Framework for modeling emotions in communities of agents

Petr Skripal[1] and Timo Honkela[2]

[1] Czech Technical University in Prague
Address: Zikova 4, 166 36 Prague 6, Czech Republic
skripp1@feld.cvut.cz
[2] Helsinki University of Technology
Laboratory of Computer and Information Science
Neural Networks Research Centre
P.O. Box 5400, FIN-02015 HUT, Finland
timo.honkela@hut.fi

Abstract. This paper describes a framework for modeling emotions within cognitive agents as an extension to an earlier SOMAgent model of communication and language learning, information fusion and emergent semantic memories. Emotion is considered as a continuous mechanism for flexible adaptation and it is captured through the emergence in an agent's reaction-emotional memory. In addition to the elementary framework of architecture modifications, a behavioral model with two pass processing is presented in this paper.

1 Introduction

Exact definition of psycho-physiological state of so-called emotional or affective behavior seems to be a hard task. There are many different approaches and consequently several, often contradictory conclusions. The baseline for this particular work is based on the component process model of affective states proposed by Scherer [5]. For the purpose of emotion modeling, an earlier SOMAgent simulation model [2] was simplified as well as extended in several ways. The focus in the new model is on a set of evaluation check criteria described in [5]. These criteria are called Stimulus Evaluation Checks (SEC). Scherer's model is not described in greater detail in this article and our argumentation can be followed without knowledge about it. General overview of our model, its simplification and correlations with the original model and some assumptions for modeling are presented in the following [3]. At this stage the model is a conceptual framework. Experimental results will be reported later.

[3] The basic architecture of the communicating, adaptive and semantic agent model is mainly due to TH and the extensions for modeling emotions stem mostly from PS.

2 General overview

The emotional system is a central element in adaptive living systems. It interlinks organism's cognition, needs, goals, motivation and behavior. The model of emotions proposed in this paper could be characterized as a cognition appraisal theory. Moreover, distinct emotions are considered as emergent labels for the evaluation of prototypical situation or events (modal emotions) rather than basic discrete entities achieved by a response program. Emotions can be considered to be used as signalling mechanisms between different subsystems inside an agent, as well as between agents [6, 1, 4, 7].

Scherer's component process model handles several components of which the most important are (1) information processing, (2) support and (3) monitoring [5]. In the earlier SOMAgent model presented in [2] an agent has the following properties: it can perceive its environment, it can move in its environment, it can perform some simple actions, and it can send and receive messages. In this implemented simulation model, the agent associates linguistic expressions and visual perceptions. The linguistic expressions are not symbolic but pattern-like. In [2], a simulation environment for a community of communicating agents has been presented. The basic idea in the model is that the agents have limited resources available in their environment. They explore the environment and learn to communicate with each other in order to facilitate information sharing. For these tasks, they need to be able to associate different modalities. The main point in the earlier study was that the agents gradually develop a mutually shared language through self-organization.

In this paper, we introduce some extensions to the SOMAgent model: information processing component to semantic memory recognition, support component for the evaluation of stimulus evaluation checks (SECs), adaptation and behavioral unit, and a monitoring system for anticipated future operating upon agent's feelings that are reflections of system's changes. One should take into account that the assignment was done purely for better orientation in both model's common features and not as an attempt to describe its internal functionality. Main simplification has been acquired in one level processing in contrary to three level processing of component process model (sensory-motor, schematic and conceptual level). The emotional model built on the SOMAgent model focuses on modeling relations among several units within an agent that deal with affective behavioral output. Therefore, certain evaluation checks in the original SEC units [5] were omitted. The emotional model consists of main components whose names were selected based on the SOMAgent model with several new elements added:

– semantic memory (based on the self-organizing map, SOM)
– reaction-emotional (R-E) memory (based on the SOM)
– stimulus evaluation check (SEC) unit
– behavioral unit
– adaptation unit
– attitude (also called "psyche") with attributes

The word 'unit' stands for a representative of collection of functions that are performed during a particular phase. The SEC's output serves evaluation pattern transformed together with perceived object characteristics to become an input for R-E (reaction-emotional) memory that is based on the self-organizing map. There, due to the inherent clusters of interrelated pairs, object reaction appears. Emerging categories might then be labeled by verbal emotional labels. For further discussion about verbal emotional labels and possible related problems see [5] and [8]. An associated pair in the R-E memory serves as one of the inputs for the behavioral unit. The behavioral unit performs decisions concerning actual agent's attributes (e.g. motivation and condition), the state of the agent's current attitude or "psyche" (see below) and the pure output of SECs.

3 Basic architecture

This section describes the main modifications in both the environment and the agent representation in comparison with the model presented in [2]. The architecture of the emotional module is described in a rather detailed manner.

3.1 Environment

The simulation runs in a simplified environment that generally consists of agents, edible objects and obstacles. Every object is described by its vector including pattern, experience, linguistics expression and message indicator elements. For the purposes of this work, we focus on pattern and experience elements in the following description.

Pattern element. The pattern element distinguishes among several different objects and allows agent's association during cognition process to work properly. It is an identifying set of attributes that might or might not have a reasonable meaning in the real world. Agent uses pattern for correct mapping of the environment onto its semantic memory.

Experience-need element. The experience component is called the *e*xperience-need element (Exp-Need), that indicates both experience and need information values. It contains characteristics of the object and its value states physical properties (seen at an abstract level), behavior and main decision factor for an agent's future reactions. Similar approach has been in use also in [3].

An agent's inner architecture shown in Fig. 1. The SECs expect as their input a set of needs that could be satisfied and that can be evaluated by the agent.

Need name. The name of a need roughly matches agent's possible action that can be evaluated upon the object. *S*afety is general aspect of the object that probably strongly influences further agent's decisions and consequent reactions or emotions. Its value means how much safe is the object for an agent. Therefore, *e*dibility could denote either food (correlation to safety shows

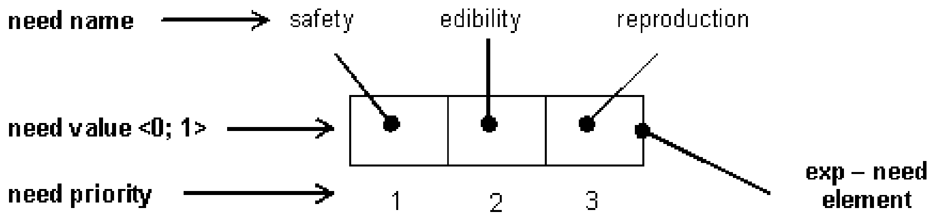

Fig. 1. Experience-need element.

object's poisonousness) or an inedible obstacle. *R*eproduction indicates how much the object could satisfy agent in his reproduction need.

Need value. The need values can be taken from the range $< 0; 1 >$, where the value means measure of fulfillment, i.e. low value of safety need indicates that object is rather dangerous for an agent. The value can be considered in a probability scale.

Need priority. The need priority is an important factor during agent's SECs. Its values can be computed by some mathematical functions (linear/non-linear) when a check is performed. In this article, we do not specify in detail any specific need priority function.

3.2 Agent

The understanding of the environment is based on the agent's semantic memory that holds a summarized "image" of the previous experiences. The vector contains, among other things, two elements that represent agent's experience: experience pattern and experience-need pair (Exp-Need). Exp-Need stands for an agent's need-relevant stimuli that is handled and considered during the computation by other units. Terms stimuli and need are here mutually exchangeable. The same can be said also about the use of terms affective and emotional. The term goal refers to rather long-time tendencies of agent's behavior satisfying particular needs on its path (see chapter 3.2.3). An association in the semantic memory serves as an input to the SEC evaluation unit.

SEC evaluation unit. The SEC evaluation unit creates a pattern vector that is obtained by the behavioral unit and used for pattern recognition in the R-E memory. It consists of several different results (outputs) of evaluation checks shortly described below (for detailed description, see [5]). Sequential perform of SECs checks and related explanation of this choice in contrary to parallel computation can be found in [5]. Some of the checks included in original SECs were omitted due to the attempt to simplify the current model, some of them were removed due to the internal architecture of the system - like novelty check (for explanation, see chapter 3.2.2). One can consider the full list of SECs as a plan for the future work.

Intrinsic pleasantness check refers to the general evaluation about whether perceived stimuli is likely to result in pleasure or pain. The motivation and the actual “psyche” do not affect this check.

Goal-need significance check is the most important check evaluating how much the stimuli contributes to agent’s “psyche” equilibrium (see chapters 3.2.3 and 3.2.4). Priority and motivation serve as crucial factors for this computational phase. The check itself may consist of several subchecks (only list of the relevant, for description see original SEC list):

– **r**elevance - motivational factor
– **p**robability of outcome - agent belief in increase in need satisfaction
– **u**rgency - priority factor

Coping ability check evaluates the agent’s ability to cope with the stimuli concerning agent’s actual attributes (condition, motivation). This check could be used i.e. for the reproduction need in relation to agent’s current physical state.

Reaction-emotional (R-E) memory. Once the SECs receive their input together with the Exp-Need, the vector of the observed object is sent to the R-E memory. As in the SOMAgent model, it is assumed that the visual perceptual characteristics of the objects (pattern element) strongly correlate with their need-relevant properties (Exp-Need element). This leads to the situation that the R-E memory gathers information about particular kinds of objects and for the previous SECs output, respectively the memory constitutes object-related reactive repository. We nay consider the asssociations between patterns and the potential actions or tendencies in action memory as emotions or affections. Therefore this memory can be called emotional memory as well.

At the very beginning of the simulation, agent experience with the objects in the environment is very poor, and thus the R-E memory can be thought to be be in a state known as "tabula rasa" [4]. As experience grows with time, the R-E memory is filled by reasonable data and might therefore be used for behavioral predictions. As shown in Fig. 2, behavioral unit obtains an R-E association and the result of its antecedent SECs. Suppose e as a difference between R-E association output and SECs output. Hence $e >> 0$ might refer to an agent’s reliability of the object, respectively previous experience with the object. It might provide helpful information for behavioral unit computation concerning actual “psyche” as well as motivation and other factors. The model actually enables agent to decide under what conditions the object has been observed (whether the object is known to the agent), or which particular emotional reaction arises along with experiencing the object. The novelty of an object can therefore be derived from the values of the memory. It is one of the factors that leads to the 2-pass processing of an agent’s behavior described in Section 3.2.5. The recognition is followed by the fixation of the associated emotional state. The term fixation is used in the meaning as far as the denotation of the change of SOM’s winning pattern towards its input could be comprehended in the context.

[4] Naturally, the model could include some evolutionary elements of instincts.

Behavioral unit. The behavioral unit concludes its results interpreted as an output behavior of the agent from several inter-dependent inputs. The direct SEC output and the E-R output are compared with each other. The "psyche" is taken in account although it has already influenced the SEC evaluation and other agent's attributes are included in the final computational process. The result of the behavioral unit greatly varies. However, two essential modes of the behavior can be considered:

- action towards the object (admittance) and
- action away from the object (refusal).

Refusal or admittance behavior influences further activity of the adaptation unit and its consequences are described in Section 3.2.5 (Adaptation unit). The specific output behavior based on the incoming data into behavioral unit is not the matter of this work and will not be discussed in greater detail in this paper.

The conditional part of the computation would resolve to agent's specific actions and its main processing would be dependent on the SEC conclusions seen as affective action predispositions finally untwined by the behavioral unit. Affective behavior therefore emerges from evaluated affective patterns stored in the R-E memory. The clusters within the R-E memory appear as emergent conceptual categories for the evaluation of the prototypical situations or the events seen by humans as emotions.

SOMAgent model supports two elementary goals of an agent:

- looking for food (survival mode) and
- examining the environment (exploration mode).

It could be seen appropriate to expect that if the particular needs are sufficiently well satisfied fulfilling the safety need, it can turn into the exploration mode and start to examine the environment. In addition, several other goals could be defined upon proposed needs and therefore could be declared somewhat selective behavior of the agent. In another words, equilibrium of its "psyche" may lead to temporal change in the priority order of its goals.

Psyche and attributes. As a main purpose for modeling of psyche (attitude structure) is, on one hand, the obvious subjective role in the model of agent, on the other, an attempt to include a necessary component that holds recent information of behavioral computation. Regarding proposed simplified model, the authors assign "psyche" mainly for the latter purpose. Along with an agent's attributes (see below), it is the main factor that influences evaluation made by the SECs. It could be seen as a container (buffer) of last recent modified outputs that had previously came from the SECs. It consists of last emotional states achieved by the previous behavior while its modification is conducted during the admittance mode (see Section 3.2.5). The specific influence of the SECs might be explained by labels as emotional tinge or subjectivity. They could be performed by some algebraic manipulations, i.e., the Exp-Need input of the SECs could be slightly shifted towards the actual most recent state of the "psyche". In a more sophisticated way, the same could be gained as a sum of gradually weighted pairs (input of SEC, "psyche") in a descending manner. The attributes attempt to distinguish such ambiguous terms as the motivation, the present needs and the physical state of an agent. In the current model it is assumed that the motivation could be derived from present needs, that reflect, to some extent, an agent's physical state solely described by its condition at a particular moment. To avoid undue complications at the very beginning of the model creation we may assume that the condition is a present variable and the motivation is algebraically derived from the proposed basic needs (safety, hunger, reproduction) regarding its priorities. The equilibrium of the "psyche" would mean a state that somehow reflects satisfied needs corresponding to modified related attributes (and probably need-stable content of the psyche) and which leads to different goal-oriented behaviors (as discussed in the previous section).

Adaptation unit. The adaptation unit deals with all further adaptation of these components: (1) semantic memory ("pattern" in Fig. 3), (2) psyche and attributes, and (3) reaction memory ("emotion" in Fig. 3).

It would be reasonable to expect that the adaptation of all components would not be performed every time the agent treats with an object or a message from the environment but rather under certain conditions particular adaptation processes are performed or omitted. The conditions are briefly introduced in Fig. 3 that graphically describes data flow in the computational system within an agent.

2-pass processing: admittance or refusal. During the first pass an object is detected and through pattern recognition it is associated with a specific semantic field. Therefore no real Exp-Need values of the object are associated but recognized values in the semantic memory are delivered to the SECs. The SECs evaluate potential reaction-emotion that serves as the basis for the behavior. Adaptation of emotional response is performed (called fixation in this work). Complex output behavior results basically in a refusal or admittance of the object. If the object is refused, data flow ends at this point and no adaptive process is run. If it is admitted, the second pass is computed and the real Exp-Need values are considered through a similar data flow. Repeated fixation of the concurrent emotion is followed by two adaptive processes:

- semantic memory adaptation and
- psyche (attitude) and attribute adaptation.

The semantic memory adaptation refers to the previous implementation of the SOMAgent model [2] in which experience learning is accomplished by gradual learning using semantic memory SOM. The psyche adaptation refers to the final affective state after an agent has executed its evaluated action which will influence all the future SEC evaluations. The attribute adaptation refers to the change of actual needs, motivations and the condition. Fixation in both cases of

2-pass behavioral model would describe agent's adaptation of possible reactive-affective states in the R-E memory used for further considerations. The state is adapted even if the agent refuses the action towards the object establishing hence its prototypes of the certain kinds of behavior concerning observed object.

The 2-pass behavioral model is valid for objects directly experienced or indirectly experienced within agent's cognition. If the message containing information about experience with an object is delivered from other agent, different model of adaptation would be proposed in this case.

If the simulation runs for sufficient time and agent stores relatively enough experience from the environment it seems that, aside from the language emergence, also emotional reaction behavior emergence takes its place. It could be therefore be possible to compute all results obtained from the SECs by direct pattern recognition in the R-E memory. Emotional adaptation or fixation at the environment would seem to be the appropriate description.

4 Conclusion

The attempt has been to propose sufficiently elementary model of affective behavior that could be directly integrated with the SOMAgent simulation model and that is able at the same time to support the main ideas of the modal emotions theory and the cognitive appraisal approach. On the virtue of Scherer's component process model, the work composes the main idea of evaluation checks together with pattern recognition methods.

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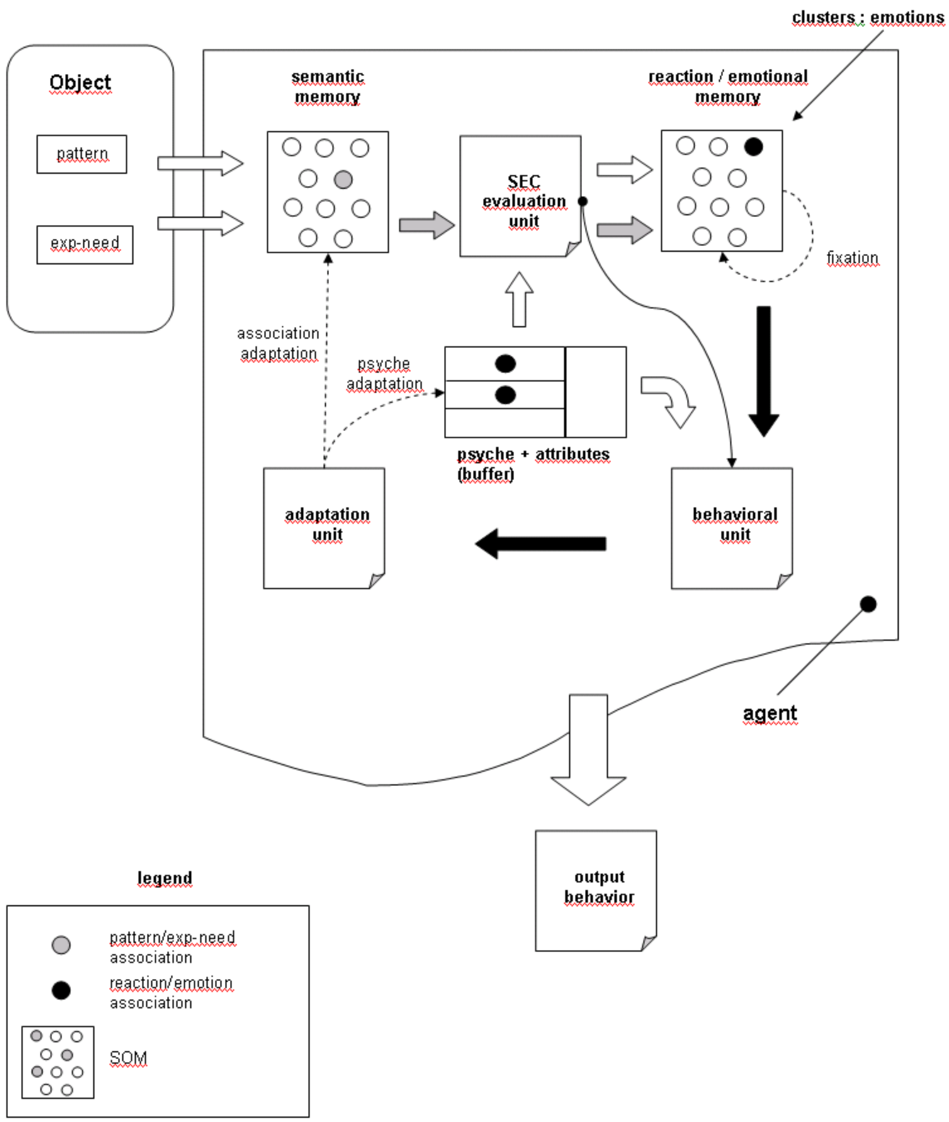

Fig. 2. Extended SOMAgent.

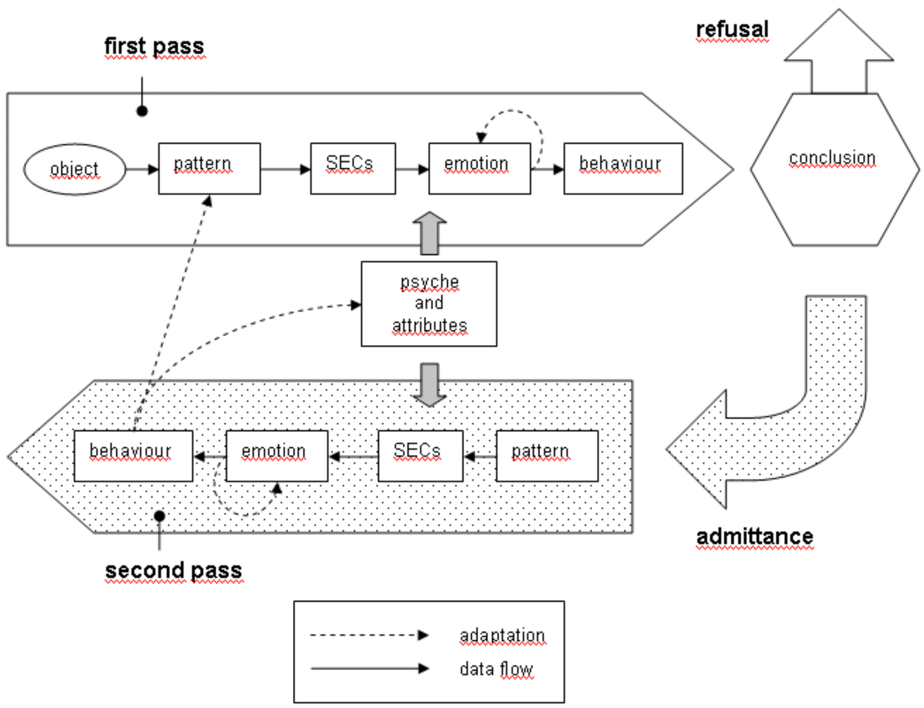

Fig. 3. Behavioral model with 2-pass processing