Human Emotion and Machine Emotion - Studies of Emotion in AI

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***Abstract*—Artificial Intelligence (AI) is undoubtedly a hot word in the field of contemporary art in recent years. The consciousness, intuition and emotion of AI have attracted the attention of artists in particular, and many art works have explored this topic. Does AI have the emotional characteristics of humans? Is the emotion of AI equal to the emotion that defines human beings? This paper attempts to step out of the anthropocentric perspective, examine the boundary and relationship between human emotion and machine emotion, and inject a new theoretical perspective into the AI artistic practice. This paper first discusses what emotion is in the biological sense, analyzes whether a machine can have emotion from both positive and negative aspects, and puts forward the definition of "machine emotion". This paper also reviews some theories and practices related to emotion in the AI field. The conclusion of this paper is that although artificial intelligence cannot possess human emotions, it can possess "machine emotions" beyond the narrow sense of human emotions, and the construction of emotional mechanisms inside AI may become a new research direction in this field.**

Keywords-Emotion; Artificial Intelligence; Machine Emotion.

I. INTRODUCTION

Picard [27] told the story that children think Barney the toy dinosaur produces emotions, and Barney's conscious expression encourages them to believe that Barney has emotions. As far as we know, children have always attached their emotions to dolls and stuffed animals, and we all agree with the experience that toys never have and cannot have emotions. So, drawing an analogy between a toy dinosaur and Artificial Intelligence (AI), we have to ask: why would humans think about whether AI can have emotions?

Arkin [3] believes that roboticists mostly focus on pragmatic functionality and ignore emotional features. As humans demand more of AI's ability to communicate, researchers are increasingly assigning some of the characteristics of human emotions to machines. So, are the emotional features of the AI (as Barney the dinosaur) merely empathic effects of human beings projecting their own emotions onto the machine? However, the emotional interaction between AIs and humans goes far beyond what humans and toys can do, and AI's emotional capacity brings to mind the term "machine emotion". At this point, it seems necessary to re-examine the definition of human emotion. Is the definition of emotion based solely on anthropocentrism insufficient to include machine emotion? Can we go beyond human or biological emotions to redefine machine emotions? These are the questions that this paper wants to discuss.

In Section 1, we discuss the emotion in the general biological sense from the aspects of its origin, definition and classification. In Section 2, we argue the motive and purpose of humans giving emotion to AIs, and then analyze whether AIs can have emotion from both positive and negative aspects, and put forward the definition of "machine emotion". In Section 3, we review human-based and machine-based emotions ontologies. In Section 4, by reviewing relevant literatures in recent years, we find that more and more researchers are trying to explore the construction of "machine emotion" inside artificial intelligence machines. The last section is the conclusion of this paper.

II. WHAT IS EMOTION

From a neurobiological point of view, the source of emotion lies in the tight interaction between the amygdala and the cerebral cortex [2]. We know that the emotional expression of organisms is directly related to the transmission of facial expressions, which belongs to the emotion within organisms. In brain movement, the observation of facial expressions can activate the amygdala. If the amygdala is damaged or defective, it will lead to confusion of emotional expression, making it difficult to observe and recognize facial expressions [31]. The amygdala and the prefrontal cortex of the brain are also involved in the construction of social emotions, which are key components of social interaction [10]. The amygdala, for example, is the mechanism by which organisms make judgments about sensory events by triggering the system of expectation, punishment or evaluation associated with emotion, in response to neural stimulation.

Different scholars define emotion from different angles. Mayers [24] defined emotion by relationship between emotion and body: "Emotions are our body's adaptive response". R. Lazarus and B. Lazarus [21] laid emphasis on how emotion reacts to external environment: "Emotions are organized psycho-physiological reactions to news about ongoing relationships with the environment". Plutchik [29] deemed that emotions are involved in all parts of the link from psychological to actual actions, a continuous status: "Emotion is a complex chain of loosely connected events which begins with a stimulus and includes feelings, psychological changes, impulses to action and specific, goal-directed behavior".

Nowadays, there are two major emotion classification models. One is basic emotion theory, and the other is emotion dimension theory. In the context of psychological science, the concept of basic emotions is deemed as a classification that defines a group of similar emotions with specific color. Emotions are marked by extents such as joy, happiness, or ecstasy [19]. Ekman proposed that the "basic" term has three layers of indication: first, the perspective of basic emotions could help us to distinguish those perspectives that believe emotions are consistent and only differs in intensity and extent of joy, such as some simple classifications that counterpose negative and positive emotions; second, basic emotional states reflect the fact that emotions are of adaptive value evolution when dealing with basic life tasks. It is embodied in human's status when they handle repeated tasks (such as, response to interpersonal relationship, response to emotional reaction to personal life. Basic emotional states are also related to our intuitive characters and life experience); third, basic emotions are also used to describe components that constitute complex emotions. For instance, smugness might be considered to be a blend of the two elemental *emotions, happiness and contempt* [12].

Many scholars have tried to classify basic emotions (for some attempts in this direction, see [4][11][17][25][28][38]-[41]. For example, facial emotions of human, according to Ekman's model, have six identifiable basic emotion states, which are, respectively: Anger, Fear, Distress/Sadness, Enjoyment/Happiness, Disgust, and Surprise [11]. Silvan Tomkins [38]-[41] describes innate emotions that are exhibited by toddlers since birth as affects: anger, embarrassment, sorrow, fear, interest, happiness, surprise, disgust. In Minsky's six-element model, it is believed that basic emotions include empathy, envy, love, aggression, awe, respect [25].

In psychological science, there is another classification model called the dimensional emotion, which is frequently utilized in recent emotion measurement research. The dimensional emotion uses some indicators to measure emotional intensity - the extent of how behavior is affected by emotions, such as stimulation, energy, and activation [19]. The first scholar who proposed emotion dimension theory is Russell. He believed that emotions could be indicated and measured by two dimensions of a circumplex: 1) valence, which indicates extent of joy when an individual experienced the state; 2) arousal, which indicates possibility of the individual to take certain action due to its specific state [18].

Afterwards, many scholars conducted their development and exploration about dimension models of emotions [23][28]-[30][36][37]. Thereinto, Thayer's circle of emotion, Plutchik emotional wheel and Lövheim's cube of emotions are regularly used in recent research [13][32][33][43].

III. WHETHER MACHINES CAN HAVE EMOTIONS

A. Why do humans endow machines emotions?

Why do humans endow machine with emotions? Picard [27] identifies four motivations for human beings to endow machines with certain emotional abilities: 1) The first goal is to build robots and synthetic characters that can emulate living humans and animals – for example, to build a humanoid robot; 2) The second goal is to make machines that are intelligent, even though it is also impossible to find a widely accepted definition of machine intelligence; 3) The third goal is to try to understand human emotions by modeling them; 4) The fourth goal is to make machines less frustrating to interact with. All four of Picard's motivations seem to be human-centric: hoping machines become more human-like in appearance, intelligence, and behavior, and further exploring the intellectual pedigree of human emotions through machines.

Arbib and Fellous [2], on the other hand, point out four reasons why people are interested in giving emotions to machines from the perspective of anthropocentrism: 1) the current technology already shows the value of providing robots with 'emotional' expressions (e.g., computer tutors) and bodily postures (e.g., robot pets) to facilitate human–computer interaction; 2) They raise the question that the value of robots in the future may not just be to simulate human emotional expression, but to actually "have emotions"; 3) It, in turn, requires us to revisit the neurobiology of emotion to generalize some new concepts, because what we know was first proposed for humans and then extended to organisms and machines, which makes it interesting to study emotions in robots; 4) It suggests that building "emotional robots" can also provide a novel test-bed for theories of biological emotion. Arbib and Fellous posed a series of related questions: Will machines in the future actually "have emotions", in addition to imitate human emotional expression? Will theories and concepts based on human beings (e.g., neurobiology, biological emotion theory) lead to new research directions with the birth of robots? This article can't help but ask a further question: how to define "having emotions"? Can robots be included in the category of "living things" like humans and animals? Does "having emotions" mean that robots produce emotions, or even thoughts, that are independent of humans?

B. Machines cannot have emotions

Opponents often argue that machines cannot have emotions in three ways: First of all, the emotional transmission and recognition system of the machine is related to its ability to comprehend, recognize and execute tasks. However, when the designers put too much emphasis on the technical execution of the machine in terms of communication and cognition, this shaping method exposes certain emotional defects. As stated by Parisi and Petrosino [26], the actions of existing "emotional robots" are controlled by symbolic, role-based systems.

Second, AI is based on, but also limited to, human emotions. Becker [5] 's research explores the passive role of machines in human-computer interaction. According to him, machine's emotion is positioned only in its ability performing in activities of social networks; AI entities are artificial objects constructed according to the model of human communication and cognitive ability. They have no personality and are relegated to being an interaction partners of humans.

For example, the Embodied Conversational Agents (ECAs) project attempted to build embodied emotional entities of AIs. In order to enable machines to generate special activities related to human emotions and to regenerate new activities reconstructed by the machine itself, ECAs classifies human emotions to construct samples for emotion recognition. Through psychological experiments, they set up seven basic emotions, including "angry, sad, happy, frightened, ashamed, proud, despairing" [34]. However, Becker [5] believes that these patterns of subjective feelings and the variety of associated physiological processes are only taken into account in a highly reductionist manner. On the one hand, ECAs takes human beings as the basic reference model for the emotional entities of AI, which is an extension of human emotion based on machines. On the other hand, it also reflects the human-centered perspective in the process of emotion observation. Therefore, machine emotions, which are set as samples, have regular processing patterns that limit the scope of machine emotions. Becker [5] believes that when a human makes an observation based on his perspective and interest, he can get the specific emotion he wants to collect. This is a perspective from the observer, which implements a certain dominance for machine emotion. Then, the "emotion" generated by the emotional robot is derived from the designer's understanding and construction of the human emotion model. The ability of machines to perform

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emotional tasks contributes to the misconception and illusion that machines have emotions.

Finally, from the point of view of motivation selection, the machine is not capable of producing emotion. The implementation of behavior is directly related to biological motivation. When organisms face competition among various motivations, they will make a choice and trigger strategic emotions.

Arbib's Schema Theory reveals the generation process of various biological motivations and analyzes the strategic emotions caused by biological selections of behaviors. With the praying mantis as a model, he explained that the actions of organisms are not only affected by the changes of external environment, but also related to the visual stimulus situation in which the praying mantis is located, the internal variables of the living body, and the existing experience about the stimulus [5]. Compared with motivation, emotion can provide organisms a more efficient, accurate and rapid channel for their actions [5]. Emotions arise from biological body/brain sensations that present a special state when a creature makes a choice among motivations [5]. For example, feeding and mating are competitive behavioral motivations among different activities of organism. Emotional states, then, combine the creature's perception of the external environment to help it make choices and act on them.

Fellous and Arbib [14] argued that machines could not be considered as having emotions at this point, because they could not control their own behavior to make motivational choices in a given situation. Moreover, in the construction system of AI, motivation is the driving mechanism of the machine and the main manifestation of functionality. The motivation control of artificial intelligence lies with the designer and its communication user. The robot only realizes the technical action, and there is no strategic or motivational response action. As Parisi and Petrosino [26] put it, if a robot does not have autonomous motivation, it will not have emotions.

C. Machine emotion

Arbib and Fellous [2] divide the application of emotion in AI into two parts: one is the external aspect of emotion, which refers to the emotional expression made for communication and social collaboration; the other is the inner aspect of emotion, which can influence behaviors (such as action selection, attention and learning).

Researches concerning the external (or social) aspects of emotion, following the anthropomorphic tendencies, promote the production of robots with emotional and empathic relationships between robots and human beings.

Researches concerning the intrinsic (or individual) aspects of emotion focus on the production of robots' subjectivity whose behavior is influenced by endogenous regulatory processes modelled on natural emotion regulation mechanisms [8]. Parisi and Petrosino [26] point out that "current emotional robots can express emotions or recognize our emotional expressions, but they cannot be considered to have emotions because emotions do not play any functional role in their behavior". According to them, AI that simulates or identifies human expressions of emotion is not considered to "have emotion", but only if it interferes with and influences behaviors. In other words, the inner aspect of emotion more closely meets the criteria that "AIs have emotion".

Giving a robot a mechanism of subjective emotional regulation is considered to be an attempt to truly generate "artificial emotion" [8]. In sum, machine emotion is not the same as human emotion. However, machine can form an autonomous regulation mechanism just like human beings, which can play an important role in influencing its behaviors.

IV. THEORIES ABOUT EMOTIONS AND MACHINE

A. Picard's 4 emotional components

Picard [27] believes that the four emotional components of human beings could be a part of machines, thus, to help machines to better adapt to human beings. The components include emotional appearance, multiple levels of emotion generation, emotional experience and mind-body interaction. The first component she proposed, emotional appearance, includes some actions and behavior with emotional appearance expressed by systems. Machines could simulate facial expression, voice, and physical language of human beings to express emotional appearance similar with the emotion expression of human beings. Such emotional appearance is based on learning by machines of human beings' emotion appearance data, thus enabling the establishment of communication mechanism with human's emotions.

The second component is "multiple levels of emotion generation": human's emotions are of different levels. Different external stimulation triggers different levels of reactions. Machines could use this rule to learn about emotions of human beings, or synthesize an internal emotional status tag for themselves to trigger appropriate reactions. Emotion levels include quick-response sub-consciousness, moderate- response and acquired pre-consciousness, and slow-response reaction generated by rationality [27].

The third component is emotional experience, which actually relates to AI's cognition about the emotional field of its own. Emotional experience refers to the generation by machines of emotional status and series of feelings similar with those sensed by human being. Moreover, machines could also sense the thing their bodies are doing [27]. Though "human feelings" is definitely different from "machine feelings", machines could use such feelings and experience to adjust and improve their behavior.

The fourth component is mind-body interaction: emotions include both physical system changes outside and inside the brain. The interaction between emotions, bodies and cognition status is very active. For example, when someone's required to express love, his behavior of telling truth or a lie is totally different. In other words, emotion expression of his body is selectively interfered by status of telling truth or lie. "If a machine wants to copy human being's feelings, the extent of such copy must involve components like signals and adjustment of such emotions. They constitute interactive connection between the body and mental status" [27].

B. Somatic theory and appraisal

In psychology science, there are two major theoretical factions in discussion about emotions: somatic theory and appraisal. The somatic theory fraction believes that emotions are prior to the cognitive processes: "Before analyzing a sensed entity or even recording of any impressions, the brain could instantly call for emotions related to such entity" [19]. Cañamero [7] proposed that emotions (at least part of emotions) are mechanisms used by biological factors against the environment. This makes generation of autonomy and adaptation easier. Bellman [6] agreed with Cañamero's opinions. He believes that animals

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with emotions could survive better than animals without emotions. Cañamero [7] proposed that emotions' function in this aspect could be applied to design an autonomous robot. Emotions could enable robots to: 1) react faster; 2) make better decision about choosing among several options; 3) send signals about important events to others.

The appraisal, on the contrary, believes that analysis on process of cognizing stimulation is prior to generation of emotions. Many scholars who research on machine emotions build their emotion model with appraisal as the starting point. Some researchers do their consideration from the actual aspect of engineering. They deem that the function of emotions in cognition (see Figure 1) could strengthen the robots' expression in the establishment of emotion models [7][15]. Furthermore, it has been proven by neurological research that emotions' influence to human beings does not interfere with rationality. On the contrary, emotions are of critical function to some basic rational behavior in our general understanding, such as perception, learning, attention, memory and some other abilities [1][9][22]. Gadanho and Hallam [16] deem that emotions could also affect several basic cognition mechanisms like perception, attention, memory and reasoning.

Gadanho and Hallam [16] further proposed that some features of emotions could be transferred to AIs:

a) Attention control: emotions could, by affecting perception and reasoning mechanisms, force the subject to focus on the most urgent problems;

b) Adaptability strengthening of the subject: emotions could check on behavior of the subject, thus to change plans and actions of the subject when necessary;

c) Memory filtration: emotions could better call up memories consistent with current emotion status. Such memory could help the subject to learn about happiness or sadness they once experienced, thus influence the final decision.

d) Reasoning auxiliary: the actor's emotion system could rapidly acquire perceptive clues that could be used to guide acquisition of cognitive information, so as to support thinking of the cognition system.

e) Behavior trend related to certain emotional scenes or even rigid response: these built-in responses enable automatic triggering of appropriate behavior under urgent circumstances, and thus avoid spending unnecessary time on complicated reasoning.

f) Physiological activation of body: intense emotions are usually related to energy release of anticipated necessary action response. Its application into AI system could include adjustment to system parameters, such as speed of behavior actions;

g) Support to social interactions: emotion expression enable individuals to deliver information essential to their own survival to others, thus gives it high value of adaptability.

It is deemed by many scholars that emotions could affect cognition process, especially in two aspects of issue-solving and decision-making [9] [26] [44]. For them, the most basic and common function of emotions is to "realize more efficient operation of the intentional decision-making mechanism of the body" [26].

Cognition is a periodical behavior that could be classified into several levels. For example, Sloman [35] proposed that cognitive behavior of robots include three major stages: 1) reactive (direct actions); 2) review stage (selecting better and more effective behavior among optional behaviors); 3) integrated management (allowing monitoring, classification, evaluation and control on internal stages). Moreover, Ortony also analyzed mutual influence, motivation (action trend) and cognition (definition) of emotions, as well as three-stage behavior in information processing, respectively are reactive (electronically set action mode- primary level emotions), daily (practiced automatic behaviors- primitive emotions), and reflex (senior cognitive functions, comprehensive cognition, non- consciousness, self-reflected- high level emotions). If third-stage cognitive capability is realized, robots would be required to be capable of handling tasks without preset rules in unpredictable environment. Such machine could be enabled of curiosity and self-awareness, so as to get better ability in problem-solving.

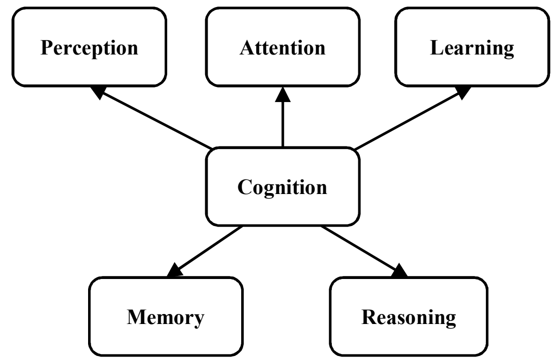

Figure 1. Five aspects of how emotions affect cognition

V. THE STUDIES OF EMOTION IN AI AREA

As mentioned earlier, machines that simulate or recognize human emotional expressions are not considered to have emotions, but are considered to have "machine emotions" only when a machine, as human beings, generates an autonomic regulatory mechanism that plays a role in influencing the machine's behavior planning. It is found that, although many studies of emotion in AI area still focusing on making AI stimulate or recognize human emotional expressions, more and more attempts and explorations have been made in recent years to construct "machine emotion" inside AI machines.

Parisi and Petrosino [26] built an emotional circuit with a neural network to control the behavior of the AI. This mechanism would allow the AI to make more accurate motivational choices. The neural network can break through the rules of motivation and behavior set by human beings and activate the robot's motivational decision-making and emotional representation in response to the situation. This emotional state, dominated by virtual dialogue, can realize machine function in different ways of, from executing aimlessly to behaving under multiple motives. In addition, thanks to AI's computational and mechanical mechanism, it can disassemble the original motive selection of human beings or other creatures with the help of algorithm. According to evaluation theory, among several competing motives or emotions, AI can evaluate the next action that human beings or other creatures are about to take. This decision is made by the AI, which will react to the motives or emotions and affect the future actions of the living creature.

In addition, some studies try to build a bridge between physiological emotions and computer computation. They try to reflect changes of some neuro-modulating substances in human bodies through number changes of computer computation, so as to present own emotion changes of machines. For example, Kugurakova, Talanov, and Manakhov [20] tried to build a human-simulated subject which has internal emotional statuses, can make responses to emotional stimulation and may show emotions such as sympathy or infringement towards the one it talks with. As believed by them, the real AI feelings need a complicated structure which can decide responses and emotional states of a machine subject. Based on the Emotion Rubik's Cube theory of Lövheim and the chemical and physiological process mechanisms in human brains, they simulated dopamine, serotonin and noradrenaline in a machine model and manifested machine emotions through changes of these neuro-modulating substances. Vallverdú, Talanov, Distefano, Mazzara, Tchitchigin, and Nurgaliev [43] proposed a similar model: Neuromodulating Cognitive Architecture (NEUCOGAR). NEUCOGAR, "based on the architecture of Von Neuman, aims to recognize the mapping from influences of serotonin, dopamine and noradrenaline to computer programs, so as to realize emotion phenomena which can be operated in a Turning machine model". Different from the research of Kugurakova, Talanov, and Manakhov, they expanded the Emotion Rubik's Cube of Lövheim using indexes of the architecture of Von Neuman.

Besides reflection of machine emotion changes based on neuro-modulating substance changes in human bodies, some scholars tried to use some tools, such as variable fuzzy sets and fuzzy cognitive maps, to compute original data, reflect changes in machine emotions, predict these emotions, design an emotion decision making system, etc. For example, Fan Deng, Su, and Cheng [13] presented a prediction model of machine emotions based on emotional dimensions and the theory of variable fuzzy sets. As found in the research, any original data input can be computed by a variable fuzzy set, which provides a mathematical method to express emotion changes which are quantitative, gradually qualitative and mutation qualitative. For another instance, in the thesis published by Salmeron [32], based on the Thayer's emotion model and Fuzzy Cognitive Maps (FCMs), a new method was proposed for prediction of machine emotions and design of an emotion decision making system. As found in his research, machine emotions can be predicted by original data generated by a FCMs sensor. Based on this paper, Salmeron [33] proposed again in 2015: taking Fuzzy Grey Cognitive Maps (FGCMs) as an effective tool to predict machine emotions of an autonomous system immersed in a highly uncertain and complicated environment.

VI. CONCLUSION

As early as 1950s, Alan Turing already asked the question "whether a machine can think" [42]. A lot of researchers have explored this topic, while "emotion" has always been mentioned in particular as the most outstanding feature that can distinguishes humans from machines, and as believed, perceptual emotions can play a crucial role in rational behaviors. Therefore, scholars mainly focus on the problem whether a machine can have emotions just like humans or not.

First of all, this paper describes the definition of emotions in the general biological sense and tries to explore whether an AI machine can own such emotion. As found in the research, humans give machines the emotions mainly because they want to make machine behaviors further similar with those of humans and then machines can serve humans better. Because of the human centered standpoint, machines cannot possess an independent emotion mechanism. Scholars argue that the expression of simulating or recognizing human emotions cannot be deemed as possession of emotions, so they further propose the concept of "machine emotions" – it can form an automatic regulation mechanism in machines just like human emotions and can influence behavioral organization.

Based on reviewing some theoretical and practical application of emotions in AI during recent years, the research finds that emotion cognition, emotion prediction, emotion-aided decision making or the like are still core topics in the field of emotion and machine research (see Figure 2). However, it is also found in this paper that this field has a new trend to build a machine emotion mechanism inside AI machines. These new studies try to break the borders between creatures and machines, and build a bridge between them. They try to simulate humans' emotion change mechanism in machines rather than implant human emotions in the form of inputting, so that influences of external surroundings on machine emotions are further emphasized.

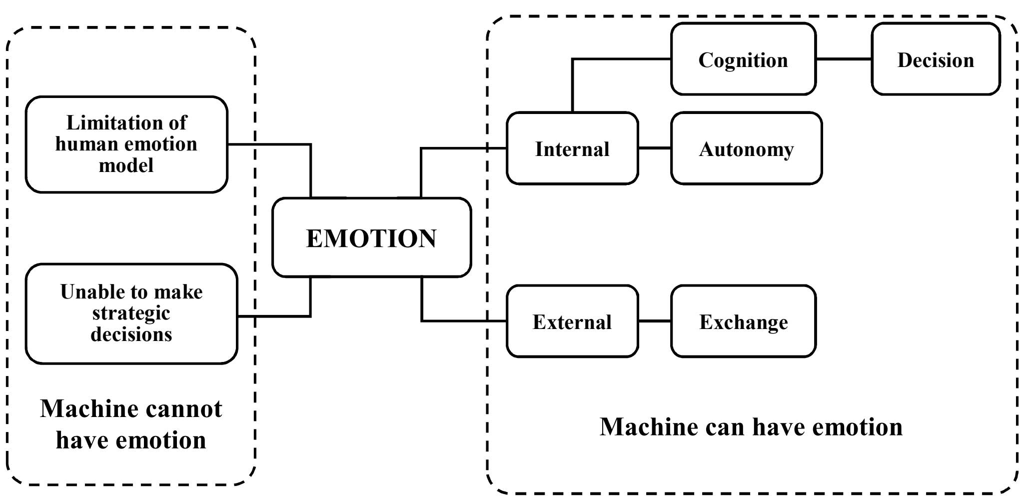

Figure 2. Conclusion

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