Journal of Visual Languages and Computing 31 (2015) 70–86

Contents lists available at ScienceDirect

Journal of Visual Languages and Computing

journal homepage: www.elsevier.com/locate/jvlc

A survey of technologies on the rise for emotion-enhanced interaction ☆

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ARTICLE INFO

Article history:
Received 16 June 2015
Accepted 5 October 2015
Available online 16 October 2015

Keywords:
Emotion detection
Emotion measurement
Social aspects
Collaboration support
Emotion-driven adaptation
Emotion-enhanced interaction

ABSTRACT

Emotions are a major part of the human existence and social interactions. Some might say that emotions are one of the aspects that make us truly human. However, while we express emotions in various life settings, the world of computing seems to struggle with supporting and incorporating the emotional dimension. In the last decades, the concept of affect has gotten a new upswing in research, moving beyond topics like market research and product development, and further exploring the area of emotion-enhanced interaction.

In this paper, we highlight techniques that have been employed more intensely for emotion measurement in the context of affective interaction. Besides capturing the functional principles behind these approaches and the inherent volatility of human emotions, we present relevant applications and establish a categorization of the roles of emotion detection in interaction. Based on these findings, we also capture the main challenges that emotion measuring technologies will have to overcome in order to enable a truly seamless emotion-driven interaction.

1. Introduction

All of us experience emotions throughout our entire lives and in the most varied circumstances. They influence our decisions and experiences, but most of all they affect our social interactions and interpersonal relations. And while emotions manage to spill into almost every aspect of our days, there are still some areas that are almost exclusively absent of human emotion.

One such context is given by our interactions with technology. Nowadays, we may work with specialized tools, communicate online, organize our lives with apps, have fun with games and experience an entire set of emotions while doing so, anything from joy to excitement and to frustration. Yet, while we do bring our emotional selves into the world of computing, this field has still very little in the way of supporting out emotion-escorted interaction. We communicate our subjective states online through emoticons, emojis and "like"-buttons, we smile in the face of an aesthetically pleasing interface but without any reaction from the system, we work together with our colleagues without knowing how they feel about our work. As stated by Picard [1] in her work in the field of Affective Computing: "Basic affect recognition and expression are expected by humans in communication. However, computers today cannot even tell if you are pleased or displeased. They will scroll screenfuls of information past you regardless of whether you are sitting forward eagerly in your seat, or have begun to emit loud snoring sounds." All this makes our current technology seem dry, without the ability to capture the entire human experience and interaction, and center on the most important element of the equation: the *user*.

☆ This paper has been recommended for acceptance by Henry Duh.

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http://dx.doi.org/10.1016/j.jvlc.2015.10.001
1045-926X/

To obtain affective technology that truly shapes itself on the human paradigm, we need to be able to recognize or estimate user emotional states and employ these findings in the design, functionality and interaction support of our digital systems. But before we focus on how we can use technology to detect emotions, we need to clarify what emotions are and how they are classified. Certainly, subjective human experiences are inherently subtle and hard to define, resulting in publications that intermix concepts like affect, emotion, mood, and sentiment. Furthermore, cognitive psychology offers a relatively wide array of definitions for all these concepts, leaving many degrees of freedom in selecting a view on the topic.

In the following, we provide a brief overview of the most widely accepted definitions and classifications of affective states. The notion of 'affective state' covers a set of concepts, including *core affect*, *emotions*, *moods*, and *personality*. These concepts differ in multiple ways, one of which is their temporal persistency. *Core affects* are defined as "a simple primitive non-reflective feeling most evident in mood and emotion but always available to consciousness" [2]. Core affect is thus constantly present in an individual, and it can be experienced either as part of an emotion or mood, or completely independently [3]. Furthermore, core affect can be linked to Russell's circumplex model of affect, detailed later in this section. Some elementary building blocks of emotion that are included in the core affect category include pleasure–displeasure and high–low energy levels.

Next, *emotion* is defined as a medium term affective state that is characterized by its appearance as a response to an external or internal stimulus [4,5], represented by a person, an event, a memory, an image, a scent, etc. Thus, emotions are not bounded by time or reality, as emotions can be generated also by imaginary experiences or by events from the past. Examples of emotional states include love, fear, anger, and sadness.

Compared to emotions, *moods* are generally not elicited by a concrete stimulus, thus having a more diffuse nature. While the origin of a mood is rarely known, it is also an affective state that remains active for longer periods of time than emotions [6]. Finally, *personality* is a more persistent subjective aspect encoding attitudes towards a concept or object. In this paper, we focus on technologies that have been employed to estimate user emotions and moods, with an emphasis on the former. Emotions are of particular importance in affective computing and interaction, as they can be linked to events or objects, thus offering feedback about the interaction cycle of a user with his/her collaborators or a system.

In terms of classification, emotion theory has centered around two ways of grouping affective experiences. On the one hand, some theories focus on defining and analyzing emotions as a set of distinct states. Some of the more widely used theories include Ekman's theory of six basic emotions [7,8] (disgust, anger, fear, joy, sadness, and surprise) and Plutchick's theory of eight basic emotions [9] (disgust, anger, fear, sorrow, joy, acceptance, anticipation, and surprise). Emotions that do not fall into the category of basic ones are usually defined as combinations or variations of basic emotions [10].

Fig. 1. Russell's circumplex model of affect [12] encoding user emotions in terms of two dimensions: valence (positive and negative emotions) and arousal (high and low excitement).

One characteristic of the basic emotions is that they are, by their nature, easier to recognize with various technologies, as they would generate distinct functional patterns in the human body (e.g., brain activation patterns or physiological patterns). However, studies have shown that non-basic emotions like frustration, boredom and confusion can be more frequent and thus more useful in human–computer interaction scenarios [11].

On the other hand, there are theories of affect that focus on distributing and describing all emotional states through a set of dimensions. While the number of possible considered dimensions is variable, most widely accepted approaches focus on a 2D or 3D model: Russell's circumplex model of affect (see Fig. 1) encodes emotional states in a two-dimensional space defined by valence (positive-negative) and arousal (excited-calm) [12]; and the three-dimensional model of Mehrabian incorporates the three axes of pleasure (valence), arousal and dominance (abbreviated: PAD) [13]. Note that Ekman's six basic emotions have counterparts in Russell's two-dimensional model, basically offering a correspondence between the two categories of models.

Contrary to affective computing, *affective interaction*[1] focuses on the importance of the emotional experiences of the users from the perspective of awareness and reflexion, and the level in which they are grounded in interaction itself [14,15]. Furthermore, affective interaction focuses less on accurate emotional readings and more on raising user emotional awareness for enabling him/her to analyze and evaluate the experience, communication and interaction.

Section 2 illuminates the functionality and abilities of a selected group of technologies, currently used in affective computing and interaction. We then present applications that use emotion estimation technology to enhance or augment the user interaction (Section 3). Finally, we

[1] Note that we use the terms 'emotion-enhanced interaction' and 'affective interaction' interchangeably in this paper.