Emotional Intelligence and Agents – Survey and Possible Applications

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ABSTRACT

Recently, research on emotional intelligence has advanced significantly from its theoretical basis, analytical studies and processing technology to exploratory application. The main intention of this paper is twofold. First, it will give an overview of the state-of-the-art in emotional intelligence research. Then, it will suggest a systematic order of research activities and steps with the idea of proposing an adequate framework for real-life applications. We recognize that it is necessary to apply specific methods for dynamic data analysis and pattern mining/recognition in order to identify and discover new knowledge from available emotional information and data sets. Finally, the paper will propose research activities in order to design an agent-based architecture, in which agents are capable of reasoning about and displaying some kind of emotions based on emotions detected in human speech, as well as online documents. This kind of virtual emotional agent could be employed in intelligent human-computer interaction, within areas such as tourism, education, and virtual cultural exhibitions.

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1. INTRODUCTION

With the development of information technology, human dependence on computers has steadily increased as well. In recent times, emotion recognition and simulation have become an important research subject in the communication between machines and human beings.

Emotional intelligence is an emerging discipline that deals with modeling, recognition and control of human emotions. It provides the key theory and technical basis for further studies of new generation sensor networks, intelligent information processing techniques, man-machine conversation technologies, machine intelligence services, and many other types of applications. The ability to correctly interpret emotional signals is crucial in many real-life situations. For example, infant laughter can reflect their sense of security or their prediction of developments in the environment, or at least demonstrates that the infant is active and healthy, without pain, illness or other bad things happening. On the other hand, infant's cry (some possible reasons: hunger, pain, fatigue, discomfort and so on) can be used to express their needs or other problems. The ability to correctly in-

terpret emotional signals is crucial in different real-life situations.

Five essential domains for emotional intelligence were defined in [24]: knowing one's emotions, managing emotions, motivating oneself, recognizing emotions in others, and handling relationships. According to the authors, emotional intelligence deals specifically with one's ability to perceive, understand, manage, and express emotion within oneself and in dealing with others.

In the late 1990s, many researchers in domains like artificial intelligence and human-computer interaction began to take the notion of emotions and emotional intelligence quite seriously. An important milestone in this area was publication of the book "Affective Computing" by Rosalind W. Picard in 1997 [23]. In the book, the author presented a framework for building machines with emotional intelligence. In the following years, many other researchers in this area have built machines that can reason about emotions, and also detect, handle, understand and express emotions [27].

Efforts in building emotionally intelligent machines and entities have been concentrated on a few key efforts: empowering the machine to detect emotions, enabling the machine to express emotions, and embodying the machine in a virtual or physical way. Different projects that have appeared in the meantime to incorporate these aspects; however, the remaining difficult challenge is the additional complex ability to handle and maintain an emotional interaction with a user.

Another important research field highly connected to the application of emotional intelligence in real domains is the field of *multi-agent systems* (MAS). Some researchers in this domain have been interested in developing logical frameworks for the formal specification of emotions. The main concern is to exploit logical methods in order to provide a rigorous specification of how emotions should be implemented in an artificial agent.

Many researchers have projected that machines, or intelligent agents of the future must connect on an emotional level with their users [22]. Recent work in this area has been focused on enabling intelligent software agents to detect emotions via verbal, non-verbal, and textual cues, and also to express emotions through speech and gestures.

1.1 Description of a Multi-Agent System

A large part of the scientific literature describes multi-agent systems as *societies of agents* [6, 33]. The most complex MAS solutions tend to model human societies by, for example, incorporating agents with distinct roles and organizational structures. Moreover, agents employ many techniques for cooperation, negotiation and action coordination to their own benefit (so-called selfish agents), or in order to improve the "well-being" of the entire society. Over the years, the focus of many researchers has been on exploring and improving this social aspect of agents, turing it into one of the defining characteristic of the agent technology.

In many practical distributed systems (e.g. [13, 21, 32]), however, this complex agent interaction is not desired, due to its computational complexity. That is, although the inter-agent communication is utilized, it is strictly reduced and limited in order to preserve valuable system resources. The focus of these systems is also on additional properties of agens, such as adaptability and goal-directed behavior, accomplishing the following features:

- Fault-tolerance: it has been shown in [21] how a relatively simple network of agents can detect changes in dynamic computational networks;
- Scalability under heavy computational loads [32]; and
- Performance analysis and prediction for improved load-balancing [13]

The importance of these features is also recognized by agent platform and framework developers, which implement them in their respective solutions (e.g. [2, 31]).

The focus of the work on this paper is, therefore, on building a distributed environment which utilizes agents for efficient processing of emotional information. Therefore, we will use the term "multi-agent system" to refer to a distributed software system which exhibits aforementioned features that stem from the usage of, primarily, intelligent agents. While our agents still communicate and coordinate their actions and jobs, complex interaction patterns are deemed unnecessary and are avoided.

1.2 Influence of Emotional Intelligence on Intelligent Systems

Modern cognitive psychology considers human emotions to be caused by specific situations. Emotional change is a psychological phenomenon unique to humans, and can trigger a series of physiological responses through the nervous system, and form a unique subjective experience. This, in turn, may cause external expression changes, in form of gestures, actions, and so on. By detecting different physiological signals and external features, it is possible to compute and identify the emotional state of a subject to a certain extent.

With the development of artificial intelligence (AI) technologies and their increasing widespread applications, many new requirements have been put forward in real-life complex environments: the new generation of intelligent machines should not only possess the character of rational intelligence, but also the ability to make personalized responses in accordance with the specific environmental perception and psychological demand. Therefore, the research on emotional intelligence has become a hotspot and an important domain in this interdisciplinary research field.

In the last years, research in artificial intelligence and computer science has addressed modeling and communication of expressive, emotional content (research on affective computing at MIT, Kansei Information Processing in Japan). Such research has led to the development of prototype systems for many different uses: expressive personal assistants, embodied conversational agents (ECAs), virtual environments conveying emotional information for enhanced user experience, robots displaying emotional behavior, virtual agents for entertainment (video games, interactive storytelling), etc.

The broad idea is that people must have a direct access to a large set of services without many demands and steep learning curves regarding the use of the services. Since the complexity of an interactive system increases with the complexity of the services it offers, society urgently needs understandable and intuitive interfaces and systems. Consequently, a major objective is to develop interactive systems that are more attractive and closer to the user, which can also be considered believable. These systems must possess refined communication capabilities. In this perspective, a

technological challenge is to build machines capable of reasoning about emotions, predicting and understanding human emotions, and processing emotions while reasoning and interacting with a human user. This challenge is connected to the development and usage of a large variety of interaction systems, including virtual agents, tutoring agents, and personal scheduler agents.

With the aim of creating a new generation of emotional interaction systems, the study of affective phenomena has become a "hot" topic in computer science and artificial intelligence.

Different logical methods have been recently exploited in order to provide a rigorous specification of how emotions should be implemented in an artificial agent and how agents should reason about and display some kind of emotions. Although the application of logical methods to the formal specification of emotions has been quite successful, there is still much work to be done. For example, there exists no formal model capable of adequately characterizing complex emotions such as regret, jealousy, envy, shame, guilt, reproach, admiration, remorse, pride, and embarrassment. These emotions involve very sophisticated forms of reasoning, such as self-attribution of responsibility, counterfactual reasoning, reasoning about norms and ideals.

With the increasingly strict demands on robots, it has been suggested that more attention be shifted into the issue of vocal emotion design of AI robots, in order to facilitate the communication between man-machines and human beings. To upgrade the voice design of robots, it is necessary to analyze and understand the human vocal processing mechanism, and the acoustic features of vocal stimuli. With this it is expected that, apart from facial expression and recognition, future designs of interactive robots need to be not only emotionally rich in vocal expression, but also capable of performing vocal emotion recognition.

Recently, a lot of evidence has been gathered to suggest that virtual agents induce positive feelings in humans during interaction if the agents are capable of displaying emotions, as well as recognizing and responding to human's emotions. In turn, this also improves the virtual agent's performance.

The main objective of the paper is to analyze, select, and propose application of appropriate AI techniques in the design of modern emotionally-equipped interactive systems. These systems should be capable of reasoning about emotions, predicting and understanding human emotions, and processing emotions while reasoning and interacting with a human user. At the moment, it is useful to also propose a framework and develop simple prototypes that include different kinds of artificial intelligent agents, and, finally, test them in several attractive and challenging areas, such as tourism, education, and virtual cultural environments.

The principal contribution of this paper is in the elaborate discussion of research questions and efforts needed for building usable emotionally-aware and emotionally-expressive intelligent systems in various application domains. Notably, research steps are identified and systematically ordered with the purpose of building a framework for producing such systems. Also, two concrete directions involving emotion detection in human speech and online documents are highlighted as areas of immediate future research focus.

The rest of the paper is organized as follows. Major recent research achievements in the domain are briefly presented in Section 2. In Section 3, systematic order of research activities and steps for building an adequate framework that incorporates emotional intelligent agents is proposed. Section 4 is devoted to the concretization of the initial essential activities directed at achieving the main research goals. Concluding remarks and expected results are briefly presented in Section 5.

2. RELEVANT WORK

In general, emotion detection has been recognized as a very important factor in man-machine interactions. It can enhance student's performance in e-learning systems [1, 18], improve driving experience [14], and increase customer satisfaction [7, 17]. Therefore, significant research has been invested into devising efficient algorithms and techniques for emotion detection.

Three different research directions for emotion detection exist, in order to deal with facial, vocal and text recognition. Facial recognition poses probably the most complex set of problems, but some efficient solutions do exist. For example, a *support vector machine* can be used to classify motion signatures as either non-expressive, or belonging to one of the predefined six categories [4]. On the other hand, the work presented in [11] includes adaptation and learning in a neuro-fuzzy system in order to analyze facial animation parameters.

The processing of vocal emotions generally consists of three stages [7]: feature extraction, data classification, and post-processing. Data classification and pattern matching represent the central point, and different approaches have been evaluated. These include *k-NN* and *linear discriminant classifiers* [17], *artificial neural networks* [35], *support vector machines* [26], and *hidden Markov models* [30]. More recently, improvements to generative classifiers, such as *Gaussian mixture models*, have been proposed in [5].

There are a number of efficient approaches for text emotion detection. The approach proposed in [3] is aimed at improving text-to-speech systems for children's fairy tales by recognizing emotions in the text. Sentences can also 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 [34]. Finally, in [29] several algorithms have been employed(simple heuristics, *naive Bayes* classifiers, etc.) in order to classify news titles based on their emotional content.

Finally, there exist some combined approaches. For example, it has been shown in [8] that the combination of vocal and text recognition yields better results than when only a single approach is used, while the authors of [9] have proposed a neural network-based approach to analyze facial and vocal input.

Intelligent software agents can be applied to and use both vocal and facial emotion recognition in a number of ways. Agents are distributed by nature, and can therefore be used to optimize selection, classification, and pattern recognition processes used in related work presented in [20]. A special sub-type of *pedagogical agents* are already used in aforementioned e-learning systems and are designed to guide and motivate students [10,12]. Much research has also been invested into building emotions into agents, resulting in a number of formal models for emotional intelligent agents [19, 28]. Finally, some challenges of developing successful embodied conversational agents are outlined in [25], namely the lack of a solid psychological foundation.

Having the presented relevant work in mind, in this paper we will concentrate on determining research efforts in order to propose several key steps and procedures for development and implementation of virtual agents as crucial parts of emotional interacting systems.

3. EMOTIONAL INTELLIGENCE AND ITS INFLUENCE ON INTELLIGENT SYSTEMS

3.1 Usability of Emotional Intelligence: Necessary Research Activities

Emotional expression is an important factor in human communication, because it provides sensitive feedback information. In today's world, users are not satisfied with simple visual and audio responses of interactive systems. They also want to employ all their sensory organs in order to receive the details of a multimedia presentation, and require tactile, olfactory, and other modes of communications. An interesting and important trend in the development of intelligent man-machine communication is, therefore, to build interactive systems that are more attractive and closer to end-users, and that the users consider to be believable and trustable.

Consecutively, users also want to provide information to the computer in different ways, using e.g. gestures, postures, languages, graphics and emotions. So it is extremely important for future intelligent systems development to consider how exactly can emotions be embedded in voice, gesture, posture and presentation styles.

With these complex and interlaced elements and areas in mind, in the rest of the subsection we will specify and suggest a systematic order of research activities and steps which will lead us, in a straightforward manner, to the proposal of an adequate emotional framework for real-life applications. The following research challenges and activities need to be systematically followed and performed:

- Analysis and evaluation of different emotional classification methods, such as those found in speech, expression, gesture, action, and electrophysiology information (e.g. pulse, blood pressure, *ECG*, *EEG*, etc.). In the domain of emotion recognition in human voice, it is justifiable to apply speech signal processing and pattern recognition techniques, such as *cepstrum analysis*, *dynamic time warping*, and *hidden Markov modelling*. Therefore, it is necessary to investigate and propose new or modify existing techniques in order to obtain better results.

- In order to improve the stability and accuracy of emotional information pattern recognition, it is necessary to use different recognition algorithms, or even a combination of multiple algorithms; to distinguish between and choose more appropriate parameters or combined features; to apply more than speech recognition technology, and combine it with, for example, facial recognition; to use appropriate testing of emotional signals. In order to verify and test such approaches, it is necessary to obtain appropriate data sets. Researchers usually exploit some of well known data repositories, but an additional challenge is to try and prepare more adequate data sets.

- Exploiting logical methods in order to provide a rigorous specification of how emotions should be implemented in an artificial agent. The design of agent-based systems, in which agents are capable of reasoning about and displaying different emotions, can benefit from the accuracy of logical methods.

- Identifying desirable features of emotion theories that make them ideal blueprints for agent models. These new findings will be introduced into the design, in order to explore their application in concrete areas such as services of tourism, education, or in recognition of infants' emotions.

- After the aforementioned logically sequenced steps, a natural consequence is to build a prototype of a multi-agent system capable of the following: reasoning about emotions, predicting and understanding human emotions, and processing emotions by reasoning and during the interaction with a human user. Such a complex system could be tested in small, real-life environments, including tourism virtual agents, personal education agents, etc.

3.2 Emotional Intelligence and Agent Technology

In the domain of employing emotional intelligence in interactive systems, significant attention needs to be given to other important aspects, i.e. multi-agent systems (MAS). Some researchers in this domain have been interested in developing logical frameworks for the formal specification of emotions (usually based on the so-called *BDI /belief-desire-intention/* logic). Their main concern is to exploit logical methods in order to provide a rigorous specification of how emotions should be implemented in an artificial agent. The design of agent-based systems where agents are capable of reasoning about and displaying some kind of emotions can indeed benefit from the accuracy of logical methods.

Computational models of emotions are useful in a variety of domains such as development of believable agents, video games, virtual environments, etc. Most of existing models are inspired by the *appraisal theory* and focus on the agent's cognitive behavior, for which they often generate emotions according to static rules or pre-determined domain knowledge. From this follows a description of the elements theoretically needed to construct a virtual agent with the ability to display human-like emotions and to appropriately respond to human emotional expression.

The second important objective of these research efforts is to apply specific methods for dynamic data analysis and pattern mining/recognition in order to identify and discover new knowledge from available emotional information. The main focus here needs to be placed on the following specific activities:

- The investigate the problem of choosing the appropriate analysis methods for large amounts of dynamic and temporal data (collected from simulations and experiments) which can be used in explanations and modeling of human emotions.

- To explore possibilities of modeling multi-agent systems which incorporate emotional intelligence.

- To build a logic that enables specification of complex emotions (e.g. regret, jealousy, envy, shame, guilt, reproach, admiration, remorse, pride, embarrassment).

A logic of complex emotions should be sufficiently expressive not only to characterize different types of agents' mental attitudes (beliefs, desires, goals, intentions), but also to characterize concepts of responsibility, counterfactual thinking, norms and ideals. It is expected to be a combination of BDI logic of agents' mental attitudes, with logic of norms and ideals, and with logic of agency and multi-agent interaction.

- To perform experiments on numerous appropriate data sets. Different software systems need to be selected and tested to assist the user in this important and demanding task. For this purpose we can suggest the usage of a system based on *FAP – Framework for Analysis and Prediction* [16]. In fact, FAP is a multipurpose and multifunctional library that implements the main techniques and methods needed for the analysis of time series (pre-processing, similarity measures, representations) and temporal data mining (indexing, classification, prediction, etc.).

- Consequently, a prototype MAS needs to be implemented using methods from emotional and artificial intelligence. The MAS needs to be based on previously conducted extensive experiments, and the encompassing previous results.

Based on theoretical and empirical analysis, the proposed steps of our investigations will provide insight into emotional information pattern recognition, modeling and implementation of intelligent emotional software agents applicable in different real-world applications, including services of tourism, education, and recognition of infants' emotion.

4. MULTI-AGENT INTELLIGENT SYSTEM FOR EMOTION RECOGNITION

Having in mind the discussion presented in Section 3 – existing research efforts, available results, proposed research directions, and suggested research steps – here we define concrete research topics to be focused on in the near future: emotion detection in human speech, as well as in online documents.

4.1 Emotion Detection in Human Speech

The voice characteristics and emotion expression of human speech are detectable in sound data. There is an emergent need for this kind of derived information in various aspects of telephone services. Telephone companies need to develop a "strong customer service sense," with the most important customer contact point being in the area of complaint handling. In order to improve customer experience, two major problems are faced: customer emotions which are delayed and hard to detect, and the lack of an effective problem-solving strategy for different cases of customer emotional response.

The first problem can be tackled with emotion detection techniques that operate on sound data. In order to detect emotions such as joy, trust, fear, surprise, sadness, disgust, anger, anticipation, as well as different gradients of each, classification models are built on top of various features extracted from sound data, belonging to various types: excitation source, vocal tract system, and prosodic features [15]. The first phase of our research will consist of acquisition and preparation of data in Chinese and English languages, determination of features suitable for the task, and development of a prototype system that can detect emotional content and intensity in recorded voice data.

The second problem of constructing a strategy for solving customers' problems based on emotional response lends itself to the application of techniques involving emotional agents, which can help in devising appropriate strategies through simulation of various scenarios of voice interaction, as well as the development of a "helper agent." The goal of this agent would be to assist customers and service operators by dissipating emotional tension and providing hints toward a more constructive mode of interaction. Although we plan to primarily target the first problem, if time and resources permit, we will investigate this avenue of research as well.

4.2 Emotion Detection in Online Documents

Agent technology will be employed to perform distributed emotion detection in online documents, such as blogs, discussion forums, social networks, news that report on emergency events, etc. Two types of agents will be developed: *harvester* and *analyst*. Harvester agents will have the role of web crawlers. They will scan the web in search of documents that meet the given criteria, and then download and store them into a local database.

Analyst agents will perform text analysis in a distributed setting. Their functionality will be based on the state-of-the-art approaches and algorithms for emotion detection. The process will be parallelized and run on a computer cluster for efficiency purposes [21].

At this stage, the focus will be on English documents, with the goal of expanding to other major European languages, such as German and French. For this purpose, several freely available sentiment lexicons will be used.

5. CONCLUSION

Emotion modeling is expected to have an interesting and important role in the next generation man-machine interactive systems. It can be realized by modeling both input and output parameters of the interactive system. For instance, the visual expression of the input-user-interface, such as laughter, cry and other forms of facial manifestation can directly be regarded as input to the computers. On the other hand, the emotional expression of a computer can be realized by synthesizing emotions either on the video display unit or on an artificial emotional creature, depicting the machine response.

In upcoming research efforts it is important to exploit logical methods for specification and modeling of emotions suitable for implementation in agent-based systems. It is also important to propose and develop a specific multi-agent architecture capable of reasoning about emotions, predicting and understand human emotions, and processing emotions in reasoning and during the interaction with a human user. For testing capabilities and effects of such an architecture it is unavoidable to evaluate it in several characteristic real environments, such as smart services in education, reception in exhibitions, recommendation in e-business, etc.

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