GUEST EDITORIAL PREFACE

Benefits and Limitations of Continuous Representations of Emotions in Affective Computing:

Introduction to the Special Issue

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Affective computing (Picard, 1997) has witnessed tremendous progress over the past decade, in all four of its core areas: recognition of human emotions by machines, affective user modeling, modeling of emotions in agent architectures, and expression of emotions in virtual agents and robots (Gunes & Pantic, 2010; Hudlicka, 2011a).

Thus far, affective computing can best be characterized as an engineering discipline. A number of methods, techniques, algorithms and architectures have been developed in all four of the core areas. These have enabled achievements in emotion recognition that are beginning to approach human performance (Gunes et al., 2011; Pantic & Bartlett, 2007; Zeng et al., 2009), and the development of increasingly affectively realistic virtual agents (Schröder et al., 2012; Dautenhahn, 2007; Castellano et al., 2008; Becker et al., 2007; Prendinger & Ishizuka, 2004) and robots (Breazeal, 2002, 2003), which integrate techniques from multiple areas of affective computing. Advancement in affective computing techniques has also given rise to a distinct subfield in game development: affective gaming (Gilleader et al., 2005; Sykes, 2004; Hudlicka, 2011b).

Yet in spite of these successes, the field still lacks firm theoretical foundations and systematic guidelines in many areas, particularly so in emotion modeling (Broekens, 2010): the construction of computational models of emotion generation and emotion effects, both as standalone models and as models integrated in agent architectures. This is in large part due to the difficulties associated with developing theoretical explanatory frameworks for emotions and affective phenomena in general, as well as the difficulties in obtaining the necessary empirical data about transient, multi-modal affective states (Hudlicka, 2011a).

Recent developments in the field have contributed to an integrated effort to transition affective computing into a more scientific discipline (e.g., Broekens et al., 2008). This is evidenced by an increased emphasis on comparing and validating existing emotion models (categorical vs. dimensional models), with the aim of developing systematic guidelines for affective modeling (e.g., Hudlicka, 2011a; Broekens & Hudlicka, 2009), creating frameworks that use these models for automatic analysis (e.g., Nicolaou et al., 2011a, 2011b) and synthesis purposes (see Gunes et al. 2011, for a review), and in attempts to develop standards in the form of affective markup languages, e.g., EmotionML (Schröder et al., 2011), and open source development frameworks and tools, e.g., the Semaine API (Schröder, 2010) and the ALMA architecture (Gebhard, 2005).

An important component of this effort is the increased interest in understanding the relative benefits and drawbacks of alternative theoretical perspectives on emotions, and the associated representations. Three dominant theoretical perspectives on emotions have emerged in affective computing: discrete / categorical, dimensional, and componential. In emotion modeling, emphasis has been on the use of cognitive appraisal as a means of generating emotions in agents, with the majority of models using the Ortony, Clore, and Collins theory (OCC) (Ortony et al., 1988). In automatic emotion analysis and recognition, the past emphasis has been primarily on discrete representations of emotions (Zeng et al., 2009) for a detailed review). However, as affective computing moves away from the controlled and restricted laboratory settings towards the more challenging naturalistic settings (Gunes et al., 2008), dimensional representation of emotions (typically using the pleasure-arousal-dominance (PAD) dimensions) has been advocated to be a more suitable model (see the paper by Cowie et al., in this issue) to capture the complexity of everyday emotions conveyed by very rich sources of information (for a detailed review see Gunes & Pantic, 2010). In addition to the trend that shifts from discrete to dimensional representations of emotions, more recently, increased attention is being paid to the componential perspective, and the use of appraisal variables associated with cognitive appraisal (see the paper by Mortillaro et al., in this issue).

Recognizing the need for more systematic exploration of the use of continuous representations of emotions in affective computing, Gunes, Schuller, Pantic, and Cowie organized a workshop at the 9th IEEE International Conference on Automatic Face and Gesture Recognition in the spring of 2011: the EmoSPACE2011 workshop (Gunes et al., 2011). Its goal was to present emerging research in dimensional and continuous analysis and synthesis of human emotional behavior, and provide a forum for identifying and discussing challenges faced in the relevant fields, in both research and applied contexts.

The workshop in turn gave rise to this special issue, whose original objective was to further explore the benefits and drawbacks of alternative representations of emotions, with an emphasis on continuous representations. To enhance the cohesiveness of the special issue, and to ensure that the core topics were directly addressed in each paper, we asked the authors to answer the following questions regarding the use of a particular theoretical perspective and representation of emotion:

1. Why did you choose the particular representation? What are the benefits and drawbacks of the selected emotion representation, as compared to the other alternatives?
2. How applicable is the selected theoretical perspective and representation to other aspects of affective computing (e.g., if your focus is on recognition, comment on how your representation might extend to emotion modeling; if your focus is emotion generation, comment on how applicable your representation would be for modeling emotion effects, across multiple modalities).
3. How well does the theoretical perspective and representation accommodate multiple modalities of emotions?
4. How readily are the necessary data available?
5. How would you validate your approach and what data would you need?

We thought that a systematic set of answers to the questions above would have provided a more solid theoretical foundation for all areas of affective computing, as well as providing a basis for the development, and analysis, of techniques using continuous representations of emotions. As it turns out, answering these questions proved more difficult than we anticipated. This led us to the realization that questions we posed go beyond merely facilitating a cohesive organization of the existing research, and in fact define broader research areas that are yet to be explored.

Although the papers in this special issue focus on emotion representation and modeling, they have significant implications for several other core areas of affective computing: emotion measurement and recognition, and emotion synthesis. The papers discuss various aspects of the dimensional emotion representation: the PAD dimensional model (Broekens), approaching emotions as (continuous) traces (Cowie et al.), the componential representation and appraisal variables (Mortillaro et al.), and a continuous representation that integrates dimensions from multiple theoretical perspectives (Bach), and simultaneously address several theoretical and practical issues. We introduce the papers and provide brief summaries of their contributions.

In "Tracing Emotion: An Overview", Cowie, McKeown, and Douglas-Cowie discuss how creating automatic emotion-sensitive systems based on continuous representations depends on obtaining continuous representations from human labelers. They describe in detail a technique termed 'emotion tracing', whose aim is to capture perceived affect, and the tools that they have created, i.e., FeelTrace and Gtrace, that can be used to accomplish this vital task. The paper discusses the psychological and the statistical challenges faced when setting out to acquire 'traces' from human raters, how these issues can be potentially solved, and what implications these have for creating emotion-sensitive systems. The relevant issues include tracing emotion- or communication-related categories (as well as dimensions), the number of continuous dimensions used for tracing, divergence in the traces (widely known as disagreement between human labelers), the patterns of divergence for different dimensions, the scale used for tracing (which appears to have direct effect on the trace divergence), and measures used for analyzing, summarizing and representing the traces (correlation and averaging), as well as the implications of these choices. These issues are further contextualized with a number of experiments and results on tracing naturalistic and multimodal human affective behavior data (e.g., from Humaine and Semaine databases). Cowie et al. argue that the issues faced in tracing emotions do not necessarily pose an obstacle for creating automatic emotion recognizers; rather, they confirm the existence of significant research questions that may lead to new research avenues in affective computing.

In "Advocating a Componential Appraisal Model to Guide Emotion Recognition", Mortillaro, Meuleman, and Scherer point out that black-box approaches to emotion recognition, based on the discrete theoretical perspective and a limited set of emotion labels, and using purely statistical methods, have a number of practical and theoretical drawbacks. The paper first discusses how, to date, emotion production (synthesis) and emotion recognition has been treated independently. The authors then suggest establishing a link between models of emotion recognition and emotion synthesis via appraisal models. This link aims to enable the addition of contextual information into automatic emotion recognizers, and enrich their interpretation capability in terms of multiple scales (more sensitive representation) and continuous dimensions (richer representation). Essentially, their approach suggests the use of continuous appraisal variables as an intermediate layer (intervening variables) between the input expressive features and the emotion label output. This approach thus divides the emotion recognition process into two mappings: expressive features to appraisal variables, and appraisal variables to emotion label. Mortillaro et al. point out the relative lack of research regarding the first mapping, and underscore the benefits of using data about the different effects of appraisal on facial expression, voice and body movements as a basis for defining this mapping. They argue that the use of the componential theoretical perspective, with its set of continuous appraisal variables, provides a number of benefits for emotion recognition: 1) enhanced recognition of mixed (or multiple) emotions, mediated by the use of appraisal variables as outputs of the emotion recognition process; 2) ability to integrate the crucial, but currently missing, contextual information into automatic recognizers; and 3) facilitation of a finer level of interpretation (in terms of intensity and subtlety of the emotions predicted).

Broekens' "In Defense of Dominance: PAD Usage in Computational Representations of Affect" discusses why the dominance dimension is needed for a more complete representation of emotions. He clarifies some misconceptions about the dominance dimension, emphasizes the fact that a 3rd dimension is necessary to differentiate among emotions that share similar arousal-valence configurations (e.g., anger and fear – both high arousal and negative valence), and highlights the usefulness of the dominance dimension for representing approach-avoidance reactions and coping-related appraisals. He also notes that this dimension is useful in emotion measurement. The paper also highlights the important distinction between the computational utility of dominance (as outlined), and its psychological validity. Broekens acknowledges that the dominance dimension may not correspond to an actual underlying physiological system (in agreement with Russell's work on core affect, Russell, 2003), but at the same time emphasizes its utility in computational models. This discussion begins to address the broader issue regarding the need for, and benefits of, building computational affective models that are consistent with psychological and neuroscience data.

In "A Framework for Emergent Emotions, Based on Motivation and Cognitive Modulators", Bach makes the case for the needs and benefits of process-level models, which emphasize the underlying mechanisms of affective processes, and, more broadly, cognitive-affective processes. He terms these models *internalist* models, to contrast them with more application-focused, *externalist* models. He then presents a cognitive-affective architecture, the MicroPsi architecture, based on Dörner's theories (1999, 2002), which implements a process-level, internalist model of emotions. A distinguishing feature of MicroPsi is the lack of a dedicated emotion module and emotion 'objects', common in most cognitive-affective architectures. Rather, MicroPsi represents distinct affective states in terms of distinct values of a set of global parameters (modulators) that influence the architecture processing, and thus determine the observable agent behavior. These parameters/modulators are derived from Dörner's theory and go beyond the familiar valence and arousal (components of PAD models of emotions) to also include resolution level, selection threshold, goal directedness, securing rate (explained further in Bach's paper). The modulators thus provide a set of continuous parameters, defining a multi-dimensional space within which distinct affective states are located. This model of emotions is based on the assumption that emotions are not 'natural kinds' (Feldman-Barret, 2006), but rather should be viewed as 'perceptual gestalts' that modulate cognition (and other behavior). Bach concludes his paper with a discussion of the benefits and drawbacks of representing emotions as emergent phenomena.

The special issue concludes with two book reviews of the recently published "Affective Computing and Interaction: Psychological, Cognitive and Neuroscientific Perspectives", a compendium edited by D. Gokcay and G. Yildirim (2011).

As guest editors, our hope is that the collection of papers in this special issue, together with two independent reviews of a newly published book, will put the continuity aspect of emotions under the spotlight, contribute to the emerging theoretical efforts in affective computing, and provide a firmer foundation for the continued development of more principled and systematic design of affective models and systems.

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