communicate with the maximum probability.

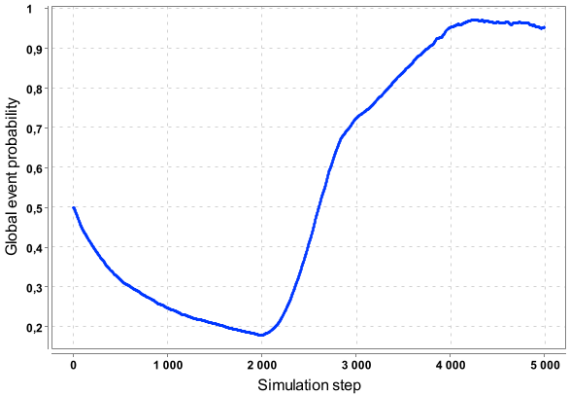

Figure 5: Global average of an event rate change in time – modified agent's event probability, selection of best-rated partners from step 2000.

5 CONCLUSIONS

The paper presented a detailed model of emotional appraisal of events in a multiagent environment simulating the dynamics of a social network built on communication links. The output of the appraisal process was the single value of the agent's mood, which can be further used in the process of coping to modify the agent's actual parameter's values. To simply implement the appraisal process was together with the study of its dynamics also the goal of the model. The proposed model can be the basis for further discussion about the modeling of emotions in computational models (procedures used allow various implementations).

Three experiments were conducted with the model to study its behavior and the overall approach and to investigate agents' behavior in different situations. Especially the experiments focused on the practical use of emotional appraisal of messages (for the selection of message senders or for modifying the message acceptance probability) have brought results usable for further investigation and utilization.

This paper aimed to show a specific implementation of emotional appraisal of events and to open discussion of the proposed procedures. Future work on the model will focus on the methodology of its validating which is crucial for every simulation model. The problem here is the used format of messages and events and the availability of necessary metadata. Attention will also be layed on refining the appraisal process. The open topics here are the transformation functions for getting an emotional appraisal from content and metadata and correct setting of the weights for calculating the mood in Eq. 3. Further testing is also needed on using the mood to modify the behavior of the agent in accordance with the influence of emotions on the human being in the real world.

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