Representing Emotion and Mood States for Virtual Agents

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Abstract. Emotional agents are an active research domain, with direct application in several industrial fields such as video games, interactive environments or enhanced human computer interactions. Emotional behavior should consider both the representation of the emotions and the mood states. There are two mostly accepted, and used, cognitive psychological models for this: OCC model and PAD model.Based on these models, this paper includes two main contributions, on one hand, we discuss the use of common representation for both mood states and emotions and, on the other hand, this paper introduces the concept of the Mood Vector Space and analyzes the properties and foundations of such a space to support emotional agent representation and operation.

Key words: Emotional Model, OCC, PAD, Mood Vector Space

1 Introduction

The creation of more believable agents for virtual environments and simulation scenarios is putting the emotion synthesis and analysis in the spotlight. Many theories are created for this purpose, some are rather complex based on numerous parameters derived from empirical data, but are inapplicable from an engineering perspective; others are tractable from a modeling and a computational point of view but have less psychological basis.

The main objectives that the emotional synthesis has to deal with are (1) the emotion creation based on the environment analysis, (2) the projections of these emotions into the actions of the agent and (3) the influence of the personality over all the process. After a coherent analysis of the emotions prompted by the environment changes, the agent has to experience different reactions to these emotions, this process has the difficulty of creating a reasonable projection between the emotions and the reactions (or actions) that the agent has.

In this paper, we present a model, based on the PAD Temperament and Emotional models created be Mehrabian [8, 7] which produce the psychological

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foundations for the projection and representation of the emotions in a continuous space. Using these ideas, we define the Mood Vector Space to represent the emotions and the transitions among them in a clear and computation-friendly manner (which means being computationally efficient during execution and reasonably easy to configure at design time). Also, we establish, in this vector space, the set of functions necessary to ensure the achievement of certain psychological characteristics that the emotional synthesis and analysis must have to grant the correct representation of emotions in computational agents.

The paper is organized as follows: In section 2 we shortly review models from cognitive psychology that we use throughout the paper and present related work regarding computational models of emotions. In section 3 we introduce and formally describe our MVS model for representing the dynamics of mood and emotions. Finally, in section 4 we present our conclusions and future work.

2 Background

In this section we briefly discuss some well-known psychological models of emotions and review some computational approaches that draw upon them.

2.1 OCC Model

Ortony et al. developed a computational emotion model, that is often referred to as the OCC model [9], which has established itself as the standard model for emotion synthesis. This model specifies 22 categories for the emotions (JOY, HATE,...) based on valenced reactions to situations constructed either (i) as being goal-relevant events (they could be acts from an accountable agent, including itself), or (ii) as attractive or unattractive objects. It also offers a structure for the variables, such as likelihood of an event or the familiarity of an object, which determines the intensity of the emotion types. We use the emotional tag derived by the OCC model as input for the Mood Vector Space model.

2.2 Pleasure–Arousal–Dominance Emotional & Temperament Models

The works on the use of the three parameters for classifying, measuring and applying emotions and temperament are presented by Mehrabian in [8] and [7]. The author proposed a framework for the representation of emotional states and temperament of a person. First, the emotions can be represented in a three dimensional space and, second in this space we can also present a more stable and lasting emotional states that we call moods.

The PAD Emotion Model The PAD Emotion Model[8] is an extremely general , yet precise, system for the measurement and description of emotions. Three basic dimensions of emotion are used: Pleasure-Displeasure ($\pm P$) or estimation of the liking or disliking, Arousal-Nonarousal ($\pm A$) or general level of physical activity and mental alertness, and Dominance-Submissiveness ($\pm D$) or feelings of control vs. lack of control over one's activities and surroundings.

PAD Temperament Model The PAD Temperament Model[7] is a very general descriptive system for the study of temperament and personality. The model is based on same three dimensions of the PAD Emotion Model (P-A-D).

Temperament is distinguished from emotional states in that it refers to an individual's stable or lasting emotional characteristics (i.e., emotional traits or emotional predispositions). More precisely, temperament is an average of a person's emotional states across a representative variety of life situations. A set of three PAD temperament scales has been developed and shown to provide a reasonably general description of emotional traits or temperament.

2.3 PAD Space for Emotions and Temperament

These works of Mehrabian postulate that the PAD Space is suitable for representing emotions, as a concrete and isolated event given at a specific instant; and emotional states (moods) representing emotional information gathered along a period of time, more stable and lasting over the time.

This two separated elements are relevant for the emotional behavior of a person. The temperament of a person, creates a tendency of the emotional states that must be achieved if the emotional stimuli are weak or inexistent. On the other hand, the emotions prompted by the consequences of the events perceived by a person are relevant by two aspects: the reactive behavior derived by a particular strong emotion, and the aggregation of several emotions which change the emotional state (mood) of a person.

The present work, as we show in the Section 3, introduces this formalization and the mechanism to translate emotions and moods in the same space.

2.4 Computational models

Computational models for emotional agents and emotional behavior take different ways to model the dynamics of emotions and their influence on the behavior of the agents. In the following, we focus on work that uses OCC as basis for the analysis and/or synthesis of the emotions, and the models that use PAD as projection/management system.

In FAtiMA [2], the OCC model is treated as initially conceived: each tag separates the type of emotion, and each emotion has associated an intensity derived by the concrete parameters attached to it, for example the desirability of a consequence can produce Joy or Distress. Then, the emotions produced are evaluated against a set of rules trying to match some preconditions to trigger that rule and the actions derived by it.

Other approaches, like WASABI [1] or EBDI [5], use a projection of OCC emotions into a three dimensional PAD space. They consider the different emotions as a vectorial value of $\mathbb{R}^3$. In the case of WASABI the emotions are treated differently depending on whether they are primary or secondary: while the former are denoted by points, the latter are treated as regions of the space. Once an event is analyzed, the agent is aware of which emotions are more likely to elicit according to the distance to the central point of each of the emotions, make the behavior of the agent change according to this information. In EBDI, the projection of the OCC emotions into the PAD space makes the agent change its rational strategy into an emotional strategy according to the decomposition of the relationship that the three parameters (Pleasure, Arousal and Dominance) have among them. This decomposition is treated as a general estimation of the emotional state of the agent which influence in the maximization of the worth of each strategy.

There are many other ways of analyzing the emotional components of the events but almost all of them make some reference to the OCC model. For instance, the EMA model [6] uses a general decomposition of desirability, appealing and praiseworthy, and the FLAME [3] approach applies a fuzzy estimation of the desirability of an event and analyzes the possible emotions according a set of rules, etc.

The ALMA model [4] uses the OCC model as reference for the emotion prompted by the environment on the agent, this emotions are transformed in the PAD components, the main difference with our approach is that the ALMA model estimates that current mood movement is based on a pull-push strategy that takes the center of the PAD space as reference and the center of the emotions elicited as influence to the mood, in our approach the PAD space is homogeneous for the transitions, supporting the psychological concept of accumulation of emotions in our mood, also, the relevance of a point in the mood space is according to the distance to the default mood point derived by the personality, the operations over the mood applied by the emotions or decay are supported by the Mood Vector Space presented in this paper.

In summary, while the OCC and PAD models are certainly interesting starting points for computational models of emotions, we notice a certain lack of formalism in present approaches. Within computational approaches the semantics and especially the dynamics of the model elements are not clearly defined. The Mood Vector Space introduced in the next section constitutes a homogeneous formal framework for modeling a software agent's emotional states and mood along time.

3 Mood Vector Space

The Mood Vector Space (MVS) is conceived as a formal structure that can represent in the same space the two major items of the emotional behavior models: the emotions and the emotional state (mood). This structure is conceived to accomplish the following requirements that are important for the mood simulation:

- **R1**: Must represent different moods and emotions in the space. According to the PAD representation, bounded in the range $[-1, 1]$.

- **R2**: Support the addition of emotions with the current mood to represent the influence of all of the perceived events over the mood.
- **R3**: The structure must provide the mechanism to classify the continuous value of the mood into a discrete set of mood tags.
- **R4**: The decay of the current mood along the time, moving it to the default mood, usually extracted by the personality of the agent.

3.1 Mood Space

A Mood Space M is define as an algebraic structure $M = (\mathcal{M}, \oplus)$ where the first element is a subset of 3D real number space $\mathbb{R}^3$ bounded between -1 and 1, $\mathcal{M} = [-1, 1]^3$; and the second element is a binary operation in $\mathcal{M} : \oplus : \mathcal{M} \times \mathcal{M} \longrightarrow \mathcal{M} \quad : \quad (\overrightarrow{u}, \overrightarrow{v}) \xrightarrow{\oplus} \overrightarrow{u} \oplus \overrightarrow{v}$. Considering all the properties necessary to treat the Mood Space $M = (\mathcal{M}, \oplus)$ as an abelian group. With this properties, we fulfill the requirements **R1** and **R2**.

3.2 Mood Vector Space

If we include the scalar multiplication/division by a real number and the subtraction to the Mood space set $\mathcal{M}$, it represents a vector space. Thus, we have denoted the elements of $\mathcal{M}$ as vectors.

In order to achieve a vector representation for all of the elements inside of the MVS we need to specify this operations. We want to create a vector space because of the interesting properties that we can implement, such as dynamics, tendencies or distances. In many cases, the representation of the emotions are well interpreted as "vectors", some kind of impulse with certain intensity that moves a person to do something, with some decay latency.

3.3 Extended Mood Space

An Extended Mood Space M is an algebraic structure $M = (\mathcal{M}, \oplus, \odot, \| \cdot \|)$, where $(\mathcal{M}, \oplus)$ is a Mood Space, presenting also the properties for being a Mood Vector Space (respect $\oplus$ operator and real number multiplication). If we add the $\odot$ operator as an inner product operator and the $\| \cdot \|$ operator as the norm; M is considered a normed vector space.

The norm, of course, it is necessary for calculating distances between two points in the MVS space. Usually, the distance between emotions or moods are necessary for the correct identification of the behavior to use given a sequence of event perceived (requirement **R3**).

3.4 Topological Mood Space

The existence of a normed vector space M with the properties presented in Section 3.3, together with $\odot$ operation and the $\| \cdot \|$ operator, and the properties given by this norm operator; provides the possibility to define a topological field

K, based on the element addition $\oplus$ and the scalar multiplication. If M is a vector space over a topological field K, M is a topological vector space. Indeed, all normed vector spaces are topological vector spaces.

Additionally, if the inner product $\odot$ satisfies the properties of: 1 symmetry over the product, 2 linearity with respect the product and 3 linearity with respect the addition; they make inner product to be complete over the field $\mathbb{R}$, thus the Topological Mood Space define with this operation is a Hilbert space.

3.5 Attenuated Mood Space

The dynamics of the emotions requires the inclusion of a mechanism to express the decay of an emotion or the transition to the basic temperament position in the PAD space. Therefore we define an Attenuated Mood Space M as an algebraic structure $M = (\mathcal{M}, \oplus, \odot, \|\cdot\|, A)$, where $(\mathcal{M}, \oplus, \odot, \|\cdot\|)$ is an Extended Mood Space and A is a family of functions indexed by $\mathcal{M}$ denoted as $A = \{a_{\overrightarrow{v}} : \overrightarrow{v} \in \mathcal{M}\} = \{a_{\overrightarrow{v}}\}_{\overrightarrow{v} \in \mathcal{M}}$, for which $\forall \overrightarrow{v} \in \mathcal{M}$ is possible to define an infinite sequence: $\langle \overrightarrow{u_n} : n \in \mathbb{N} \quad \overrightarrow{u_n} \in \mathcal{M} \rangle_{\overrightarrow{v}}$ such as:

$$\begin{aligned} \forall \overrightarrow{u} \in \mathcal{M} : \text{the sequence} \langle \overrightarrow{u_0}, \overrightarrow{u_1}, \cdots \rangle_{\overrightarrow{v}} \quad & \text{starts with} \quad \overrightarrow{u_0} = \overrightarrow{u} \\ \text{generated by } a_{\overrightarrow{v}}(\cdot) \text{ as} \quad \overrightarrow{u_i} = a_{\overrightarrow{v}}(\overrightarrow{u_{i-1}}) \quad & \text{such as} \lim_{n \to \infty} \overrightarrow{u_n} = \overrightarrow{v} \end{aligned} \tag{1}$$

The family of functions A represents a set of functions $\{a_{\overrightarrow{v}}\}_{\overrightarrow{v}}$ that converge to given values of $\overrightarrow{v}$ for all the elements $\overrightarrow{u} \in \mathcal{M}$.

In order to be complete, it is necessary to define how the limit of the sequence is computed (eq. 1). As M is a normed vector space according to the properties presented in Section 3.3:

$$\lim_{n \to \infty} \overrightarrow{u_n} = \overrightarrow{v} \Longrightarrow \lim_{n \to \infty} \| \overrightarrow{u_n} \ominus \overrightarrow{v} \| = 0^3 \tag{2}$$

The creation of the Attenuated Mood Space is necessary to create the emotional dynamics required at **R4**.

3.6 Emotional Agent System in a Mood Vector Space

It is possible to define an Emotional Agent System $\mathcal{A}$ as an algebraic structure $\mathcal{A} = (M, A, E, m_0)$, where M is a Mood Vector Space, A a finite set of agents $A = \{A_0, A_1, \cdots, A_n\}$, and E is a set of elements defined as $E = \{(a, t, v, \alpha)/a \in A, t \in \mathbb{N}, v \in \mathcal{M}, \alpha \in \mathbb{R}\}$, named as the emotion set, which represents all the emotions elicited by all the agents, together with its intensity at a give time stap. Finally, m_0 is a function that represents the default mood state for the agents (mood state in absence of any emotion, thus the initial state): $m_0 : A \longrightarrow \mathcal{M} \quad : \quad A_i \xrightarrow{m_0} \overrightarrow{u}_i^0$

[3] The $\ominus$ operator represents the addition operation $\oplus$ using the inverse element.

The state of an Emotional Agent System, can be represented as the mood state of all its agents, and it is denoted as $M(\mathcal{A}, t) = \{\overrightarrow{u}_0^t, \overrightarrow{u}_1^t, \cdots, \overrightarrow{u}_n^t\}$, being $t \in \mathbb{N}$. This state can be defined as follows:

$$\forall i \in [0, n] : \text{if } t = 0 \quad \overrightarrow{u}_i^0 = m_0(A_i) \quad \text{Initial mood state} \tag{3}$$

$$\text{if } t > 0 \quad \overrightarrow{u}_i^t = \overrightarrow{u}_i^{t-1} \oplus E_{(A_i,t)} \tag{4}$$

$$\text{where } E_{(A_i,t)} = \alpha_0 \overrightarrow{v_0} \oplus \cdots \oplus \alpha_m \overrightarrow{v_m} \quad \forall (A_i, t, v_j, \alpha_j) \in E \tag{5}$$

$E_{(A_i,t)}$ represents the aggregation of all the emotions elicited by the agent A_i at time stamp t scaled according to the intensities α_j and combined by means of the $\oplus$ operator.

If we want to include a mechanism that ensures that the mood state of the agents returns to their default initial state along time (and in absence of new emotions); we must satisfy that M is an Attenuated Mood Space in order to redefine the equation 4 as:

$$\text{if } t > 0 \quad \overrightarrow{u}_i^t = a_{\overrightarrow{v}}(\overrightarrow{u}_i^{t-1} \oplus E_{(A_i,t)}) \tag{6}$$

where $\overrightarrow{v} = m_0(A_i)$ is the default (initial) mood state and $a_{\overrightarrow{v}}(\cdot)$ is the function, from the family of function A in the Attenuated Mood Space, that defines the infinite sequence that converges to this default (initial) mood state $m_0(A_i)$.

Also, we can include a mechanism to discretize the MVS in order to obtain a specific mood tag $M_i^\tau \in M^\tau$. To do it so we include a function of neighborhood $f_\nu(A_i)$ (for instance a minimal norm distance function) that returns the mood tag from the current mood for the specific agent A_i: $f_\nu : \mathcal{M} \longrightarrow \mathcal{M}^\tau \quad : \overrightarrow{u}_i^t \xrightarrow{f_\nu} M_i^\tau$

An Emotional Agent System supports the requirements proposed as objective for this representation of emotions and moods.

4 Conclusion and Discussion

This paper has presented a formalism for the representation of emotions and moods based on the psychological frameworks of PAD space. Using the Mood Vector Space we can manage the emotional behavior of an agent having the background for the transitions and relations across a three dimensional space granted by the algebraic formulation of the properties and functions making this model technically applicable in computational models.

This model is created for the application in different architectures and models for emotional agents. The main contribution is the homogeneous representation of emotional components, opposite to the traditional view of the OCC categories, in a well founded framework, psychologically and mathematically supported.Also, MVS provide the ability to include in the same space the emotions and moods, granting the mathematical tools to manipulate these elements.Therefore, the Mood Vector Space enables the representation of emotions and mood in a unique continuous space, setting the formulation necessary for the transformation and manipulation of the dynamically changing emotional elements, composition of emotions into emotional states, etc.

The MVS representation can include a decay and threshold mechanism for fulfillment of the psychological theories of emotional and temperament dynamics. The EEP model has already been applied[11] to represent emotional behavior using a commercial video game [Neverwinter Nights$^{\mathrm{TM}}$[4]], and it is planned to use the EEP in the online video game of Diplomacy [DipGame[5]] exploring the implementation of multilevel MVS to represent the mood that we have when we are dealing with different agents (different nations). Moreover, an extended description of this formalism is in [10].

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