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A fuzzy physiological approach for continuously modeling emotion during interaction with play technologies

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Abstract

The popularity of computer games has exploded in recent years, yet methods of evaluating user emotional state during play experiences lag far behind. There are few methods of assessing emotional state, and even fewer methods of quantifying emotion during play. This paper presents a novel method for continuously modeling emotion using physiological data. A fuzzy logic model transformed four physiological signals into arousal and valence. A second fuzzy logic model transformed arousal and valence into five emotional states relevant to computer game play: boredom, challenge, excitement, frustration, and fun. Modeled emotions compared favorably with a manual approach, and the means were also evaluated with subjective self-reports, exhibiting the same trends as reported emotions for fun, boredom, and excitement. This approach provides a method for quantifying emotional states continuously during a play experience.

Keywords: Emotion; Affective computing; Fun; Games; Physiology; Galvanic skin response; Electromyography; Heart rate

1. Introduction

Computer games have grown during recent years into a very popular entertainment form with a wide variety of game types and a large consumer group spread across the world. As researchers develop novel play environments, computer and console game markets continue to grow rapidly, outperforming the film industry in terms of total revenues in many regions (Pagulayan et al., 2002). Although gaming technology has continued to evolve, researchers and traditional computer game developers suffer from a lack of effective evaluation methods.

The development of evaluation methodologies in human–computer interaction research (HCI) has been rooted in the cognitive sciences of psychology and human factors, in the applied sciences of engineering, and in computer science (Norman, 2002). Although the study of human cognition has made significant progress in the last decade, the idea of emotion, which is equally important to design (Norman, 2002), is still not well understood, especially when the primary goals are to challenge and entertain the user. Traditional measures for productivity environments, such as task performance, are not applicable to affective environments since we are not interested in performance; we are interested in what kind of emotional experience is provided by the play technology and environment, regardless of performance (Pagulayan et al., 2002). Although traditional usability measures may still be relevant, they are subordinate to the emotional experiences resulting from interaction with the play technology and with other players.

Our research interest is in how to quantify emotional experience when engaged with affective technologies, by developing an evaluation methodology for entertainment environments that is as robust as methods for evaluating productivity. This paper motivates why we need such an approach and describes the process by which we designed a new evaluative methodology for measuring emotional experience with interactive entertainment technologies.

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1.1. Affective evaluation of entertainment technologies

Traditional evaluation methods have been adopted, with some success for evaluating entertainment technologies, and include both subjective and objective techniques. The most common methods of assessing emotion are through subjective self-reports including questionnaires, interviews, and focus groups (Fulton and Medlock, 2003) and through objective reports from observational video analysis (Lazzaro, 2004).

The success of a play environment is determined by the *process* of playing, not the *outcome* of playing (Pagulayan et al., 2002). We must consider this when evaluating emotional experience during interaction with play technologies, as current methods suffer from low evaluative bandwidth, providing information on the whole experience, rather than continuously throughout time.

Subjective reporting through questionnaires and interviews is generalizable, and is a good approach to understanding the *attitudes* of the users, but subjects are bad at self-reporting their *behaviors* in game situations (Pagulayan et al., 2002). In addition, subjective techniques only generate data when a question is asked, and interrupting game play to ask a question is too disruptive. Desmet (2003) developed a non-verbal questionnaire designed specifically to assess 14 separate emotional responses to products. Although it addresses some of the drawbacks of language scales, the evaluative bandwidth is still low.

Using video to code gestures, body language, facial expressions and verbalizations, is a rich source of data; however, there is an enormous time commitment, which requires between 5 and 100 h of analysis for every hour of video (Fisher and Sanderson, 1996).[1] Also, the analysis is generally event-based (user is smiling now), rather than continuous (degree of smile for every point in time), which could be important for exploring the process of play.

There has been some recent research on using inspection methods, such as heuristics (Wiberg, 2003; Desurvire et al., 2004; Sweetsner and Wyeth, 2005) to evaluate the playability of an entertainment technology, but these discount methods do not involve actual users, but are administered by usability specialists. Heuristics also give an overview of the playability, rather than examining a user's change in emotions over time.

Researchers in human factors have used physiological measures as indicators of mental effort and stress (Vicente et al., 1987). See Mandryk and Inkpen (2004) for an overview. Psychologists use physiological measures to differentiate human emotions such as anger, grief, and sadness (Ekman et al., 1983). Recently, physiological measures have been used to assess a user's emotional experience when engaged with computing systems (see Section 2.4); however, physiological data have not been employed to identify a user's emotional state, such as fun or excitement, when engaged with play technologies. Based on previous research on the use of psychophysiological techniques, we believe that capturing, measuring, and analyzing autonomic nervous system (ANS) activity will provide researchers and developers of technological systems with continuous access to the emotional experience of the user. Used in concert with other evaluation methods (e.g. subject reports and video analysis), a complex, detailed account of both conscious and subconscious user experience could be formed.

We designed an experiment to create and evaluate a model of user emotional state when interacting with play technologies. We record users' physiological, verbal and facial reactions to game technology, and apply post-processing techniques to quantitatively and continuously measure emotional state. We envision that when combined with other evaluative approaches, our technique can help create a rich and robust picture of user experience.

2. Physiological metrics for evaluation

In this section we briefly introduce the physiological measures used, describe how these measures are collected, and explain their inferred meaning. Based on previous literature, we chose to collect galvanic skin response (GSR), electrocardiography (EKG), and electromyography of the face ($EMG_{smiling}$ and $EMG_{frowning}$). Heart rate (HR) was computed from the EKG signal.

2.1. Galvanic skin response

GSR is a measure of the conductivity of the skin. There are specific sweat glands (eccrine glands) that cause skin conductivity to change and result in the GSR. Located in the palms of the hands and soles of the feet, these sweat glands respond to psychological stimulation rather than simply to temperature changes in the body (Stern et al., 2001). For example, many people have cold clammy hands when they are nervous. In fact, subjects do not have to even be sweating on the palms of the hands or soles of the feet to see differences in GSR because the eccrine sweat glands act as variable resistors on the surface. As sweat rises in a particular gland, the resistance of that gland decreases even though the sweat may not reach the surface of the skin (Stern et al., 2001).

Galvanic skin response is a linear correlate to arousal (Lang, 1995) and reflects both emotional responses as well as cognitive activity (Boucsein, 1992). GSR has been used extensively as an indicator of experience in both non-technical domains (see Boucsein, 1992 for a comprehensive review), and technical domains (e.g. Wilson and Sasse, 2000a, b; Ward and Marsden, 2003). We measured GSR using surface electrodes sewn in Velcro straps placed around two fingers on the same hand.

[1]There are a few consulting firms that specialize in observational analysis of entertainment technologies (Lazzaro, 2004); however, many researchers rely on subjective data for user preference, rather than objective observational analysis.