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Emotional Intelligence for Artificial Intelligence: A Review

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Abstract: ***The emotional intelligence has emerged as an important area of research in artificial intelligence covering wide range of real-life domains. A significant contribution has also been made to bring new insights in the field of emotional intelligence and intelligent software agents. Learning agents and educational activities are very attractive for incorporation of emotional aspects in artificial intelligence. Emotions have an important role in intelligent behavior and influence the human decision-making process. An overview of the state-of-the-art in emotional intelligence research with emphasis on emotional agents has been given covering the area like Emotion detection, Emotional agents, Text emotion detection, Modelling artificial agent's environments, Emotional intelligence and different forms of learning, Emotional agents in robotics, Emotional intelligence in decision support processes, Emotional intelligence in interactive environments, Emotional intelligence in classificationand search, Emotion models. The review will be usefulto the wider section of the researchers***

Keywords: Emotional Intelligence, Artificial Intelligence

1. Introduction

Emotions and Intelligence are co-related phenomenon and therefore emotions must be taken into consideration for designing true intelligent agent. Emotional intelligence as an emerging discipline deals with several aspects like modeling, recognition and control of human emotions. It also provides the key theory and technical basis for further studies of new generation sensor networks, intelligent information processing, intelligent services, and many other types of emerging applications. The ability to correctly interpret emotional signals is crucial in real-life situations. The emotional intelligence deals with one's ability to perceive, understand, manage, and express emotion within oneself and at the same time in dealing with others. The essential domains for emotional intelligence are shown in Fig. 1[1].

Many researchers in artificial intelligence and human-computer interaction have started in taking emotions quite seriously only in the late 1990s. Picard [2] gave a framework for building machines with emotional intelligence. Subsequently, many other researchers in this area have built machines that can reason about emotions, and also detect, handle, understand and express emotions [3]. Efforts in building emotionally intelligent entities continued to be concentrated on the following areas:

- Empowering the machine to detect emotions
- Enabling the machine to express emotions
- Embodying the machine in a virtual or physical way

The application of emotional intelligence in real domains led to an important field of research called multi-agent systems (MAS) in order to exploit logical methods for providing a rigorous specification of how emotions should be implemented in an artificial agent.

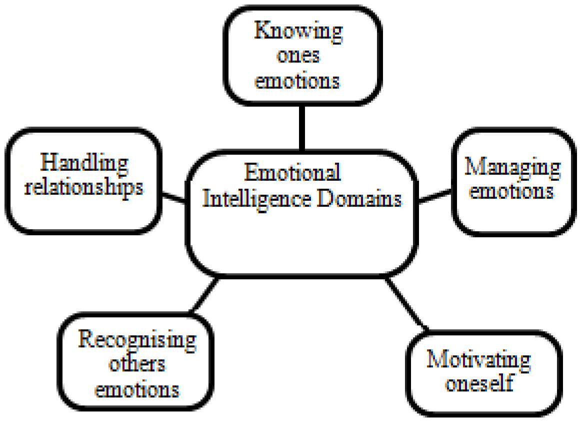

Figure 1: Domains of Emotional Intelligence

Recent research work in this area has been focused on enabling software agents to:

- detect emotions via verbal, non-verbal, and textual cues
- express emotions through speech and gestures

Mirjana et. al. [4] focused their research on proposing a distributed environment utilizing agents for efficient processing of emotional information. The authors used the term MAS to refer to a software system which exhibits such features.

Recent active research in AI has addressed modeling and communication of emotional contents leading to the areas shown in Fig. 2.A technological challenge is to build machines capable of the following:

- Reasoning about emotions
- Predicting and understanding human emotions
- Processing emotions while reasoning and interacting with a human user

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2. Emotional Agents and Detection

Significant research has been done into devising efficient techniques for emotion detection for new generation of intelligent systems based on agent technology. Emotion detection h a s been recognized as a very important factor in man-machine interactions. It can lead to the following advantages:

- Enhancing student's performance in e-learning [5]
- Improving driving experience [6]
- Increasing customer satisfaction [7][8]

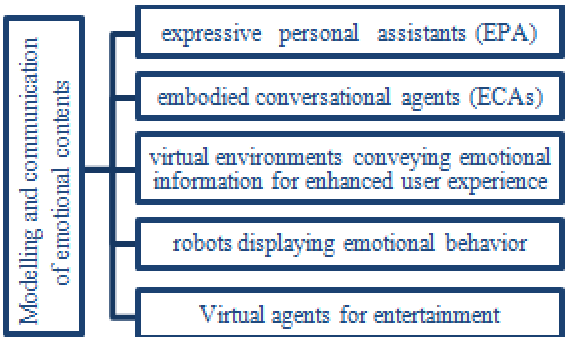

Figure 2: Modelling and Communication of Emotional Contents

An effort was made to study humans as affective beings and necessity to develop complex artificial agents that are capable of affective communication [9]. The author proposed independent reasons for the utility of developing affective agents. In a different study, it was concluded that intelligent agents or non-player characters (NPCs) in human interaction scenarios are required to react in ways that are consistent to the training scenario [10]. They developed a model for incorporating emotional enhancements (anger, sadness, anxiety and fear) into intelligent agents. The model allows NPCs in virtual training applications to simulate human behaviour incrisis management.

Tosa and Nakatsu [11] have analysed life-like communication agent-emotion sensing character and considered emotions which are interpreted from human voices and emotional responses. Camurri and Coglio [12] proposed a general, flexible, and powerful architecture to build software agents for artificial emotions for conveying human emotions, thus allowing more effective, stimulating, and natural human-agent interactions. Anderson and McOwan [13] presented a real-time automated system for the recognition of human facial expressions. Within the emotional intelligent agent domain, following three important directions for emotion detection were identified. These were facial, vocal and text.

Facial recognition raises the most complex set of problems, but some efficient solutions do exist. Ioannou et. al. [14] presented a model that includes adaptation and learning in a neuro-fuzzy system in order to analyze facial animation parameters. Burkhardt et. al.[8] have proposed that the processing of vocal emotions consists of following three stages:

1) Feature Extraction
2) Data Classification
3) Post-Processing

Data classification and pattern matching is the central point. The different approaches which have been evaluated are as follows:

- k-NN and linear discriminant classifiers [7]
- artificial neural networks [15]
- support vector machines [16]
- hidden Markov models [17]
- Gaussian mixture models [18]

Alm et.al.[19] aimed at improving text-to-speech systems for children's fairy tales by recognizing emotions. Wu et. al.[20] proposed that sentences can be represented as sequences of semantic labels and attributes and then processed by a separable mixture model in order to calculate similarities to emotion generation rules. Strapparava and Mihalcea [21] proposed several algorithms which have been employed in order to classify news titles based on their emotional content. Chuang and Wu [22] argued that the combination of vocal and text recognition yields better results than when only a single approach is used. Fragopanagos and Taylor [23] have proposed a neural network-based approach to analyze facial/vocal input. Intelligent software agents can be applied to and use both vocal and facial emotion recognition. These agents are distributed by nature, and can therefore be used to optimize selection, classification, and pattern recognition [24]. A special pedagogical agent is used in e-learning systems to guide and motivate students [25-26]. Many researchers have incorporated emotions into agents, resulting in a number of formal models for emotional agents and challenges of developing successful embodied conversational agents [27-29].

Suzuki et. al.[30] presented the concept of realization of an agent for intelligent interaction between humans and robots. Authors combined a computational model of artificial emotions with learning and self-adaptation features. A robot can change its "emotional state" based on human gestures, which is exhibited by means of integrated visual media, environmental lights, and changes in robot's style of movement and behavior. Yamaguchi et. al. [31] used a model of a knowledge, emotion and intention. Human-agent cooperation was generated during the dynamic determination of each robot's action. Dominguez et. al. [32] proposed that an intelligent agent in mobile robotics should be adapted to the conditions of the environments based on its physical and mental capabilities. Authors proposed a real-time agent based on: concepts, emotions and conscious processes. The motivation was to achieve behaviors that are consistent with intelligent performance in the real world.

Dominguez et. al. [33-34 identified the essential role of emotions in the control and the organization of the behavior of robotic systems. Authors proposed a real-time emotional architecture (RTEA) that allows the regulation of the behavior of robotic agents. RTEA helps robots to fulfill the goals based on its emotional state, and mental capabilities. It also permits the robot to have a more suitable control of the mental capacity and to guarantee the system integrity. Zhang et. al.[35] proposed a structure model of emotional multi-agent robot which harmonizes interaction between the human and computer. Authors extensively considered affective model construction, learning model, and the

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perception agent of the emotional model. Primary factors that attribute to the generation of robot's emotion are extracted, and then an affective model construction method based on grey system theory is introduced. The robot's learning model is based on probability and then the concept of affective correlation in the perception agent is given. Finally, a modeling method based on grey prediction for the affective correlative model is presented. Experiments showed that the robots possess significant ability of affective and intelligent interaction.

De Silva et. al. [36] considered an interactive robots and games, as instruments that may help the emotional development of children with mental-health problems. They expect people to show empathic behaviors and to take into account their emotions. Sanderson and Pitt [37] considered a vehicular agent situated in a motorway driving scenario. Agent architecture (combination of psychology and robotics models) for an enhanced theory of intent prediction with affective evaluation of expectations is presented. It has been used to create an online situation appraisal mechanism for preferential evaluation of predicted future states. The architecture required more than goal-directed planning: the agents must model the behavior of others, and predict and evaluate future states. Kim et. al. [38] proposed an episodic memory system for an affective robot with emotions. Storage, retention and retrieval of episodic memory are modeled with psychological bases. For verification of the system authors implemented a pet-like virtual agent with reactive emotion generation model.

3. Modeling Artificial Agents

The results of research work were reported in the direction of formalization of emotions in MAS [39]. Authors used the formalism of decision theory to develop principled definitions of emotional states of a rational agent. Ishihara and Fukuda [40]described an emotional algorithm evaluating an artificial emotional model. The efficiency of different characteristics of the agent with emotional algorithm was analyzed. A new traffic signal system, which optimizes the traffic flow by estimation of the driver's mind, was proposed. The emotional space within the system consists of the following four factors: (1) happy, (2) relief, (3) afraid and (4) angry. The emotional function imitates the state of driver's mind, and the emotional function achieves the different characteristics of individuality. The authors also proposed theprincipal architecture of the emotional algorithm with an individual and a traffic signal system simulator.

Vlad et. al. [41] proposed a model that simulates emotional internal states of autonomous agents. The model connects simulated touch-sensor inputs to an emotion-labeling output and includes emotional systems based on fuzzy emotions. Predinger and Ishizuka [42] developed a model of interaction between users and animated agents with basic features of affective conversation and social interaction. Pelczer et.al. [43] have presented a computer model of emotions that can be easily integrated in an avatar-based interaction context. The emotional avatars manifest expressive behavior, finally influenced by their personality definitions. Memon and Treur [44] presented model that focused on cognitive and a biological agent modeling in order to generate emotional states. The authors discussed how emotion reading can be modeled both at a cognitive and at a biological level, following the simulation theory approach to mindreading. Furthermore, a cognitive theory model for emotion reading was presented to show how the cognitive and biological agent models can be related. Bosse et. al. [45] developed a model to provide virtual, more realistic affective agents where it is necessary that they have the capability to generate and regulate emotions, and the ability to reason about the emotion regulation processes of other agents.

Jones et. al. [46] developed an architecture to support physiology, emotion and personality, and illustrated how it is used to model crisis situations. Duell et. al. [47] considered agent-based model for group emotion that supports teams in their emotion dynamics. An ambient agent, using model-based reasoning, analyzes the team's emotion level for present and future time points. The ambient agent supports the team and proposes a team leader. The authors also performed appropriate simulation experiments. Dang et. al. [48] developed a generic approach to modeling. Existing computational models of emotions (based on different psychological theories) share common properties and emotional processes. The GRACE model is aimed at unifying existing models into a single architecture. Moore [49] reported some psychological phenomena in which dramatic emotional responses are evoked.

Presently, AI is increasingly dependent on cloud computing. The goals should be to model the range of hunger human emotions, as well as their dynamics. There are different frameworks, libraries, applications, toolkits, and datasets in the AI and machine learning would. By creating a direct neural interface with the internet, humankind will be able to "plug into" higher intelligence [50]. The five components of AI with emotional intelligence are as follows; deep learning, self-awareness, safety and ethics, external awareness and big data collection and processing moderns (Fig. 3). Emotions are essential part of human intelligence and without emotional intelligence, AI is incomplete.

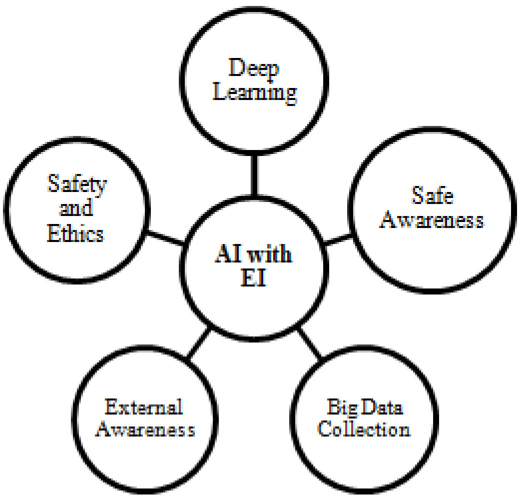

Figure 3: AI with EI Models

Another interesting aspect is to look into the mind model. A mind model for life-like agents should have the following

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features:
- expressing emotion
- generating behavior based on motivation
- learning
- selective attention
- generating reactive behavior

Information processing with emotions is not only important but also useful for many applications such as electronic secretaries, tutoring systems, and autonomous characters in entertainment [51-52]. For instance, children tend to be under the impression that characters in Disney animation have minds. A reason for this phenomenon is that the characters express rich emotions and personalities. Character's behaviors with emotions and personalities facilitate anthropomorphic view [53]. There is no switch in the brain that can be thrown to distinguish the real and mediated worlds [54]. These are some of the reasons why people personify behavior of a machine and have illusions that cartoon characters have human-like mind. Artificial agents with emotions give such illusions to the users by utilizing these human characteristics. There is strong need of combining artificial intelligence with emotional intelligence [55-56].

4. Emotional Intelligence

There are several interesting features of an artificial mind. Artificial minds understand emotions because people communicate with each other via expressing and estimating emotions. It has been emphasized that emotion is the predominant operation, mediating both cognition and action [57] and AI should have the ability of processing emotion [58]. Therefore, a machine should be able to process information about a user's emotions so that it can understand the user's goals as well as other information. To achieve this, it is crucial to build computational models of emotion. Artificial minds understand motivation. People interpret the meaning of matters according to their desires and concerns [59]. People consider others' motivation when they estimate their emotion and intention, explain their action, predict their future action. Therefore, it is necessary for user interface agents to understand user's motivation. Conversely, it will be easy for users to predict agent's behavior which is based on its motivation.

Huang et. al. [60] worked on learning in the emotional intelligence domain. Architecture of learning companion agent with facial expression of emotion was proposed. The most important achievement was realization of the transition between emotion space in the emotion module and facial expression space in the facial expression module. The emotion agent demonstrates different facial expression within experimental website. Cheng et. al. [61] were instrumental in combining the empathic virtual human with the learning system. However, there are few studies on designing interactive pedagogical agents with empathic strategies. Wang et. al. [62] proposed the concept of "Affective Computing" which made the computer's intelligence no longer a purely cognitive one. They proposed a mobile agent emotional e-learning system that recognizes and analyzes the student's emotion state, so a virtual teacher's avatar regulates student's learning psychology based on learning style.

Faghihi et. al. [63] proposed the Conscious Tutoring System (CTS) where a biologically plausible cognitive agent based on human brain functions, capable of learning and remembering events and any related information. Such an agent is able to improve its behavior by remembering previously selected behaviors influenced by its emotional mechanism. With the help of data mining algorithms, the architecture incorporates a realistic memory consolidation process. Tsai et. al. [64] tried to incorporate several aspects for student interaction in an educational environment: speech recognition, emotion inference and virtual agents. By analyzing the captured speech, they were able to indicate the emotion status of the target student and provide suitable dialogue for student-agent interaction. Experiments indicated high application potential for such systems. Chatzara et. al. [65] presented a model where the central part in the system is an emotional agent who affects the attitude of students towards learning. This synthetic character helps students to overcome learning obstacles in face to face communication. Various synthetic characters have the potential to expose emotions by recording user's emotions and reacting accordingly in improving e- learning processes. Experiments with 52 students are conducted. Arroyo et. al. [66] considered gender issues and the reactions of male and female students to the presence of animated pedagogical agents that provided emotional and motivational support. The authors did the experiments with the Intelligent Tutoring System for Mathematics. The system improved affective outcomes of all students.

Rodrigo et. al. [67] analysed the effects of the affective states exhibited by students using an intelligent tutoring system with and without an interactive software agent. Moridis and Economides [68] predicted that empathetic behavior as an effective way for Embodied Conversational Agents - ECAs to provide feedback to learners' emotions. Authors analyzed impact of ECAs' emotional facial and tone expressions combined with empathetic verbal behavior when displayed as feedback to students' emotions: fear, sadness, and happiness. Haugwitz et. al. [69] studied agents' learning abilities. An actor-critic reinforcement-learning algorithm was run on a small-scale MAS with an initially unpredictably environment. Experiments were conducted to compare two approaches: having fixed learning parameters, and using modulated parameters that were allowed to deviate from their base values depending on the simulated emotional state of the agent. The latter approach gave marginally better performance when distracting hostile elements were removed. Abdi et. al. [70] analysed the traffic flow forecasting using emotional concepts and MAS. The proposed forecasting algorithm is capable of finding the optimal forecasting approach by the reinforcement learning.

Daviet et. al. [71] developed a model for decision making in a disaster environment. The model combines personality traits of an agent, its emotional behaviors and the external events that can affect him. Three types of rescuer agents in an environment have been implemented, using different kind of intelligence. Guojiang et. al. [72] proposed that emotions should be embedded in the reasoning process of an

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intelligent agent (robot) when it aims to emulate human reactions. A behavior decision model of an intelligent agent based on emotionpsychology and artificial emotion was presented. The model incorporates emotions, motivations and behavior decision.

Rafighi et. al. [73] presented a system for assessing the state of horror emotion that the intelligent agent-based system may sense when it faces an annoying event. Three parameters related to human horror emotion were considered as inputs of thissystem. The system outputs are intended to be used in the agent decision making process. A more interesting application of the system could be for choosing a proper person for team work by combining the intensity of horror to other emotion intensities.Al-Shawa [74] was of the view that constrained rationality is a specific reasoning framework to analyze and rationalize about strategic decisions/conflicts in MAS. The framework was extended by mechanisms to:

a) Model the agents' priorities, emotions and attitudes within the context of the conflict
b) Elicit the agent's cardinal and ordinal preferences over their alternatives using the amount of achievement the strategic goals of the agents can harness from each alternative, given the collective goals, constraints, priorities, emotions and attitudes, the agents individually have.

A model with traffic and driving processes was presented by the authors [75]. Salichs and Malfaz [76] presented a new approach to the generation and the role of artificial emotions in the decision- making performed by autonomous agents-drivers (physical and virtual). As usual the decision-making system is biologically inspired and highly based on motivations and emotions. Experiments were performed on virtual agents living in a simple virtual environment. The usefulness of the artificial emotions is proven by carrying out the same experiments with and without artificial emotions, and then comparing the agents" performances. Masuch et. al. [77] presented a new application-independent model where agents possess individual personalities and dynamic emotions. The model allows rendering a rich set of behaviors for virtual characters in learning environments. Different studies demonstrated that humans interact with affective agents as social actors [78]. Lai and Hu [79] concentrated on multi-agent technology and formalization of rational and emotional agents for human- machine interface.

Abbasi and Shaikh [80] presented an approach to predict the instant emotion of chatters using only textual content. The preliminary results, achieved in a pervasive manner using software agents, reflect more satisfied chatters. Di Lorenzo et. al. [71] presented a model where ambient systems, teams and their emotion dynamics, agent-based support model for group emotion were central components. Do and King [82] presented an automatic real-time system capable of creating expressive speech using a set of mathematical models. This approach allows adding emotions in synthetic animated audio and video speech. A tracking system with a high-speed camera is used to collect the facial movement data. The proposed emotional model drives prosodic parameters to control the generation of synthetic audio, and muscle parameters to control the shape of the face. The authors tested model by developing an emotion- based chat system for creating synthetic emotional speech. Liebold and Ohler [83] proposed that usage of virtual agents with emotional expressions is seen as a natural way of utilizing interaction with the user. The effects of unimodal vs. multimodal expressions of emotions on the users' recognition of emotional state were considered. Performed experiments showed that multimodal expressions of emotions obtain the highest recognition rates. Zoric et. al. [84] provided an extensive survey of facial gestures as special kinds of facial displays: eyebrow gestures and gaze, blinks, various nods and head movements. In comparison to verbal and emotional displays, thefacial gestures are less tangible but offer more natural behavior of the face.

An affect-sensitive news agent (ASNA) that significantly differs from other similar ones was presented by the authors [85]. Main differences in comparison to other similar works are:

- The application of a cognitive theory of emotions (OCC model). The authors have integrated the approach to sense affective information from news-texts.
- The authors used common-sense and current-affairs as a knowledge base with a rule-based approach to assess each line of text by assigning a numerical valence.
- The use of natural language processing techniques to perform automated categorization of news stories on the basis of emotional affinity.

Herrera et. al. [86] presented a fuzzy-logic based system aimed to generate emotions for a virtual seller or avatar. Karim et. al. [87] presented an efficient recommendation system based on emotional web browsing agent. The system not only can take input from the environment accurately, but also provide efficient recommendations of the ranked websites. Experiments show that the proposed emotional web browsing agent can very efficiently recommend specific websites based onuser's emotions. Colhon et. al. [88] presented a sentiment classification method for the categorization of tourist reviews.

5. Conclusions and Emerging Research Issues

The authors have reviewed emotional intelligence for various applications in artificial intelligence. The research areas that emerge are the following:

- The emotions of every person are private and therefore, concerns about violations of privacy are genuine. The risks associated with AI, specifically the collection, storage, transfer and use of confidential information have to be address the issue of privacy.
- Artificial Intelligence accuracy incorrectly determining emotional contents needs to be confirmed, specifically in regards to system biases or errors, before labeling a person as high or low emotional.
- Artificial Intelligence programs should appropriately respond to human users, so as to not worsen their emotional state or accidentally facilitate advance situation.
- Response protocols are needed on how properly handle high risk cases that are flagged by Artificial Intelligence technology.

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- There is knowledge gap among key users on how Artificial Intelligence technology fits into emotional understanding. More education on the topic is needed to address this issue.
- There exists no formal model capable of adequately characterizing complex emotions such as regret, jealousy, envy, shame, guilt, reproach, admiration, remorse, pride, and embarrassment among a series of human beings.
- An extensive research is needed in the areas of vocal emotional design for man-machine communication. This is because future designs of interactive robots need to be not only emotionally rich in vocal expression, but also capable of performing vocal emotion recognition.

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