From Biologically Inspired Model of Emotions to Strategic Expressions for a Virtual Agent

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Abstract

Several computational models of emotions have been proposed based on different approaches. Biologically inspired models developed generally for robots, consider a bottom-up approach whereas virtual agents are often based on a top-down approach. In this paper, we explore these two approaches. For the top-down approach, we analyze more particularly the problematic of virtual character's expression of emotions that should be in accordance with the social context. Finally, we attempt to propose an architecture bringing the gap between these two approaches.

1 Introduction

Although there is no consensual definition of emotion, most researchers agree with the fact that emotion comes with different reactions: an expression (facial, vocal, etc.), an action tendency, a subjective feeling, a neurophysiological reaction, and a cognitive appraisal of an event [43]. These different reactions associated to emotions imply different research fields such as Neurobiology, Physiology, Psychology, etc. Moreover, emotions emerge from different levels: emotions can be elicited from basic senses, or from memory and experience, or from social interaction for example. To model these different aspects, the cognitive approach could be supplemented by the neuroscience approach. Indeed, the biological structure of the brain serves the adaptation of the agent by selecting and interpreting information into mental, behavioral, and physiological responses. The incoming information is linked to existing structures of emotions, values, and goals [45].

To express emotions with perceptiveness on a virtual character, we should consider simultaneously the emergence of emotion and the components of emotions [22]. Firstly, the base of emotions takes place in the sensory system (including a part of the cortex, a part of the limbic system and sense organs). Secondly, the information is processed on an upper level and dispatched. In this level, the memory plays a role. Then, a post processing, slower, leads someone to think about the next action. Different levels, common to neurosciences and psychology, have been identified but their definition lacks on details. With the existing definitions of level, problems of output management appear. The time is important: emotion has different speeds of appearance depending on their type [8]. An output synchronization manager is then needed for the expression of the emotions. We should consider also that the inputs are multimodal, and so that a model should have a multicanal architecture, in which each input is processed before the neocortex mixes different senses, as in some biological pathways [20].

A combined model should handle external input (mainly from senses) and internal input which can be physiological data (blood pressure for example). For this model, we should answer the question: what stimulus for which pathway, which biological emotion?

Moreover, the final expressed emotion may also depend on socio-cultural norms or specific goals. Indeed, someone may decide to express emotions for strategic reasons. Consequently, one challenge is to combine the biological emergence of emotions and their strategic expressions by a virtual character. In the literature, two main approaches have been explored: the emergence from the neurobiology, a bottom-up approach (Section 2), and the reductionism from the psychology, a top-down approach (Section 3). To create believable virtual characters, we need to fill this gap, thanks to new pathways discovered recently. It is highly challenging to reconcile these two approaches about emotions. We propose a way to build a model corresponding to a hybrid (low level) biology and (high level) social emotions model (Section 4).

2 Biologically Inspired Models of Emotions

2.1 Theoretical background

Several researchers have shown that emotion emerges from a biological process. We can cite for example the works of Damasio [7], LeDoux [20] and more recently Ratcliffe [38] and Belzung [3]. This pathway, starting from the stimulus captured by senses, goes through different parts of the body, nervous system and brain.

Generally, in the domain of virtual characters, the models built go from cognitive model to behavior and then motor reaction (reductionism). But in affective robotics, research on emotion has focused on sensorimotor processes with the aim at modeling cognition leading to a particular behavior. In robotics, the need to have the simplest model for experiments leads the researchers to isolate an emotional pathway to another, for example the emergence of basic emotions like joy or fear. About more complex emotions, the pathway of each kind of emotion (depending of the stimulus) is often different and needs deeper study. To understand this mechanism, we can use the work of Piaget: the emotions provide the energy of development (emergence) and the cognition provides the structure [35]. The sensory motor stage is the first stage of emotional development in the model of Piaget, as in the bio-inspired robotic models.

In a microscopic level, the signals from the physiological component of emotions can pass through the neuronal system, but not only. The hormones, the neurotransmitter and neuropeptides, the other chemical signals (non-synaptic signals) are important elements for the emergence of emotions [25]. In a mesoscopic level, the behavior of neuronal networks plays a role in the mimics of a basic emotion, while in a macroscopic level, the cortico-limbic circuitry is the most important part of the brain where emotions take place, where they are dispatched. For instance, an emotional memory mechanism was found recently:

the amygdala is also the center which decides if an emotion should to be registered in a long term memory or not [14].
To observe the emergence of the emotions from a physiological background, models can be integrated into agents, especially on real or virtual robotics.

2.2 Bio-inspired models

In 90's Brooks developed a biologically inspired approach for agents, especially for robots which require to build dynamically a sensorimotor experience with an environment [5]. The work of neurobiologists and psychologists like Damasio who works on emotion preceding cognition has enabled to build computational models of emotions. The ICEA (Integrating Cognition, Emotion and Autonomy) project allowed one to put together different parts of the brain (amygdala, basal ganglia, visual cortex, etc.) modeled separately showing the emotion pathways for a simulated animal [42].

For robots trying to simulate human emotions, Lagarde and al.[19] are doing research on neuronal networks, and more particularly on time synchronization between neuronal networks and regions of the brain involved in the emotion mechanisms. In another way, Colombetti [6] and Ziemke [48] use Varela's paradigms (autopoiesis, enaction) [46] to build new emotion models based on enaction.

All these bio-inspired models have been integrated on robots or on simulated robots which are agents in a virtual environment. Concerning virtual human characters, only few models have been proposed. For instance, Velasquez [47] proposes an Emotion Generation structure based on a neuroscience approach. Grandjean and al. [12] define a model with different levels of emergence of emotional experiences.
It seems that the field of biogically inspired virtual characters is still a domain to explore.

3 Strategic Expressions of Emotions

3.1 Theoretical background

Felt versus expressed emotions. Research has shown that during interpersonal interaction, people express very often emotions different from their felt emotions [10]. People generally decide to express an emotion different from the one they actually felt because they have to follow some sociocultural norms or they are pursuing specific goals. In the literature in Psychology, felt and expressed emotions are then distinguished. Ekman [10] refers to the expression of emotion consistent with sociocultural norms, as *display rules*. The sociologist Hochschild [13] defines *feeling rules* as " social norms that tell us what to feel, when to feel, where to feel, how long to feel, and how strong our emotions can be". The expression of emotion to achieve a specific goal is called *emotional gaming* [1]. To *game emotion* means to strategically modify the expression of a current felt emotion to try to influence someone else's behavior. During an *emotional game*, one may either express an emotional state that is not being experienced (i.e. fake the intensity or type of the emotion) or not express an emotional state that is being experienced (i.e. conceal an emotion) [1]. People may choose to express specific emotions, not necessarily felt, to try to influence the other's perception.

Effects of expression of emotion on other's perception. Research has shown that the expressed emotion has an impact on one's perception of another one. For instance, as shown in [26, 17], people are perceived likable when they express happiness. Persons who express anger are perceived as more dominant but less likable [17]. In contrary, the expression of distress or fear reflects a low value of dominance [17]. Positive emotion can signal cooperativeness and trustworthiness and elicit cooperation, trust, and concession from others [23]. Moreover, people have generally expectations on the other's expressions of emotion. They generally expect that their emotional expression evokes complementary and similar emotional responses in others [15, 27]. For instance, anger should evoke fear or guilt (low-power emotions [23]), distress should evoke empathy, etc. The emotion expression of another in response to one's expression of emotion traduces the likeability of the other. If the emotion expressed by another in response to one's emotions is congruent (complementary or similarity), the degree of liking increases. In the opposite case, the degree of liking may decrease. This effect of expressed emotions can be easily explained by the fact that an expression of emotion provides information on how someone appraises an event or a situation [9]. Consequently, an expression of happiness in front of someone expressing distress may be interpreted as someone who is happy about the distress of the other.

Based on this research in Human and Social Sciences, some virtual characters have been developed to express emotions, not only to give "an illusion of life" but also in order to achieve a specific goal. We present in more details examples of such characters in the next section.

3.2 Strategic expressions of emotions of virtual characters

In the domain of virtual characters, most of the researches so far have focused on felt emotions of virtual characters [11, 40] while less attention has been paid to the emotions that a virtual character *should* express during an interaction. However, some researchers have already highlighted that virtual characters, in certain situations, have to express emotions different from their felt emotions depending on the sociocultural context and on the goals of the interaction [34, 37, 30].

Some models deal with the types of emotion an agent should express. For instance, in [32], a model has been proposed to endow virtual characters with strategies of emotion expression that enable them to identify dynamically the emotion that they should express, depending on its interlocutor's emotional reaction, to try to influence his opinion during a negotiation. In [18], a virtual character expresses empathy to advertise a music player. The results of the evaluation show that a virtual character using this emotional strategy is more convincing that a non-empathic one. This emotional strategy has been particularly studied in the context of human-machine interaction showing that the expression of empathy, in certain situations of interaction, enables to improve user satisfaction [16], engagement [16], performance in task achievement [33], and perception of the virtual agent [4, 36]. However, as highlighted [2, 31], this emotional strategy may be harmful to the interaction when it is incongruous to the situation. In [41], the authors propose a fine comparison of existing studies on the impact of emotional agents on the interaction depending on the context.

Moreover, the expression of a felt emotion is different from the expression of a fake one. Models have been developed to integrate these distinctions in virtual characters. In [39], virtual characters mask a felt negative emotion of disgust, anger, fear or sadness by a smile. Two types of facial expression were created according to the Ekman's description [10]. The first expression corresponds to a felt emotion of happiness. The second one corresponds to the other expression (e.g. disgust) masked by unfelt happiness. In particular, the expression of unfelt happiness lacks the action unit 6 (AU6) activity and is asymmetric. A perceptive test has enabled the authors to measure the impact of such fake expressions on the user's subjective impression of the agent. The participants were able to perceive the difference, but they were unable to explain their judgment. The agent expressing happiness was perceived as being more reliable, trustable, convincing, credible, and more certain about what it said compared to the agent expressing a negative emotion masked by a smile. Niewiadomski and Pelachaud [28] proposed an algorithm to generate complex facial expressions, such as masked or fake expressions. An expression is a composition of eight facial areas, each of which can display signs of emotion. For complex facial expressions, different emotions can be expressed on different areas of the face. For instance, it is possible to generate an expression of sadness masked by anger.

In conclusion, to create social virtual characters able to follow some socio-cultural norms or to express emotion to try to achieve a specific goal, both a high-level representation of emotional rules and definitions of specific expressions of emotions (corresponding to a mix of felt and faked emotions) have to be considered. One challenge is still the development of models linking the biological aspect of emotional emergence and this social aspect of emotion. In the next section, we attempt to propose a mutli-levels architecture to try to response to this problematic.

4 Combining Biologically Inspired Model of Emotions and their Strategic Expressions

4.1 Multi-levels architectures

Different researchers have proposed computational models of emotions with several levels. These levels represent the levels of processing of information, from input to output. In these models, there are many outputs, one output for each type of emotions (more or less subjective, basic, complex). Norman defines three levels of processing: visceral, behavioral and reflective [29], while Sloman increases the number of layers and signals between layers [44].

Lisetti and Marpaung [24] proposed a model based on Leventhal and Scherer's theory [21]. This model could be adapted to fill the gap between neurobiology and psychology, if the levels are associated cleverly with parts of the brain controlling emotions. The three levels of this model are:

- *sensory motor level* - generates the primary emotion in response to the basic stimulus features in a non-deliberative manner;

- *schematic level* - integrates specific situational perceptions with autonomic, subjective, expressive and instrumental responses in a concrete and patterned image-like memory system;
- *conceptual level* - corresponds more closely to social labeling processes.

At the schematic level, the lifetime of the emotional reactions is longer than at the sensory motor level because it integrates learning processes and memory. At the conceptual level, the agent makes conscious decisions or choices which are slower than at the other levels. The information contained at this upper level is more abstract and includes strategic expressions of emotion of the agent.

4.2 Towards a hybrid model

Based on the research presented above, we propose a framework for a computational model of emotion. This model should be a hybrid model covering all the parts of the emotion definition. To try to find an equilibrium between the bottom-up and the top-down approaches, we propose a multilevel model. To fit in the neurobiology emergence of emotions, we should consider at each level biological aspects of emotions. For instance: in the sensory motor level - organs, senses, a part of the central nervous system; in the schematic level - limbic system, prefrontal cortex and a part of the neocortex; in the conceptual level - neocortex... Overall it looks like a McLean description of the human brain in three brains (the reptilian complex, the limbic system, and the neocortex), but with some differences.

The strategic expression of emotions could take place in the conceptual level. The representation of social norms (feeling rules) could be a problem since the socio-cultural norms are generally implicit and not explicitly listed. The fact that expression of emotions influences felt emotion could be seen as a link between one of the outputs and the internal input of the agent. Two inputs could be defined in the model: external and internal. Three outputs could match the three levels, with maybe a post processing for time synchronization.

With such kind of hybrid model, we hope to develop a program that allows us to put easily strategies into virtual characters. We hope these characters will be more believable due to their emotion management as a part of their virtual brain.

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