REAL-TIME BIOMETRIC EMOTION ASSESSMENT IN AN IMMERSIVE ENVIRONMENT

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Abstract: Both the academic and industrial worlds have increased investment and dedication to the affective computing area in the past years. At the same time, immersive environments have become more and more a reliable domain, with progressively cheaper hardware and software solutions. With this in mind, the authors used biometric readings to perform real-time user emotion assessment in an immersive environment. In the example used in this paper, the environment consisted in a flight simulation, and biometric readings were based on galvanic skin response, respiration rate and amplitude, and phalanx temperature. The detected user emotional states were also used to modify some simulation variables, such as flight plan, weather and maneuver smoothness. The emotion assessment results were consistent with user-described emotions, achieving an overall success rate of 78%.

1 INTRODUCTION

The presence of sensors, actuators and processing units in unconventional contexts is becoming consistently inevitable. This fact brings to both academic and industrial stages the term of Ubiquitous Computing as a regular one. In a parallel, yet complementary line, Affective Computing has recently gained the attention of researchers and business organizations worldwide. As a common denominator for these two concepts resides Emotion Assessment. Although this topic is no novelty by itself, it has been rediscovered in light of the mentioned knowledge areas breakthroughs, as it became theoretically possible to perform real-time minimal-invasive user emotion assessment based on live biosignals at economically feasible levels.

Having all that in mind, the authors envisioned an integrated interactive multimedia system where internal parameters are changed according to the user's emotional response. As the application example in this paper, an aviation environment was considered. The main reasons behind this decision are related to the human fascination for everything related to flying. Still, and as with most things, this attraction co-exists with the fear of flying, usually referred to as pterygophobia. According to a poll by CNN and Gallup for the USA Today in March 2006, 27% of U.S. adults would be at least somewhat fearful of getting on an airplane (Stoller, 2006).

The conducted experimental protocol was carried out in a quiet controlled environment where subjects assumed the pilot's seat for roughly 25 minutes. Internal variables were unconscientiously affected by the online assessed user emotions.

The project achieved rather transversal goals as it was possible to use it as a fully functional testbed for online biometric emotion assessment through galvanic skin response, respiration rate and amplitude and phalanx temperature readings fusion and its incorporation with Russell's Circumplex Model of Affect (Russell, 1980) with success rates of around 78%. Considering the aeronautical simulation, an immersive realistic environment was achieved, with the use of 3D video eyewear.

It was found that those without fear of flying found the experience rather amusing, as virtual entertainment, while the others considered the simulation realistic enough to trigger an emotional response – verified by biometric readings.

The present document is organized as follows: in the next section a broad, detailed revision of related work is depicted; in section 3, the project is described in a global perspective but also highlighting relevant system modules; in section 4 the conducted experimental session conditions are described and in the following section the results are presented; in the final section, conclusions are drawn and future work areas revealed.

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2 STATE OF THE ART

This section is divided into two subsections: the first concerning automatic emotion assessment; the second regarding aeronautical simulation tools.

2.1 Automatic Emotion Assessment

Until a recent past, researchers in the domains related to emotion assessment had very few solid ground standards both for specifying the emotional charge of stimuli and also a reasonable acceptable emotional state representation model. This issue constituted a serious obstacle for research comparison and conclusion validation. The extreme need of such metrics led to several attempts to systematize this knowledge domain.

Considering first the definition problem, Damásio states that an emotional state can be defined as a collection of responses triggered by different parts of the body or the brain through both neural and hormonal networks (Damásio, 1998). Experiments conducted with patients with brain lesions in specific areas led to the conclusion that their social behaviour was highly affective, together with the emotional responses. It is unequivocal to state that emotions are essential for humans, as they play a vital role in their everyday life: in perception, judgment and action processes (Damásio, 1994).

One of the major models of emotion representation is the Circumplex Model of Affect proposed by Russell. This is a spatial model based on dimensions of affect that are interrelated in a very methodical fashion (Russell, 1980). Affective concepts fall in a circle in the following order: pleasure, excitement, arousal, distress, displeasure, depression, sleepiness, and relaxation - see Figure 1. According to this model, there are two components of affect that exist: the first is pleasure-displeasure, the horizontal dimension of the model, and the second is arousal-sleep, the vertical dimension of the model. Therefore, it seems that any affect stimuli can be defined in terms of its valence and arousal components. The remaining variables mentioned above do not act as dimensions, but rather help to define the quadrants of the affective space. Although the existence of criticism concerning the impact different cultures in emotion expression and induction, as discussed by Altarriba (Altarriba, 2003), Russell's model is relatively immune to this issue if the stimuli are correctly defined in a rather universal form. Having this in mind, the circumplex model of affect was the emotion representation abstraction used in the proposed project.

In order to assess Russell's model components, one ought to consider what equipment solutions were to be selected, considering, simultaneously, different features such as portability, invasiveness levels, communication integration and transparency and direct economical impact.

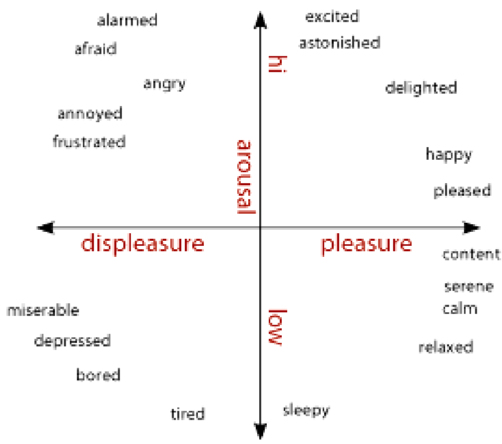

Figure 1: Russell's Circumplex Model of Affect.

Emotions assessment requires reliable and accurate communications with the subject so that the results are conclusive and the emotions correctly classified. This communication can occur through several channels and is supported by specific equipment. The invasive methods are clearly more precise, however more dangerous and will not be considered for this study. Conversely, non invasive methods such as EEG (Electroencephalography), GSR (Galvanic Skin Response), oximeter, skin temperature, ECG (Electrocardiogram), respiration sensors, amongst others have pointed the way towards gathering the advantages of low-cost equipment and non-medical environments with interesting accuracy levels (Benevoy, 2008).

Some recent studies have successfully used just EEG information for emotion assessment (Teixeira, 2008). These approaches have the great advantage of being based on non-invasive solutions, enabling its usage in general population in a non-medical environment. Encouraged by these results, the current research direction seems to be the addition of other inexpensive, non-invasive hardware to the equation. Practical examples of this are the introduction of a full set of non-invasive, low-cost sensors in several domains by Vinhas (Vinhas, 2008), Kim (Kim, 2008) and Katsis (Katsis, 2008). The usage of this kind of equipments in such diverse domains and conditions strongly suggests its high applicability and progressive migration towards quotidian handling.

For this study, the Nexus-10 hardware solution with temperature, GSR and Respiration Rate and Amplitude sensors shall be used and the data communication with the processing unit, fully described in section 3, shall be based on wireless Bluetooth technology.

2.2 Aeronautical Simulation Tools

There are two main simulator categories: Game Engines and Flight Simulators. In game engines, the most important aspect is an appealing visualization. Flight Simulators have a different approach – the main focus is on aerodynamics and flight factors present in real world, thus trying to achieve as realistic a flight as possible (Gimenes, 2008). The academic and business communities have already begun to use these cost-effective tools, benefitting from what they have to offer (Lewis, 2002).

The authors, after some consideration and analysis of available flight simulators, have chosen to use Microsoft Flight Simulator X (FSX) as the simulation environment. FSX not only provides a flexible, well-documented programming interface to interact with the environment, but also a very realistic visualization of the simulated world.
Several solutions are offered to treat pterygophobia, including medication, and some behavior therapies, together with virtual reality solutions. These are often used in conjunction with a more conventional form of therapy (Kazan, 2000), (da Costa, 2008). Though the authors are cautious regarding any conclusion about the psychological impact of this simulation tool, it is believed that this simulation, together with real-time emotional assessment, may have a positive impact in treating pterygophobia.

Summarizing, the proposed solution not only presents an online Russell's Model emotion assessment tool, based on minimal-invasive sensors, but also provides a cost-effective solution for a virtual reality simulation that can be used for treating fear of flying.

3 PROJECT DESCRITPION

This section is divided into three subsections, focusing the global architecture delineation, emotion assessment module description and aeronautical simulation component.

3.1 Global Architecture

The system architecture is based on independent and distributed modules, both in logic and physical terms. As depicted in Figure 2, and following its enclosed numeration, biometric data is gathered

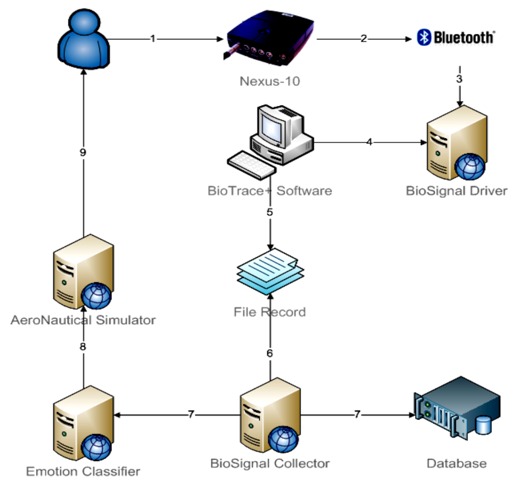

Figure 2: System's Global Architecture.

directly from the subject by Nexus-10 hardware. In more detail, temperature, GSR and respiration sensors are used. As to reduce the number of wires presented to the user, the biometric data is transmitted by Bluetooth to a computer running the adequate data driver. The next step is of the responsibility of BioTrace+ software, and beyond providing a flexible interface for signal monitoring, it also records biometric data in a text file.

The BioSignal Collector software was developed to access the recorded data and make it available for further processing either by database access or TCP/IP socket connection. In the last case, lies the Emotion Classifier, responsible for user's emotion state assessment – this process is described below. The continuously extracted emotional states are projected into Russell's model and are filled as input to the Aeronautical Simulator. The simulation endpoint has a simple architecture. The main module communicates with the emotional endpoint, receiving data from the emotion assessment module, indicating which of the four quadrants of Russell's Model should be active. The module, in turn, communicates with FSX, changing its internal variables in order to match the desired quadrant, and as explained in section 3.3. This module also produces a permanent log file, with information collected from the simulator. The simulator interacts with the user through immersive 3D video hardware, allowing the user to control simulation visualization.

3.2 Emotion Assessment

The emotion assessment module is based on the enunciated 4-channel biometric data collected with Nexus-10 and accessed via text file readings at 10Hz sample rate – which for the analyzed features is perfectly acceptable. At the same rate, emotional states are assessed and its definition is continuously uploaded to a database for additional analysis and third-party tools access. Directly related to the aeronautical simulation, the GUI also provides an expedite method to define the session's emotional policy – force a specific quadrant, contradict or maintain the current state or tour the four scenarios. The remaining of this subsection is divided in three parts, devoted to emotion model description, calibration and data fusion, and dynamic scaling.

3.2.1 Base Emotion Model

As previously referred, the adopted emotion model was Russell's Circumplex Model of Affect. This bidimensional approach permits efficient, yet effective, online emotional assessment with none or residual historical data as it is based on single valence and arousal values. The key issue is not the determination of the subject's emotional state given a pair of valence/arousal values, but how to convert biosignals into valence/arousal pairs.

In order to anticipate the assessment of emotional data pair values, a normalization process is conducted, where both valence and arousal values are fully mapped into the [-1, 1] spectrum. With this approach, emotional states are believed to be identified by Cartesian points in a 2D environment.

3.2.2 Calibration & Channel Fusion

Having into consideration the referred normalization process, one ought to point out the importance of the calibration process. Although, the 2D point (-¾, ¾) represents a normalized defined emotional state, it can be achieved by an infinite conjugation of biosignals. This reality leads to the necessity of calibration and biometric channels fusion.

The first procedure consists in, for each subject and for each session, pinpoint directly in Russell's model, what is the predominant emotional state, through a self-assessment process. By performing this action, it is possible to define a normalized emotional baseline point. For each of the four channels taken into account for emotional state assessment an initial twenty percent variability is considered. Whenever overflow is detected, the dynamic scaling is activated as described below.

The three components were considered to have similar impact. For the valence values deviation, only galvanic skin response was considered. For this computation, the normalized baseline point is considered as reference. The conjugation of such weights determines the normalized values of arousal and valence and hence the current emotional state.

3.2.3 Dynamic Scaling

As a consequence of the emotional classification process, emerging issue concerns either biosignal readings' overflow or underflow, considering user-defined baseline and initial tolerance allowed.

To overcome this potential limitation, a fully dynamic scaling approach was considered, that consists in stretching the biometric signal scale whenever its readings go beyond the normalized interval of [-1,1]. This scale update is conducted independently for each of the analyzed biometric channels. During this process, a non-linear scale disruption is created, resulting in greater scale density towards the limit breach.

In order to better understand this approach, one shall refer to the set of formulas listed through Equation 1, depicting an overflow situation.

(a) $c_1Max = Math.Max(c_1Max, Sample[c_1Index])$

(b) $c_1ScaleUp = \dfrac{1 - baseLineNorm.Axis}{c_1Max - baseLineSample[c_1Index]}$

(c) $c = Sample[c_1Index] - baseLineSample[c_1Index]$

(d) $c_1Norm = baseLineNorm.Axis + c_1ScaleUp \times c$

Equation 1: Dynamic Scaling Formulas.

First, c1 (any given biometric channel) maximum value is determined by comparing current reading with the stored value – Equation 1(a). If the limit is broken, the system recalculates the linear scale factor for values greater than the baseline neutral value, having as a direct consequence the increasing of the interval's density – Equation 1(b). Based on the new interval definition, subsequent values shall be normalized accordingly – Equation 1(c) (d). With this approach, and together with dynamic calibration and data normalization, it becomes possible for the system to perform real-time adaptations as a result of user's idiosyncrasies and signal deviations, thus assuring continuous normalized values.

3.3 Aeronautical Simulation

The desired emotional quadrant influences the simulation in three dimensions: weather, scenery and maneuvering.

The two quadrants characterized by displeasure are associated with worse climacteric conditions, ranging from thunderstorms, for the quadrant with high arousal levels, to foggy cold fronts, for the one with low levels. The two quadrants related to pleasure are coupled with fair weather, creating a more stable flight.

The chosen global scenery is an archipelago. For the two quadrants associated with high arousal levels, the itinerary takes the plane around an island, with many closed turns at low altitudes. For the two quadrants associated with low arousal levels, the path consists of an oval-shaped route around an island. The turns in this route have a superior radius and the altitude variations have smaller amplitude. As a result, the flight is experienced as a calmer one.

Closely related to the route description is maneuvering control. For the first route, typical auto-pilot controls are used, namely speed, heading and altitude controls. As for the second route, two additional features are applied – maximum bank and yaw damper, which limits the maximum roll during turns, and reduces rolling and yawing oscillations, making the flight smoother and calmer.

4 EXPERIMENTAL ACTIVITIES

The experiments were conducted using a variety of equipment, for both the biometrical emotion assessment module and the simulation module. As for the first module, sensors for skin temperature, galvanic skin response and respiration rate and amplitude were used. In order to present the user with an immersive experience, 3D video hardware was used in conjunction with the flight simulator, in the form of virtual reality video eyewear, which provides the user with a three degree of freedom head-tracker, allowing the user to experience the environment as if he was actually there.

The experiments were conducted among twenty subjects, 13 males and 7 females, aging between 21 and 56. Four of the subjects stated that they had some level of fear of flying, while the remaining declared not to.

After providing background information to characterize the sample, the subject was connected to the biometrical equipment, in order to establish an emotional baseline, as explained in section 3.2.2.

The experiment had three sequential stages. In the first, the plane takes off from an airport. After takeoff, a series of closed circuits was performed. Finally, in the landing phase, the plane lines up with the selected airport, makes the approach and lands.

After concluding the trial, the subjects described the experience, and reviewed an animation of the evolution of both simulation and emotional assessment, to confirm or refute those assessments.

5 RESULTS

The results are presented and analyzed in two main groups: emotion assessment and simulation.

In what concerns to emotion assessment, the validation model was based on user self-assessment, as previously described. These results were collected in two forms: concerning single emotions and specific regions on Russell's model, and concerning only the four quadrants. For the first method, a success rate of 78% was achieved. For the second one, this number increases to 87%. Table 1 shows the confusion table with percentages of automatic assessment versus self-assessment for each quadrant.

Table 1: Emotion Assessment Confusion Table.

		Automatic Assessment			
		1st Quadrant	2nd Quadrant	3rd Quadrant	4th Quadrant
Users	1st Quadrant	**30,7**	1,8	0,3	1,2
	2nd Quadrant	3,1	**32,8**	1	0,1
	3rd Quadrant	0,2	1,7	**10,9**	1,2
	4th Quadrant	1	0,1	1,6	**12,3**

One additional result to consider is that the automatic emotion assessment has a lower rate of failure for opposite quadrants.

Concerning the simulation, users were asked to describe their experience, and to classify, on a scale of one to five, the level of immersiveness. The results show that the majority of the individuals considered the environment to be highly immersive, with an average classification of 4,2.

Takeoff and landing are traditionally associated with higher levels of apprehension and anxiety among passengers who suffer from pterygophobia, a fact confirmed by the experimental results. All subjects that are afraid of flying also stated that those are in fact the most stressful moments, and the collected data corroborates this fact. Figure 3 shows the average arousal levels measured during the experiments conducted among these individuals. As can be seen, higher arousal levels were registered during the initial and final stages of the simulation, which represent takeoff and landing.

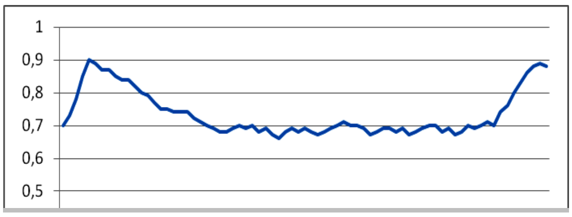

Figure 3: Average Arousal Levels During Simulation.

6 CONCLUSIONS

From an architectural standpoint, the distributed architecture with logic and physical module separation proved to be reliable and efficient. This approach enabled independence between biometric data collection, processing and simulation related computation. It also provided database collection of both raw biometric channel values and semantic emotional state information for future analysis and validation, improving system openness.

At a more significant level, the emotional assessment layer reached high accuracy levels. Through the detailed validation process, 78% of the classified emotional states were considered correct by the subjects. If simplified to Russell's four quadrants, this value reaches 87%, which supports the conclusion of an effective emotional assessment process. Still in this category, it is worth to mention the on-the-fly classification procedure that nearly suppresses the need to a long baseline data gathering and user identification as it is performed by the user at any time. Also, the dynamic scaling was valuable, as to correctly accommodate outsized signal deviations without precision loss.

In what regards the aeronautical simulation, all projected goals where completely fulfilled as users confirmed their immersion sensation, by both self-awareness and biological recorded response. It is believed that the use of 3D glasses as display device played a particularly important role in creating the appropriate environment.

Some improvement opportunities have been identified along the project. It is believed to be useful, for future system versions, to include additional biometric channels in the emotional assessment engine, such as ECG, BVP (Blood Volume Pulse) and even EEG. This signals integration would be fairly straightforward as the current data fusion process and emotional base model support that kind of enhancement. Still concerning this module, one shall mention the possibility to test Russell's model expansion to 3D by adding a dominance axis. Regarding the aeronautical simulator, it would be interesting to define and test more navigation scenarios. Still in this point, a more smooth transition between contexts, especially between quadrants characterized by high levels of arousal and those with low levels of arousal would be useful.

As a final project summary, one shall point that the proposed system has a dual application as a complete entertainment system with user emotional awareness that continuously adapts the multimedia content accordingly, and possibly a more solemn approach as a phobia treatment auxiliary.

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