

Biometric Measurement of Human Emotions

Dr. Clive Chandler and Rachel Cornes

*Faculty of Computing, Engineering and Technology, Staffordshire University, Staffordshire, England
E-mail: c.chandler@staffs.ac.uk cu000775@student.staffs.ac.uk*

Abstract

No aspect of our mental life is more important to the quality and meaning of our existence than emotions” (Sousa, 2010).

It is not surprising that emotions have been a point of interest for researchers for centuries (Sousa, 2010), however, even after considerable research effort over many years, there is no definitive answer to the question ‘What is an emotion?’ (Scherer, 2005). As computer programs and application become more complex User experience and the ability to interact successfully has become crucial, and as such the Human Computer Interaction (HCI) becomes critical to that success. One increasingly important aspect of HCI is the role played by the user’s emotional state on such interactions. But as emotions are difficult at best to define, the goal is to identify a method by which they can be analysed and predicted thus enabling a possible improvement to interface interactions, and user experience. Biometric analysis offers one solution to this complex situation. Although there are many techniques utilized in biometric analysis it is imperative that whichever method is employed has the minimum effect without causing distress or interruption to the user’s interaction. This paper reviews current biometric techniques and research available and suggests a system whereby human emotions could potentially be measured during software use.

Index Terms: Biometrics, Emotional Analysis, HCI, User Analysis

Introduction

Computers have become commonplace in modern life (Corrin et al., 2010) and as they increase in popularity, they also increase in complexity. As the complexity rises, software becomes more sophisticated and Human-Computer Interaction (HCI) has become a focal point - is new software going to be easy or frustrating for users to learn? Is a new computer game going to be fun to play, or scary where it is intended to be? Will a person involved in a real-time stressful job, such as a pilot or police officer, be able to cope with the stress involved in the job? Does a film have the desired effect on its viewing audience? To answer these questions, it is important to attempt to understand the user’s emotional state.

Asking a select test group what they were feeling at the time could be one way to find out this information, albeit not a very accurate one as: memory can distort retrospective reports on emotions; and if the experiments are stopped as an emotion is being felt so questions can be asked, the results could be affected (Hagar & Ekman, 1983).

Are there other, more accurate, ways to find a user’s emotional state? Looking at a general overview of biometrics and human emotions could help determine if there are such possibilities.

Researchers have been investigating methods whereby the process of defining the emotions felt, as they occur, can be automated. This research has been applied across many fields and in different scenarios: Human-Computer Interaction (Haag et al., 2004); measuring stress levels in Real-Time situations (Ruzanski et al., 2006); measuring user interaction with entertainment technology (Nacke et al., 2009); and eliciting the intended emotional response from users playing computer games (Callele et al., 2006).

Although Callele et al. (2006) make no attempt to utilise biometrics in their analysis of emotions others as indicated above rely on the use of biometrics to measure the emotion, as it is being felt, for example, skin conductivity, electromyography, respiration, and facial expression recognition, in particular have been used with some success.

Biometrics

Biometrics “refers to the automatic recognition of individuals based on their [unique] physiological and/or behavioural characteristics” (Jain et al., 2004) and in computing is usually used for security applications that focus on either verification (Is this person who they claim to be?) or identification (Who is this person?). Whilst in the medical profession biometrics refers to collecting the “measurements of biological and/or medical phenomena” (Vielhauer, 2006), for example, measuring a patient’s blood pressure.

For the purpose of this paper, a more traditional and non-subject specific definition will be used which is “composed of the two Greek terms “bios” for life and “metros” for metric.” (Vielhauer, 2006). Put simply, the measurement of life, or more specifically, the measurement of human life.

Although there is a body of research on the use of biometrics in a variety of domains, as yet the techniques have gained limited success and the question still remains as to which biometric technique could yield the most useful information for interaction design, providing as little disturbance as possible to the user whilst still measuring something as esoteric as emotions.

Given that the goal is to identify some reaction which will form the basis for the measurement of emotions whilst still leaving the user unimpeded or interrupted during their interaction with whatever software they may be using; such biometrics as blood pressure and heart rate which while

indicating a reaction would also prove too intrusive and would affect the performance of the user.

Therefore the most useful possibilities would appear to be;

- Finger Prints
- Iris
- Facial Recognition
- Skin Conductivity (GSR)
- Facial Thermography

Finger Prints

Fingerprints, which are made from ridges and valleys that are formed in the womb (Jain et al., 1999; O'Gorman, 1999; Lockie, 2009), have been used for many centuries (Jain et al., 2004), are considered to be unique between people, including identical twins, (Vielhauer, 2006) and between each finger of the same person (Jain et al., 1999).

However as they are generally used for security identification and verification it is arguable that they would not react to human emotional differences.

Iris

As with the fingerprint, the biometrics of the iris is generally used within security for verification and identification purposes. This is done in a similar way to the fingerprint. First an image of the iris is taken, and the points of interest, which in this case are made up from the "rich pattern of furrows, ridges, and pigment spots" (Bowyer et al., 2008), are checked for quality before extracting and storing this information in the form of a template. Once stored, this template can be checked against future images taken by the system to identify or verify a user. At this moment in time there appears to be no research on any changes which may or may not occur to the iris due to emotional state when measured biometrically.

Facial Recognition

Facial recognition is the measurement of key features of a face, such as "relation and size of eyes, nose and mouth" (Vielhauer, 2006) and has been used as far back as the ancient Egyptians to keep track of the workforce claiming provisions (Lockie, 2009).

As there are many disciplines interested in facial recognition, there are several implementations on the market, for example Eigenface, Feature Analysis, Neural Network, and Automatic Face Processing (Nanavati et al., 2002), that work using 2-D images, 3-D images, colour images, infra-red images, or a combination of them (Weng & Swets, 1998). Most systems will need a still image to compare to an image previously stored, such as a driving licence photograph, but there are some systems that work using a time-varying image sequence (video). This makes it possible to track faces and recognise facial expressions (Weng & Swets, 1998).

More recent advancements in Facial Reading applications have enabled real time measurement of critical facial nodes which indicate emotional state nominally from MIT media Lab (2011) and Noldus (2011).

Skin Conductivity (GSR)

The epidermis layer of human skin is highly resistive while the dermis and subcutaneous tissue is highly conductive

(Giakoumis et al., 2010). As a human feels emotionally aroused, sweat glands open, making the skin more conductive (Healey, 2008) by creating a pathway from the skin's surface to the more conductive skin below (Giakoumis et al., 2010). Measuring the conductivity of skin is referred to as measuring the Galvanic Skin Response (GSR), or skin conductivity.

Measuring skin conductivity is utilized in several applications: lie detectors (Lykken, 1959); measuring negative emotions, such as boredom (Giakoumis et al., 2010); and measuring interest (arousal) in a phone conversation (Iwasaki et al., 2010).

Facial Thermography

Each person emits a heat pattern that is characteristic to that person so that it can be used as a biometric measurement (Jain et al., 2004). Facial thermography is a non-intrusive method for identifying a person from their characteristic facial heat emissions that has been found to have accuracy levels reaching 99.25% (Bhowmik et al., 2010). Face, hand and hand vein thermography are all used in biometrics (Jain et al., 2004).

Biometric Measurement of Emotions

While theorists do not agree on what constitutes the elements of emotion, there are measurements indicating that when a human has an emotion, there is also a physical reaction taking place; for example, when frightened a human being's heart rate increases, muscles tense, and palms become sweaty (Haag et al., 2004). It has been proposed that these reactions can be measured to determine exactly which emotion is being experienced and to what intensity (Schut et al., 2010; Pantic et al., 2007; Amershi et al., 2006; Haag et al., 2004). As can be seen from these papers, there are different methods to measure emotions: Skin Conductivity (SC), or Galvanic Skin Response (GSR); electromyography (EMG) of the facial muscles; respiration (RESP); and facial expression recognition being among them. The most commonly explored of these being facial expression recognition (Haag et al., 2004).

Skin Conductivity (GSR)

Conductivity of the skin has been used to measure emotions in several research projects over recent years (Haag et al., 2004; Giakoumis et al., 2010; Khalfa et al., 2002; Iwasaki et al., 2010). Sensors are applied to the fingers of the non-dominant hand, as shown in

Figure 1, registering when the skin conductivity changes, or when an emotion takes place.

Skin conductivity is one of the bio-sensory methods used as the physiological change occurs as an emotion takes place (Healey, 2008). In and of itself the measurement of skin conductivity is not enough to map emotions felt, as emotional responses vary between different people and as one response could be mapped back to more than one emotion, so it is usual to utilize GSR techniques in conjunction with another measurements such as: pupil dilation or heart rate (Tapus & Mataric, 2007); electromyography, blood-volume pressure, electrocardiography, and respiration (Haag et al., 2004); although, this is not always the case (Khalifa et al., 2002).



Figure 1: Skin Conductivity Sensors (Haag et al., 2004)

Even though Khalifa et al. (2002) relied solely on skin conductivity in their research, they suggest in their conclusion that skin conductivity is better used to measure emotional arousal (calm to excited) rather than valence (negative to positive). They do, however, state that this is a good method to use in order to differentiate between conflict/non-conflict situations, such as anger and fear. One of the problems that Khalifa et al. (2002) identify with using skin conductivity is the influence of external factors such as temperature. This can be countered by calibration beforehand.

Electromyography

This technique measures the frequency of muscle tension of a specific muscle. This can be carried out in one of two ways: intra-muscular EMG or surface EMG. Intra-muscular EMG measures the frequency of muscle tension by inserting small needles into the muscle to be measured and subsequently getting the participant (usually a patient) to tense that muscle (eMedicineHealth, 2011). Surface EMG is measured by placing a sensor on the skin above the muscle to be measured, this is the method used by Haag et al. (2004) and Healey & Picard (1998), and is shown below



Figure 2: EMG sensor applied to the masseter muscle (Haag et al., 2004)

As with skin conductivity, EGM is used in conjunction with other techniques; skin conductivity; blood volume pressure; and respiration (Haag et al., 2004; Healey & Picard, 1998). One disadvantage to using EGM on facial muscles is that the results may be altered due to, for example, talking and coughing (Mandryk & Atkins, 2007).

Facial Expression Reading

Facial expressions are the most expressive way in which

humans portray their emotions (Sarode & Bhatia, 2010); it is, therefore, not surprising that facial expression recognition is one of the more researched methods of ascertaining human emotion (Haag et al., 2004). There are three approaches to facial expression recognition: analytic, holistic and hybrid.

Sarode & Bhatia (2010), among others (Lu et al., 2008), take an analytic approach and determine facial expressions by vision-based facial gesture analysis – taking the parameters of the face in a neutral state, shown in Figure 3 as a base line to work from, then all future facial parameters taken for that person are compared to the initial measurements.

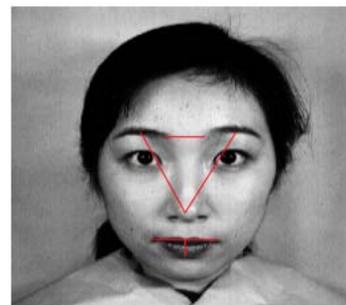


Figure 3: Parameters of the Face (Sarode & Bhatia, 2010)

Their study focused on recognising four of the six emotional states as laid out by Ekman (1993). It has been observed that if the edges of the mouth are above the original position then the emotion can be classified as 'happy'; if the centre of the mouth is raised and the centre of the eyebrows are raised simultaneously, then that will indicate the emotion can be classified as 'sad'; if the eyebrows are raised and the mouth is lowered then the emotion indicates 'surprise'; and if the centre of the eyebrows are lowered, the edges of the mouth are closer together and the nose is lowered then the emotion would be interpreted as 'anger'. This is illustrated in figure 4 below:

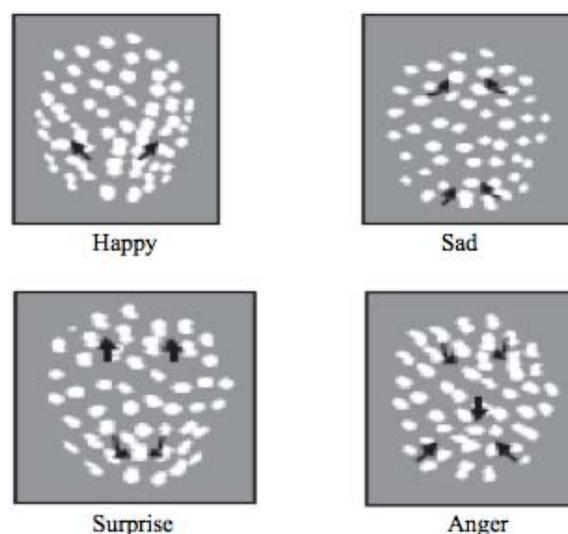


Figure 4: The Cues of Facial Expressions (Sarode & Bhatia, 2010)

This technique has been shown, Figure, to be fairly accurate for these four emotions with 'happy' and 'surprise' having an accuracy level of approximately 83%, with 'sad' and 'angry' being slightly less accurate at only 78% .

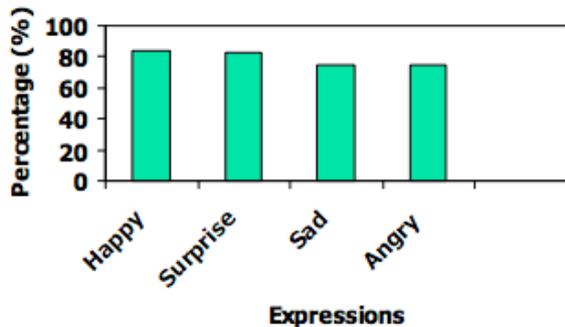


Figure 5: Accuracy of Facial Expression Recognition (Sarode & Bhatia, 2010)

Unlike the analytical approach, the holistic approach does not focus on individual features of the face; instead the face is examined as a whole. This technique is used in many research projects, for example (Lai et al., 2001; Etemad & Chellappa, 1997). These projects have resulted in a higher accuracy than Sarode & Bhatia (2010) with the levels at 95.56% and 99.2%, respectively. Part of the problem that researchers face is that the appearance of a face can change, e.g. with the addition of glasses or a different hair style, and that when acting naturally, a human will change the orientation of their face making it difficult, but not impossible (Lai et al., 2001), to make a comparison with the original neutral measurements taken.

Hybrid techniques are also abundant in research (Pantic & Rothkrantz, 2004; Ahonen et al., 2006); but, while a hybrid approach would be more robust against head orientation, a holistic approach is computationally less complex as a feature set does not have to search for and locate feature sets (Etemad & Chellappa, 1997).

One drawback with just using facial expression recognition is that a fraudulent emotion will still get recognised as being real with an 85% accuracy level, as in the case with an actor or actress portraying emotions (Busso et al., 2004). This can be overcome by using another technique alongside facial expression recognition, such as skin conductivity or facial thermography.

Biometric Emotional Analysis System

Given the previous investigation into suitable setups and analysis techniques at Staffordshire University a system has been developed using the latest face reading software from Noldus and a wireless GSR device developed at MIT Media labs in the USA, the combination of these two biometrics offer the possibility of measuring the responses of participants to use of software packages and may well lead into better guidelines for the design of effective user interfaces.

One project is in the area of Games design and it is hoped the system can be used to develop a Fear Index to aid in the

consumer information offered to parents. The system is also being developed as a mobile setup for use in areas where the user works and thus having a more realistic analysis. Initial results seem hopeful.

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