# Emotions in the models of Artificial Intelligence

**Cveta Martinovska Bande**

Computer Science Faculty, University Goce Delcev, North Macedonia

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***Abstract-***This paper investigates the aspects and interpretations of emotions, which might contribute to creating intelligent systems. Recent findings in different scientific disciplines suggest a new view of the relationship between cognitive processes and emotions. Emotions are no longer seen as mental qualities that limit rationality. It is now understood that emotions play a critical role in intelligent behavior and offer a great potential for designing artificial agents and more natural and expressive interactive technologies.

***Index Terms***- Emotions, Cognitive Processes, Emotional Robots, Affective Interfaces

## I. Introduction

The idea to implement emotions in machines was present from the early years of the Artificial Intelligence. Researchers have been suggesting that emotions are essential to achieve intelligent behavior [1] [2].

According to McCarthy "ascribing mental qualities to machines is acceptable if it contributes to the comprehensibility of their functions and behaviors, but the anthropomorphism should not include emotions" [73].

The interest in emotions as elements of agent architectures has grown dramatically in the past 20 years. The initiators of this interest are several works that explicitly emphasize the importance of emotions [3] [4] [5].

The conferences organized by Cañamero, the simulation of adaptive behavior conference SAB'98 [6] and AAAI'98 conference [7] have significant influence on recognizing the potential of emotions for creating intelligent systems.

Neurological studies of Damasio [3] and LeDoux [8] confirm the interaction of the brain regions involved in emotion and cognition processing. The studies of Damasio have shown that emotions influence the decision-making process, social conventions and moral principles.

According to LeDoux the limbic system, which is the "seat of emotions", responds to the urgent events before the cortex is involved. If relevance is determined the limbic system sends signals both to the body, inducing physiological responses, and also to the cortex, biasing attention and other cognitive processes.

## II. Cognitive processes and emotions

The relationship between the human cognitive processes (thinking, memory, learning) and emotions is investigated in several disciplines.

Studies of thinking include psychological investigations concerned at most by inductive and deductive reasoning, decision-making, problem solving and analogy [9]. Traditional approaches to thinking are based on abstract logical reasoning and context independent rules. Recent approaches take into account the characteristics of the context.

Experiments have shown that humans are not logical reasoners that use general rules of logic. On the contrary, humans make errors that are explained by encoding and processing theories.

Traditional logic says that content and context are irrelevant to the reasoning process but human errors show the opposite. According to the situated approach to thinking we do not have general strategies but the context influences the process of thinking and gives constraints. Similar approach to the situated cognition is the one that proposes embodied cognition, according to which cognitive processes are optimized for particular sensorimotor activities.

Evolutionary psychology is another approach to domain-specific reasoning, which posits specific modules selected by evolution to solve complex reasoning tasks.

In Artificial Intelligence the notion of logical rationality is different from economic rationality [10] [11]. Logical rationality is concerned with the process of reasoning and economic with the process of decision-making. Logical approach to reasoning is deductive inference while the main interest of economic rationality is to select the optimal alternative from the available alternatives.

Experiments have shown that humans systematically violate the axioms of the normative decision theory. Especially important for this work is the descriptive approach of the decision theory that studies human decision-making taking into account the psychological and sociological findings. In real world situations the decision-making process is based on imprecise and uncertain information. Fuzziness often comes from the imprecise assessment of the environmental situations.

Many of the memory and learning models in Artificial Intelligence are based on psychological theories [12] [13].

There are many approaches to study the emotions: biological, behavioristic and cognitive.

Studies of the human intelligence reveal that emotions interact with the mental processes that are central to the intelligent behavior, such as thinking, memory, learning, motivation and attention. Neurological findings suggest that emotions have an important role in the decision-making process [3] [8].

## III. Models and frameworks that include emotions

In [14] Scheutz proposed 12 potential roles of emotions in artificial agents, including: action selection, adaptation, goal management, memory control, sensor integration, self-modeling, motivation, and so on.

According to Wang [15] there are two approaches to incorporate emotions in robotics: as a link between the external environment and the internal state of the robot [16], and as part of the evaluation mechanism in the robot's learning process.

As a link between the internal and external environment, emotions can facilitate human-robot interaction because emotions carry important information from the robot to the environment and because emotions can reflect the influence of various environmental factors on the robot [17]. The other approach of using emotions emphasize that emotions can be used to adapt a robot to new situations in the environment. In addition, robots can learn and adapt to new people, which can be excellent feature in human-robot interaction. As stated in [18], the use of emotions can enhance many socially important traits of robots such as: autonomy, adaptability, learning ability and personality traits.

Information about the emotions, which may be present in the robot's internal or external state, can be used in planning [19] [20]. Emotions can be involved in the evaluation mechanism of the robot's learning process [21], which can speed up learning and encourage adaptation in the robot's behavior. For example, emotional feedback can be used for robot adaptation in the process of interaction with humans [22].

At the highest level, the role of emotions in robots is to contribute to the robot's autonomy [22] [23]. The robot is autonomous if the system can achieve the goal without human intervention or the intervention of another system. Characteristics of autonomous robots are self-learning, self-control, self-motivation, etc. [24].

The emotional influence on the decision-making process in mobile agents is modeled in [25] and the influence of emotions and moods on the decision-making process in the reinforcement learning system in [26] where the agents are more or less optimistic depending on their positive or negative moods.

Araujo [27] described a system for modeling the effects of mood on memory that consists of cognitive and affective neural network. Some researchers suggest that emotions might play an important role in agent autonomy [28] [29]. The influence that emotions have on agent's motivations is used to create synthetic characters [30]. Bozinovski [31] is concerned with the relation between motivations, emotions and expectations in adaptive systems.

The fact that emotions can focus the agent attention on relevant events, involving interruption or modulation of the current activity suggests that emotions have influence on perception [32]. The adaptive role of emotions is recognized by Darwin. According to Darwin emotional expressions serve to communicate information that is important for a survival of the organisms.

The role of emotions in social interactions is investigated from different perspectives. In synthetic characters emotions are implemented to achieve an illusion of life [33]. Besides emotions, personality traits are some of the key issues that have to be addressed in creating believable characters [34] [35].

A variety of applications that use emotional agents are described, including video games, educational software [36] and training environments [37].

Kaiser and Wehrle [38] designed a tool for generating experimental computer games, Geneva Appraisal Manipulation Environment, to analyze the cognitive processes (as for example problem solving) and emotions in microworlds. They use questionnaires and dialogs for measuring user emotions and record videos of the behavior and facial expressions induced during the game.

The project Emovox investigates the variations in speech that are connected with the emotional states [39].

Ball [40] uses Bayesian network to infer the emotional state according to some characteristics of the vocal expression. Experiments confirm that the intensity of the emotions might be coded with the pitch and energy level while detecting the emotional valence from speech is not reliable.

The researchers in robotics investigate different interpretations of the emotions. In entertainment robots, as for example animal-like AIBO robots or humanoid Sony's SDR [41] ethological and emotional studies contribute to creating believable behavior. Motives that are connected to goals determine the action selection and emotions modulate the selected behaviors [42].

Breazeal [43] uses emotions and drives to regulate and maintain the human-robot social interaction. Drives are connected with the robot goals, and emotions with the achievement of the goals. Through sensors, the robot Kismet is able to find the user and some objects in the environment and to react with facial expressions, movements and meaningless speech with affective intonation. The idea is that if the user treats the robot as similar to her, she will be able to understand and predict robot behavior.

The robot Yuppy [44] responds to certain situations by emotional expressions. The drive system controls the internal variables connected to the temperature, energy and the level of interest.

Other robot architectures use emotions as control mechanism of the goal achievements [45] [46].

There are agent architectures based on the decision-making theory, as for example agents based on the dynamic decision networks [47] and affective, socially intelligent agents that incorporate emotions in the formal definition of the rational agents [48].

In [49] agents use emotions to evaluate the states and action tendencies. They define emotion learning as a type of unsupervised learning, where emotions are internal mechanisms that guide the agent behavior. Emotion learning agents might be described as consequence driven agents that learn without advice or reinforcement.

There are several important models that are conceptually and theoretically defined, but so far only some of them have been implemented in existing robots. The Traits, Attitudes, Moods, and Emotions (TAME) model of affective behavior was proposed by Moschkina and Arkin in 2003 [50]. The goal was to lay the groundwork for creating intelligent robotic behavior that would improve human-robot interaction.

The Framework for systematic study between emotion, adaptation and reinforcement learning (EARL) was proposed by Broekens in 2007 [51]. This framework models the relationship between emotions and learning in emotional robots.

## IV. Affective interfaces

Animated agents that recognize and express emotions, provided with a personality and a social competence, and with verbal and nonverbal abilities represent a new approach to creating natural and efficient interfaces.

Several projects describe embodied conversational agents, like REA [52], Steve [53], DFKI Persona [54] [55], pedagogical agents of Lester and his colleagues [56] [57] [58].

Affective modeling is concerned with recognition and expression of emotions, personality traits and moods. Emotions are accompanied by visually perceptible behaviors, facial expressions and vocal characteristics. Although facial expressions for basic emotions within a culture are consistent according to Ekman, individual differences may also be important. Individual characteristics, like personality traits, goals and expectations as well as social conventions can influence emotion expression.

Vocal characteristics like pitch, rhythm, amplitude and duration of changes provide data for emotional arousal and valence. Sad or bored person speaks slowly, with lower pitch and little high frequency energy. Emotions like fear, anger and happiness are characterized with louder and faster speech, and strong high frequency energy [5].

Several MIT MediaLab projects describe methodologies for affect recognition through physiological and nonverbal channels, like: facial expressions [59], skin conductivity response [60], pressure sensing mouse that detects user frustration [61]. Healy and Picard [62] measure skin conductance, respiration, muscle activity and heart activity to detect driver's stress. Kaapor, Mota and Picard [63] describe student engagement during the interaction with animated instructor observing eyelid movements and body posture. Vyzas and Picard [64] show that jaw muscle activity, blood pressure, skin conductance and respiration can be used to differentiate between eight emotions.

Hudlicka and McNeese [65] identify air force pilots anxiety based on the situation assessment (difficulty and risk), events, individual characteristics (personality traits, experience and skills) and heart activity. They use fuzzy heuristic rules and propose different weights for the described factors.

A lot of studies describe affect expression through different modalities, as for example facial expressions [66]. Cahn [67] proposes a program that includes affect in synthesized speech.

The same information might be expressed using different linguistic styles that reveal the agent personality [68]. Linguistic style consists of semantic content, syntactic form and acoustical realization.

Some authors suggest that affective interfaces might be used to recover from negative emotional states that appear during interaction with computers. CASPER [69] detects user frustration and expresses empathy and sympathy to the users.

Pelachaud and her colleagues [70] use emotional facial expressions to induce certain user reactions. For example, asking for something with a sad emotional expression will motivate the user to respond positively.

Humanoid emotional robots such as Sophia [71] and Nadine [72] have also become popular in recent years. These robots are very similar to humans in physical appearance. Nadine is the first robot in the world to work as a customer service agent.

## V. Conclusion

With the aim to construct intelligent machines AI researchers tried to model reasoning, problem solving, learning and other processes that are central to intelligence. Under the influence of recent findings about the role of emotions in human intelligence the potential of emotions for designing intelligent agents and interactive technologies is recognized. Emotions are believed to interact with all the aspects of the intelligent behavior, particularly with decision-making, perception, memory and other cognitive processes.

Different roles and interpretations of emotions are investigated in AI, like the role in agent autonomy, control in accomplishment of the goals, achieving believable behavior, evaluation of environmental states and agent action tendencies.

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## AUTHORS

**First Author** – Cveta Martinovska Bande, PhD in Computer Science, Computer Science Faculty, University Goce Delcev, ul.Krste Misirkov, 10-A, Shtip, North Macedonia
cveta.martinovska@ugd.edu.mk
+ 389 78 207 763