Cognitive Computational Models of Emotions and Affective Behaviors

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ABSTRACT

Emotions are one of the important subconscious mechanisms that influence human behaviors, attentions, and decision making. The emotion process helps to determine how humans perceive their internal status and needs in order to form consciousness of an individual. Emotions have been studied from multidisciplinary perspectives and covered a wide range of empirical and psychological topics, such as understanding the emotional processes, creating cognitive and computational models of emotions, and applications in computational intelligence. This paper presents a comprehensive survey of cognitive and computational models of emotions resulted from multidisciplinary studies. It explores how cognitive models serve as the theoretical basis of computational models of emotions. The mechanisms underlying affective behaviors are examined as important elements in the design of these computational models. A comparative analysis of current approaches is elaborated based on recent advances towards a coherent cognitive computational model of emotions, which leads to the machine simulated emotions for cognitive robots and autonomous agent systems in cognitive informatics and cognitive computing.

Keywords: Affective Computing, Artificial Intelligence (AI), Cognitive Computing, Cognitive Informatics, Cognitive Models, Cognitive Science, Computational Intelligence, Emotions

1. INTRODUCTION

An emotion is a personal feeling derived from one’s current internal status, mood, circumstances, historical context, and external stimuli (Wang, 2007a). Emotions are a set of states or results of perception that interprets the feelings of human beings on external stimuli or events in the binary categories of pleasant or unpleasant. In order to formally and rigorously describe a comprehensive and coherent set of mental processes and their relationship, a Layered Reference Model of the Brain (LRMB) has been developed by Wang and his colleagues (Wang et al.,

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The LRMB model explains the functional mechanisms and cognitive processes of the brain and the natural intelligence. The main cognitive processes at the perception layer of LRMB are emotion, motivation, and attitude. It is recognized that a crucial component of the future generation of computers, known as cognitive computers (Wang, 2009), is a perceptual engine, which mimics the natural intelligence such as emotions and motivations (Wang, 2010; Wang et al., 2009).

It is observed that emotions influence human behavior in several ways. Emotions alter our processes of perception, attention, and decision making, enabling the development of emotionally driven responses (Damasio, 1994; Phelps, 2006; Wang, 2007a; Wang et al., 2006). Also, emotions help to determine the configuration of our facial expressions, body postures, and intonation of voice when interacting with others, revealing, via nonverbal behavior, our internal affective condition and attitudes towards situations, objects, and other individuals (LeDoux, 1989; Scherer, 2003).

Because of the multiple facets and components underlying the process of human emotions, it can be approached from a diversity of perspectives. Moreover, due to the nature of this process and its applications, emotions are currently the focus of study in multiple disciplines such as psychology, neuroscience, philosophy, computer science, cognitive sciences, and cognitive informatics (Fellous & Arbib, 2005; Phelps, 2006; LeDoux, 1989; Wang, 2007a, 2007b, 2007c, 2011, 2012a, 2012b; Wang & Wang, 2006; Wang et al., 2006, 2009, 2011). This multidisciplinary inquiry has provided evidence that shows the significance of emotions not only to the rational behavior of individuals, but to achieve more believable and human-like behaviors in intelligent systems. In particular, fields such as psychology and neuroscience have contributed a number of theories and models that explain the diversity of the emotion process. These theories are focused on revealing the mechanisms underlying the process by which humans transform external stimuli into emotional perspectives. Similarly, in fields such as computer science, cognitive informatics, computational intelligence, and artificial intelligence, researchers are interested in the design of formal and computational models of emotions that help improve artificial intelligent systems used for cognitive robots (Wang, 2010), autonomous agents (Wang et al., 2009), and human-computer interactions (Wang, 2007b). In this dual approach, computational modeling technologies are used for testing and refining psychological, biological, and cognitive models, which are further used to support the design of computational models of emotions.

The design of autonomous agents (AAs) aimed at embodying human-like behaviors has taken advantage of evidence from studies of human emotions. AAs have been endowed with mechanisms that simulate emotional processes in the architecture of Cognitive Computational Models of Emotions (C²MEs), which are biologically inspired models intended to describe human emotional functions such as the evaluation of emotionally relevant stimuli, the elicitation of emotions, and the generation of fast and deliberated emotional responses. In some cases, C²MEs focus on reproducing specific facets in this process, but in many others, they cover a more complete emotional cycle that goes from evaluation of stimuli to the generation of emotionally adjusted behaviors (Wang, 2007a).

Affective behaviors are thus induced in AAs through the embodiment of C²MEs in their cognitive architectures. This type of behavior is an observable consequence of the verbal and non-verbal responses implemented by the agent, which reflect its internal condition, emotions, attitudes, and motivations. Moreover, the implementation of such affective behavior is what enables the attribution of particular emotion labels to the emotional state of the agent, such as happiness, anger, and embarrassment. In this context, the development of C²MEs should be ultimately designed to allow AAs to implement affective behavior. In order to achieve such
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