Affective Computing

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INTRODUCTION

We seem to be entering an era of enhanced digital connectivity. Computers and Internet have become so embedded in the daily fabric of people's lives that people simply cannot live without them (Hoffman, Novak, & Venkatesh, 2004). We use this technology to work, to communicate, to shop, to seek out new information, and to entertain ourselves. With this ever-increasing diffusion of computers in society, human–computer interaction (HCI) is becoming increasingly essential to our daily lives.

HCI design was first dominated by direct manipulation and then delegation. The tacit assumption of both styles of interaction has been that the human will be explicit, unambiguous, and fully attentive while controlling the information and command flow. Boredom, preoccupation, and stress are unthinkable even though they are "very human" behaviors. This insensitivity of current HCI designs is fine for well-codified tasks. It works for making plane reservations, buying and selling stocks, and, as a matter of fact, almost everything we do with computers today. But this kind of categorical computing is inappropriate for design, debate, and deliberation. In fact, it is the major impediment to having flexible machines capable of adapting to their users and their level of attention, preferences, moods, and intentions.

The ability to detect and understand affective states of a person we are communicating with is the core of emotional intelligence. Emotional intelligence (EQ) is a facet of human intelligence that has been argued to be indispensable and even the most important for a successful social life (Goleman, 1995). When it comes to computers, however, not all of them will need emotional intelligence and none will need all of the related skills that we need. Yet human–machine interactive systems capable of sensing stress, inattention, and heedfulness, and capable of adapting and responding appropriately to these affective states of the user are likely to be perceived as more natural, more efficacious, and more trustworthy. The research area of machine analysis of human affective states and employment of this information to build more natural, flexible (affective) HCI goes by a general name of affective computing, introduced first by Picard (1997).

RESEARCH MOTIVATION

Besides the research on natural, flexible HCI, various research areas and technologies would benefit from efforts to model human perception of affective feedback computationally. For instance, automatic recognition of human affective states is an important research topic for video surveillance as well. Automatic assessment of boredom, inattention, and stress will be highly valuable in situations where firm attention to a crucial, but perhaps tedious task is essential, such as aircraft control, air traffic control, nuclear power plant surveillance, or simply driving a ground vehicle like a truck, train, or car. An automated tool could provide prompts for better performance based on the sensed user's affective states.

Another area that would benefit from efforts towards computer analysis of human affective feedback is the automatic affect-based indexing of digital visual material. A mechanism for detecting scenes/frames which contain expressions of pain, rage, and fear could provide a valuable tool for violent-content-based indexing of movies, video material and digital libraries.

Other areas where machine tools for analysis of human affective feedback could expand and enhance research and applications include specialized areas in professional and scientific sectors. Monitoring and interpreting affective behavioral cues are important to lawyers, police, and security agents who are often interested in issues concerning deception and attitude. Machine analysis of human affective states could be of considerable value in these situations where only informal interpretations are now used. It would also facile the research in areas such as behavioral science (in studies on emotion and cognition), anthropology (in studies on cross-cultural perception and production of

Table 1. The main problem areas in the research on affective computing

- *What is an affective state?* This question is related to psychological issues pertaining to the nature of affective states and the way affective states are to be described by an automatic analyzer of human affective states.
- *What kinds of evidence warrant conclusions about affective states?* In other words, which human communicative signals convey messages about an affective arousal? This issue shapes the choice of different modalities to be integrated into an automatic analyzer of affective feedback.
- *How can various kinds of evidence be combined to generate conclusions about affective states?* This question is related to neurological issues of human sensory-information fusion, which shape the way multi-sensory data is to be combined within an automatic analyzer of affective states.

affective states), neurology (in studies on dependence between emotional abilities impairments and brain lesions), and psychiatry (in studies on schizophrenia) in which reliability, sensitivity, and precision are persisting problems. For a further discussion, see Pantic and Bartlett (2007) and Pantic, Pentland, Nijholt, and Huang (2007).

THE PROBLEM DOMAIN

While all agree that machine sensing and interpretation of human affective information would be quite beneficial for manifold research and application areas, addressing these problems is not an easy task. The main problem areas are listed in Table 1.

What is an affective state? Traditionally, the terms "affect" and "emotion" have been used synonymously. Following Darwin, discrete emotion theorists propose the existence of six or more basic emotions that are universally displayed and recognized (Lewis & Haviland-Jones, 2000). These include happiness, anger, sadness, surprise, disgust, and fear. In other words, nonverbal communicative signals (especially facial and vocal expression) involved in these basic emotions are displayed and recognized cross-culturally. In opposition to this view, Russell (1994) among others argues that emotion is best characterized in terms of a small number of latent dimensions (e.g., pleasant vs. unpleasant, strong vs. weak), rather than in terms of a small number of discrete emotion categories. Furthermore, social constructivists argue that emotions are socially constructed ways of interpreting and responding to particular classes of situations. They argue further that emotion is culturally constructed and no universals exist. Then there is lack of consensus on how affective displays should be labeled. For example, Fridlund (1997) argues that human facial expressions should not be labeled in terms of emotions but in terms of behavioral ecology interpretations, which explain the influence a certain expression has in a particular context. Thus, an "angry" face should not be interpreted as *anger* but as *back-off-or-I-will-attack*. Yet, people still tend to use *anger* as the interpretation rather than *readiness-to-attack* interpretation. Another issue is that of culture dependency: the comprehension of a given emotion label and the expression of the related emotion seem to be culture dependent (Wierzbicka, 1993). Also, it is not only discrete emotional states like surprise or anger that are of importance for the realization of proactive human–machine interactive systems. Sensing and responding to behavioral cues identifying attitudinal states like interest and boredom, to those underlying moods, and to those disclosing social signaling like empathy and antipathy are essential. However, there is even less consensus on these nonbasic affective states than there is on basic emotions. In summary, previous research literature pertaining to the nature and suitable representation of affective states provides no firm conclusions that could be safely presumed and adopted in studies on machine analysis of affective states and affective computing. Hence, we advocate that pragmatic choices (e.g., application- and user-profiled choices) must be made regarding the selection of affective states to be recognized by an automatic analyzer of human affective feedback (Pantic & Rothkrantz, 2003).

Which human communicative signals convey information about affective state? Affective arousal

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