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Research article

A computational model of emotion assessment influenced by cognition in autonomous agents

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ABSTRACT

In this paper, we present a computational model of emotions based on the context of an Integrative Framework designed to model the interaction of cognition and emotion. In particular, we devise mechanisms for assigning an emotional value to events perceived by autonomous agents using a set of appraisal variables. Defined as fuzzy sets, these appraisal variables model the influence of cognition on emotion assessment. We do this by changing the limits of fuzzy membership functions associated to each appraisal variable. In doing so, we aim to provide agents with a degree of emotional intelligence. We also defined a case study involving three agents, two with different personalities (as a cognitive component) and another one without a personality to explore their reactions to the same stimulus, obtaining as a result, a different emotion for each agent. We noticed that emotions are biased by the interaction of cognitive and affective information suggesting the elicitation of more precise emotions.

1. Introduction

Autonomous Agents (AAs) are software entities designed to show autonomous, proactive, and social behavior. Their underlying architectures include components that implement mechanisms of cognitive and affective processing. These AAs are capable of reasoning, learning from previous experiences, and making decisions that allow them to achieve their objectives (Marsella, Gratch, & Petta, 2010; Franklin & Graesser, 1997). A key characteristic of AAs is their ability to communicate with human and artificial agents when cooperating or negotiating to achieve common goals (Ortony, Clore, & Collins, 1988). The research community in this domain focuses on improving such underlying mechanisms of AAs and their underlying cognitive architectures.

According to Salovey and Mayer (1990), social skills are a set of behaviors that manifest themselves in interpersonal situations and are based on the domain of communication skills (verbal or non-verbal such as gestures or tone of voice). Emotions have a very important role in the development of communication skills associated with the social behavior of human beings. Furthermore, it is known that emotions also influence behavior biasing the normal operation of cognitive processes associated with intelligence (Becker-Asano & Wachsmuth, 2009; Marsella et al., 2010; Pérez, Cerezo, & Serón, 2016).

Traditionally, the definition of intelligence is associated, among other aspects, with memory and capacity to learn or to reason (Scherer, 2001). However, such definition fails to consider the importance of the emotional process known as Emotional Intelligence (EI), which is object of study in fields such as artificial intelligence, cognitive sciences, and social sciences due the influence that emotions have on human behavior. According to Salovey and Mayer (1990), emotional intelligence is the ability to manage one's and others' feelings and emotions, to discriminate between them, and use this information to guide actions and behavior. Their model includes four capabilities:

1. Emotional perception: this capability perceives, evaluates, and expresses emotions through language or behavior.
2. Tendencies of thought: the emotional state facilitates or inhibits the effects of favorable or unfavorable events altering the perspective of the individual when dealing with some action or event.
3. Emotional comprehension: it allows labeling emotions to recognize the relationships between words or actions and emotions.
4. Emotional modulation: this capability mitigates negative emotions and enhances the positive ones, without overriding or exaggerating the information they transmit.

In this context, emotions are crucial in the development of AAs endowed with coherent and consistent behavior with respect to human

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behavior. As mentioned above, humans are emotional beings. Emotions influence cognitive and affective functions underlying our behavior and intelligence (Martínez-Miranda & Aldea, 2005).

A plausible design of AAs involves the construction of a cognitive architecture endowed with mechanisms for the generation of intelligent behavior. However, this type of architecture has been designed to implement mainly cognitive functions (e.g., memory, decision-making, and reasoning), leaving aside affective aspects. It is expected that through the interaction of cognitive and affective processes, AAs may be able to replicate the intelligent behavior observed in humans and thus improving the quality and believability of their expressions (Rodríguez, Gutierrez-Garcia, & Ramos, 2016). Given the great influence that emotions have on the cognitive components of agents, it is reflected in the literature an interest in including affective components that reproduce such influence and at the same time integrating emotions with the current architectures of agents easily.

Computational models of emotions (CMEs) (i.e., software systems designed to model the mechanisms of the human emotional process) represent an effort to provide AAs with affective processing. CMEs are intended to be included in cognitive agent architectures and, in this way, provide AAs with mechanisms suitable to (1) process affective information, (2) create synthetic emotions, and (3) generate emotional behaviors (Rodríguez et al., 2016).

Integrating affective processes into an already defined cognitive architecture is a difficult task that involves many challenges. One challenge is that cognitive architectures are composed of various cognitive components that were not designed to interact with each other. Another challenge is that a cognitive agent architecture may include a varying number of cognitive components and each cognitive component projects very particular information using different structures and formatting. In addition, the information provided by cognitive components changes frequently depending on the type of cognitive function these components implement (Castellanos, Rodriguez, Castro, & Perez, 2017). The challenge is to define a mechanism for integrating affective processes into cognitive architectures and emotionally influence all the cognitive components of agents, regardless of the amount or type of information they handle, resulting in a human-like behavior.

It is also important to note that currently there are CMEs such as FATiMA, ALMA or FLAME (Dias, Mascarenhas, & Paiva, 2014; Gebhard, 2005; El-Nasr, Yen, & Ioerger, 2000), that incorporate affective mechanisms to alter their cognitive processes. However, each of them has different limitations, which according to Ojha and Williams (2017) are:

- Low replicability. Most CMEs describe their components only conceptually.
- Domain dependency. The model is only applicable in one or more predefined scenarios or domains. CMEs model emotions according to specific implementation needs. Depending on the problem, the emotional process is modeled by selecting one or two aspects of the complete cognitive-affective process (Ortony, 2003; Ana & Parada Rui, 2007).
- Poor scalability and integration. It is hard to add new components to CMEs because their design is domain-specific.

In order to solve the limitations of current CMEs and, in turn, face the challenges presented above, Rodríguez et al. (2016) proposed the Integrative Framework (InFra). The InFra was designed to create CMEs capable of generating AAs with consistent emotional states and believable emotional behaviors, integrating affective components into the cognitive architecture of AAs. On the one hand, we say that the behavior of an AA is consistent if it behaves in a similar way over time during the occurrence of the same event. On the other hand, a behavior is classified as believable, if the behavior is consistent with what a human being would have done.

The InFra resolves these constraints by designing a framework that determines the necessary components for the generation of emotions. In addition, it indicates the need for an input interface responsible for interconnecting the cognitive components of agents with their corresponding CMEs. There is also a need for an output interface to communicate the result of the cognitive-affective evaluation to those cognitive components involved in the generation of behavior (component of facial expressions, voice or body language) (Rodríguez et al., 2016). These components are inspired by models and theories that explain the mechanisms and phases of human emotions (Phelps, 2006; Ledoux, 2000). Rodríguez et al. (2016) indicate that taking into account the influence of affective states on cognitive processing gives credibility to the behavior of AAs that implements a CME resulting from applying this framework. Nevertheless, the InFra is defined at a conceptual level, i.e., its modules are described at a high-level perspective without providing computational implementation details.

The main objective of this paper is to propose a CME designed on the context of the integrative framework. In particular, the proposed model focuses on the implementation of mechanisms for the emotion assessment phase and emotion generation process. In this work, we develop a CME capable of solving the limitations of current CMEs and, in turn, define the way in which cognitive information is influenced by the emotional evaluation of stimuli perceived by agents. The resulting CME provides concrete mechanisms for representing emotional stimuli and evaluating them using appraisal variables. In addition, the proposed CME implements a mechanism that biases the emotional evaluation with cognitive information projected by cognitive components of the agent architecture. By implementing the model in the context of the integrative framework, we aim to take into account and resolve the limitations presented above regarding low replication, domain dependency, scarce scalability, and integration.

This paper is structured as follows. In Section 2 we discuss related work, explain the phases of the emotional cycle, and present a brief comparison of current CMEs according to the affective and cognitive components that determine an emotion. In addition, we describe the components of the InFra. In Section 3, we present the proposed computational model of emotion assessment influenced by cognition. A case study is presented in Section 4. Finally, in Section 5, we present some concluding remarks.

2. Related work

This work focuses on defining mechanisms to evaluate emotional stimuli and generate emotions in AAs. Therefore, in order to identify what aspects should be taken into account, it is important to define what an emotion is. This section defines emotions and the phases of the emotional cycle implemented in most AAs. We compare some existing CMEs and finally describe the role of each component in the InFra and how they relate to the emotional cycle.

2.1. Emotional cycle

Emotions can be defined as psychophysiological reactions produced in response to stimuli that an individual perceives from an event, action or object (Ortony et al., 1988). Psychologically, emotions alter attention, prioritize individual actions, facilitate decision-making and activate associative networks in memory. Physiologically, emotions determine the configuration of facial expressions, body postures and voice modulation (Ledoux, 2000; Damasio, 1995). Emotions can be regarded as a sequential cycle of three phases: emotional evaluation of stimuli, generation of synthetic emotions, and generation of emotionally-biased responses (Rodríguez et al., 2016). This perspective is adjusted with the model of Salovey and Mayer (1990) as discussed below.

Emotional evaluation of stimuli

In this phase, the stimuli that an agent perceives is identified, interpreted, and evaluated to assign them an emotional meaning. The perception process is carried out using appraisal theory, which states