Affective Computing

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***Abstract*—Affective Computing is currently one of the most active research topics, having increasingly intensive attention. This strong interest is driven by a wide spectrum of promising applications in many areas, such as perceptual interface, virtual reality, affective agents or recommender systems. Affective Computing concerns multidisciplinary background knowledge, such as psychology, cognitive and computer sciences. In this paper, we present an overview of some fields where AC has been applied, as well as some background knowledge in emotion theories.**

I. Introduction

The research on affect or emotion can be traced from nowadays to 19 century [1]. Traditionally, "affect" was seldom linked to lifeless machines, being normally studied by psychologists. It is quite new in the recent years that the affect features were captured and processed by the computer.

The original version for Affective Computing (AC) was designed to recognise what users are experiencing, when they are interacting with the systems. The emotional responses from these interactions need to be modelled, and the resulting model used to modify the interaction (perhaps to create new emotional experiences or to fix problems like for users relieve frustrated or something that make the interaction needs to be adapted and changed). These ideas really came out from Artificial Intelligence (AI), from the strong idea of the possibility to understand people and to bring emotions. As one of those things that humans should understand in the system. But this was a while ago...

The term "Affective Computing" was establish only in 1998, with the book "Affective Computing" by Rosalind Picard (see [2]). Since then, a lot of work was been done, and several branches/modifications of the original version (such as Affective Interaction, see section III) were created.

AC can be seen as a branch of computing concerned with the theory and construction of machines which can detect, respond to, and simulate human emotional states. It is an interdisciplinary field spanning the computer sciences, psychology and cognitive science. Nowadays, AC is trying to assign computers the human-like capabilities of interpretation, observation and generation of affect features. An important topic for the harmonious human-computer interaction, with the purpose of increasing the quality of human-computer communication and improving the intelligence of the computer.

There are several goals in AC. One is to sense and responder respectfully to human emotion. For instance, if a person is communicating with a technology and he is frustrated or confused, the technology needs to be able to respond differently to that person. If the humans respond differently to the technology, the technology should to do the same! Another goal of AC is to enable people to communicate emotions more clearly. Equally important is to look at the role that emotion plays in intelligence processing. AC is, in part, about understanding how emotions plays vital rules in us for regulating our intention, helping us make good decisions, changing the way we emphasise and prioritise things, organising or figuring out what matters. These roles of emotions are ones that the people do not usually think about as emotional, because usually we are not 'emotional' when we do that, it is just some background regular mechanisms that are important for functioning intelligently.

With the purpose of increase the quality of human-computer communication, and also improve the intelligence of the computer, affective computing builds an "affect model" based on the various sensors-captured information. This way, it is possible to build a personalised computing system with the capability of perception, interpretation to human's feeling as well as giving us intelligent, sensitive and friendly responses.

AC is a rapidly developing field within industry and science. There is now a great drive to make technologies, such as robotic systems, avatars in service-related human computer interaction, e-learning, game characters, or companion devices more marketable by endowing agents, robots, among others. This new peace of technology brings the ability to recognise and adjust to the user's feelings as well as the ability to communicate appropriate emotional signals.

Computer science believes that the human intelligence can be described to the point that it can be simulated by a machine. Its aim is to design an AI that can process, recognise, interpret and simulate human affect. The ultimate goal being simulated empathy. Even though the machine does not feel emotion it must be able to express and interpret those emotions to interact better with us humans.

This paper presents some of the theories behind AC, and its importance in other fields. The remainder of the paper is organised as follows. In section II it is presented theories about emotions. Section III focus in a new research branch of AC, Affective Interaction. Before concluding (section VII) we present three related topics where AC has been applied: artificial agents, multiagents systems and recommender systems (sections IV, V and VI, respectively).

II. Emotion Theories

Emotions in humans are complex biological, psychological, social, cultural processes that must be studied interdisciplinary. Moreover, it has been clear for a long time [3] that the word "emotion" has no unique and clear meaning. A proliferation of definitions can be found in psychological and philosophical literature. In the meantime, we can introduce new technically defined terms and use these to define the word "emotion". This is best done using architecture based concepts. Starting from an architecture we can derive the types of states and processes the architecture can support [4] [5] [6]. As a result, emotions can be distinguished as primary and secondary.

A. Primary Emotions

Human brains have many components which are evolutionarily old. Some are responsible for "animal" emotions, such as being frozen with terror, startled, nauseated or sexually aroused. Information from perceptual systems fed to a fast pattern recognition mechanism can rapidly trigger massive global changes. Indeed, these mechanisms apparently include the brainstem and the limbic system [7], [8]. Damasio [9] calls these "primary emotions", as does Picard [2]. These products of our evolutionary history are still often useful. As they involve physiological reactions relevant to fleeing, attacking, freezing, and so on, sensors measuring physiological changes (including facial expression and posture) can detect such primary emotions.

B. Secondary Emotions

Primary emotions may be less important for civilised social animals than certain semantically rich affective states generated by cognitive processes involving appraisal of imagined situations or perceived. These are referred to by Damasio as "secondary emotions", and described by Picard (see [2] on page 35). They can arise only in an architecture with mechanisms for processes such as envisaging, recalling, planning and reasoning. Patterns in such processes can trigger learnt or innate associations in the "alarm" system which cause rapid automatic evaluations to be performed. Possible effects include:

i) reactions in the primary emotion system including physiological changes (e.g., weeping, muscular tension, flushing, smiling). These reactions that can produce a characteristic "feel" (e.g., "a flush of embarrassment" and "growing tension"), for example.
ii) rapid involuntary redirection of thought processes (see for instance [4] [10]).

It is not always appreciated that effects of type ii) can occur without effects of type i).

C. Mixed Emotions

Picard offers blending and rapid alternation as possible models of such mixed emotions (see [2] on page 171). Neither is plausible, since coexisting emotions (e.g., jealousy and guilt at feeling jealous) endure and preserve their identity [11]. A more accurate model would be a collection of coexisting dispositions, possibly implemented as concurrent (mostly unconscious) cognitive processes striving for attention and control. For instance, infatuation could coexist with unrelated jealousy over a colleague's promotion.

In the literature we can find a big set of emotions already identified by researches. These emotions vary, among other aspects, because of the point of view of the research in which they should or would be used. Table I presents the selection of the most important sets of basic emotions [12].

TABLE I
VARIOUS SETS OF BASIC EMOTIONS.

Reference	Basic emotions	Basis for inclusion
[13]	Anger, aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness	Relation to action tendencies
[14]	Anger, disgust, fear, joy, sadness, surprise	Universal facial expressions
[15]	Desire, happiness, interest, surprise, wonder, sorrow	Forms of action readiness
[16]	Rage and terror, anxiety, joy	Hardwired
[17]	Anger, contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise	Hardwired
[1]	Fear, grief, love, rage	Bodily involvement
[18]	Anger, disgust, elation, fear, subjection, tender-emotion, wonder	Relation to instincts
[19]	Pain, pleasure	Unlearned emotional states
[20]	Anger, disgust, anxiety, happiness, sadness	Do not require propositional content
[21]	Expectancy, fear, rage, panic	Hardwired
[22]	Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise	Relation to adaptive biological processes
[23]	Anger, interest, contempt, disgust, distress, fear, joy, shame, surprise	Density of neural firing
[24]	Fear, love, rage	Hardwired
[25]	Happiness, sadness	Attribution independent

D. Linguistic Expressions

Some authors proposed a novel way to automatically calculate the affective values for emotional words [26]. The affective dimensions are based on the factorial analysis of extensive empirical tests [27]. As a result, researchers, not only discovered three major factors (potency, evaluation and activity) that play a role in the emotive meaning of a word, but also set the basis for the circumflex of affect [28].

Some years latter, a novel way for textual affect sensing was proposed [29], by exploiting commonsense knowledge, rather than using keyword spotting techniques that only work when specific keywords occur in the text. As an example, the sentence "I just had a car accident" does not contain any emotional keyword, but contains affective information. A person that just had a car accident is certainly not happy, and most probably sad or even frightened. This kind of evaluation of emotional content embedded in text can be extracted by using common-sense knowledge and by reasoning over this knowledge.

State of the art in sentiment has been studied at three different levels: word, sentence, and document. It has been created methods to estimate positive or negative sentiment of words [30], sentences [31], and documents [32]. As an example, some researchers proposed machine learning

methods to identify words and phrases that signal subjectivity [33] [34]. Previous approaches for assessing sentiment from text are based on one or a combination of these techniques. Next, we present other approaches for assessing sentiment from text. Some of them are based on one or a combination of techniques.

- ◇ keyword spotting, lexical affinity [35];
- ◇ statistical methods [36];
- ◇ fuzzy logic [37];
- ◇ knowledge-base from facial expression [38];
- ◇ machine learning [31];
- ◇ domain specific classification [39];
- ◇ valence assignment [34].

III. Affective Interaction

AC is considered one fascinating new area of research emerging in computer science. It dwells on problems where "computing is related to, arises from or deliberately influences emotions" [2]. Following this new research direction and considering the human element as crucial in designing and implementing interactive intelligent interfaces, AC is now influencing the way humans design, shape, construct, and evaluate human-computer interaction.

For instance computer gaming has been acknowledged as one of the computing disciplines which proposes new interaction paradigms. Nowadays, taking advantage of high-performance, yet lightweight and wireless controllers, it is possible to take into account the individual affective expressibility of each player and the possibility to exploit the social networking infrastructure. As a result, new gaming experiences are now possible, maximising users' skill level. Consequently, new gaming perspectives, affective and social computing, have brought increased interest in the field in terms of interdisciplinary research.

An affective interactional view is different from the AC approach in that it sees emotions as constructed in interaction (Affective Interaction), whereas a computer application supports people in understanding and experiencing their own emotions (see for instance [40] hook08. An interactional perspective on affective design will not aim to detect a singular account of the true emotion of the user and tell them about it as in a prototypical AC application, but rather make emotional experiences available for reflection. These new systems create a representation that incorporates users' everyday experiences that they can reflect on. Users' own, richer interpretation guarantees that it will be a more veracity of what they are experiencing. A range of systems have been built to illustrate this approach, see for instance Affector [41], eMoto [42] and Affective Health [43].

IV. Affective Artificial Agents

In the previous topics, we described the main functions of emotion for human beings. Their main advantages are communication, survival and well being. The role of emotions in cognitive processes, e.g., planning or decision-making, is essential for this achievement. So, we can ask why do not agents take similar advantages from emotion. An affirmative answer to this question is argued by many researchers, particularly those defending the strong notion of agency (see for instance [44]). The ascription of affective features to agents gives rise to terms such as emotional agents, believable agents [44], motivational agents, affective agents, Affective Computers [2] (see section I) or recently Affective Interaction [45] (see section III). Based on the recent advances in neuroscience and psychology, these agents are expected to decide, plan, learn or even reasoning better than those that do not take advantage of emotions.

Although affective artificial emotions field is in an initial phase, several applications have been developed. Some of these applications are entirely new, others are simply a different approach of dealing with problems that, up to now, were solved ignoring the influence of emotion on problem solving. The existing approaches can be organised into three main groups:

- ◇ systems that recognize emotions;
- ◇ systems that express emotions;
- ◇ systems that generate or synthesize emotions.

The first and the second group can be seen as one, because most of the systems that recognise emotions also address the issue of expressing emotions. However, most of the emotion-based computer systems are about generating or synthesising emotions and about the influence of emotions on cognitive processes, i.e., decision-making systems.

V. Affective Interaction in MultiAgent Systems

The study of agent-based systems emerged from the field of distributed Artificial Intelligence (AI) in the early to mid 1980's, with the development of intelligent Multiagent Systems (MAS), being given new impulse by the emergence of the World Wide Web. Solving the problems associated with, and taking advantage of the opportunities offered by, this inherently distributed and unstructured environment are seen as major application areas for intelligent and MAS. Traditional affective interaction is just based on the single human computer interaction procedures. In contrast to these classical applications in AI, the central ideas underlying MAS-based affective interaction are:

- ◇ the affect of one agent could be influenced by the other agents;
- ◇ the system exhibits goal directed behaviour;
- ◇ one agent can interact with and negotiate with other agents (can be a human) in order to achieve their goals;
- ◇ the whole system can apply intelligence in the way they react to a dynamic and unpredictable environment.

Besides the implementation of practical and useful systems, another goal in the study of MAS-based affective interaction systems (see for instance [46]) is the interaction understanding among intelligent entities, whether they are computational, human or both.

VI. Affective Recommender Systems

A. Detecting Affective States

Affective states of end users (in any stage of the interaction chain) can be detected in two ways:

- ◇ **explicitly**: the explicit detection of emotions is more accurate, however it is an intrusive process that breaks the interaction process. Some authors defend that explicit acquisition of users' affect has negative properties, as users may have side-interests that drive their explicit affective labelling process (e.g., asocial tagging, egoistic tagging or reputation-driven tagging) [47]. The most commonly used procedure for the explicit assessment of emotions is the Self Assessment Manikin (SAM) [48] (a questionnaire where users assess their emotional state in the three dimensions: valence, arousal and dominance).

- ◇ **implicitly:** whereas the implicit approach is less accurate, it is well suited for user interaction purposes since the user is not conscious of it. The implicit acquisition of emotions is usually done through a variety of modalities and sensors: speech, video cameras, EEG[1], ECG[2], among other sensors. These equipments measure various changes of the human body (e.g., facial changes, posture changes, changes in the skin conductance, among other features) that are known to be related to specific emotions. For example, the Facial Action Coding System (FACS), proposed by Ekman [49], maps emotions to changes of facial characteristic of the human face. There are excellent surveys on the topic of multimodal emotion detection, see [50] [47] [51]. In general, raw data is acquired from one or more sensors during the user interaction. These signals are processed in order to extract some low level features. Then a classification or regression technique is applied to yield distinct emotional classes or continuous values.

B. Affective user modelling in Recommender Systems

With the technological advance registered in the last decades we have been seeing an exponential growth of the information available. In order to cope with this superabundance of information, Recommender Systems (RS) are a promising technique to be used. The most common division of RS differs between (i) content based recommender systems [52], (ii) collaborative filtering recommender systems [53] and (iii) hybrid recommender systems [54].

These traditional RS consider only two types of entities, users and items, and do not put them into a context when providing recommendations. Nevertheless, the most relevant information for the user may not only depend on his preferences, but also in his context. In addition, the very same content can be relevant to a user in a particular context, and completely irrelevant in a different one. For this reason, it is important to have the user's context in consideration during the recommendation process [55]. However, it is accepted that context can change the state for a item be recommended, i.e., user mood can change the state and that's why it is a context of the user.

User' context can be modelled by using on of the generic user modelling approaches described by Adomavicius et al. [54]. Yet, there have been no strong related work in RS with affective user modelling (with the exception of [56] and [57]). Some authors suggest to use affective labels for tagging the content by using unobtrusive emotion detection techniques [58]. Moreover, some researchers focus on the unobtrusive acquisition of users' emotions through various modalities [59], but as far as we know RS based on affective user modelling is something starting to be explored.

[1]Electroencephalograph (EEG) is an instrument for measuring and recording the electric activity of the brain.

[2]Electrocardiography (ECG) is a commonly used, non-invasive procedure for recording electrical changes in the heart.

VII. Concluding Remarks

Affective Computing (AC) is currently one of the most active research topics, having increasingly intensive attention. This strong interest is driven by a wide spectrum of promising applications in many areas, such as affective agents and multiagents or even recommender systems.

The book "Affective Computing" by Rosalind Picard (see [2]) is considered a good start point for those who are starting in this area, however best literature on this topic has yet to be written, perhaps by readers challenged and stimulated by the theories presented in the book, or by related work in the field. Nevertheless, it is important to note that this area requires a broad multidisciplinary background knowledge, such as ethology, psychology, neuroscience, computer science, software engineering, AI and philosophical insight, in the context of creative engineering design.

In this paper, we described some emotional theories behind AC and the emerging topic of Affective Interaction. Then, some notions on artificial agents with emotion features, were presented. In addition, central ideas underlying multiagents based in affective interaction, were detailed. We also surveyed some work that deals with some of the issues that arise in the pursuit of affective recommender systems, a relevant field that is booming.

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