DYNAMIC MULTIMEDIA ENVIRONMENT BASED ON REALTIME USER EMOTION ASSESSMENT

Biometric User Data towards Affective Immersive Environments

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Abstract: Both the academic and industry sectors have increased their attention and investment to the fields of Affective Computing and immersive digital environments, the latter imposing itself as a reliable domain, with increasingly cheaper hardware solutions. With all this in mind, the authors envisioned an immersive dynamic digital environment tied with automatic real-time user emotion assessment through biometric readings. The environment consisted in an aeronautical simulation, with internal variables such as flight plan, weather conditions and maneuver smoothness dynamically altered by the assessed emotional state of the user, based on biometric readings, including galvanic skin response, respiration rate and amplitude and phalange temperature. The results were consistent with the emotional states reported by the users, with a success rate of 78%.

1 INTRODUCTION

The presence of dissimulated sensors, actuators and processing units in unconventional contexts is becoming consistently inexorable. 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 this in mind, the authors envisioned an integrated interactive multimedia bidirectional system where internal parameters would be changed according to the user's emotional response. As the application example in this paper, an immersive aviation-based environment was considered. The main reasons behind this decision are related to the human fascination for everything related to flying. However, 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). By using the briefly described multimedia system, the authors were able to provide distinct practical scenarios to apply in several situations that range from traditional entertainment applications to therapeutic phobia treatment. The conducted experimental protocol was carried out in a 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 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 phalange temperature readings fusion and its incorporation with Russell's Circumplex Model of Affect (Russell, 1980) with success rates of around 78%. 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 results also suggested a trend to pterygophobia mitigation.

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2 STATE OF THE ART

This section is divided in three concerning automatic emotion assessment; aeronautical simulation tools; and pterygophobia treatments.

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.

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 universally defined.

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).

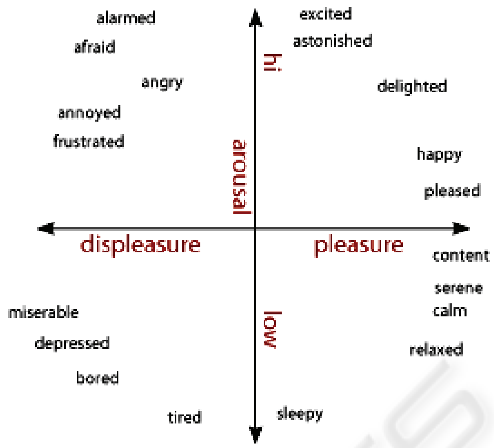

Figure 1: Russell's Circumplex Model of Affect.

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 inexpensive, non-invasive hardware to the equation. Examples of this are the introduction of a full set of non-invasive, low-cost sensors by Vinhas (Vinhas, 2008), Kim (Kim, 2008) and Katsis (Katsis, 2008). The usage of such equipments in diverse domains and conditions suggests its high applicability and progressive migration towards quotidian handling.

2.2 Aeronautical Simulation Tools

Simulation tools and simulated environments are used in virtually every field of research, providing researchers with the necessary means to develop their work in a time- and cost-effective manner.

In the aviation field, simulation is heavily used, from multi-million dollar full simulators used to train professional pilots to freely available flight simulators used mainly for entertainment purposes and by aviation enthusiasts. In the past few years, these low-cost software simulators have achieved a higher level of realism.

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).

2.3 Fear of Flight

Several solutions are offered to treat pterygophobia, including medication, and some behavior therapies, including virtual reality solutions. These solutions are often used in conjunction with a more conventional form of therapy (Kazan, 2000),(da Costa, 2008). One such example is Virtually Better, a clinic which offers several solutions based on virtual reality technology to support therapy in anxiety disorders (Anderson, 2006),(Rothbaum, 2006). However, and despite having around fifty clinics worldwide – the majority located within the United States – it cannot offer its solutions to a very wide audience at an affordable cost. Some companies, such as Virtual Aviation, offer an even more realistic experience, using the same multi-million dollar simulators used to train professional pilots (Bird, 2008).

3 PROJECT DESCRITPION

3.1 Global Architecture

The system global architecture is based on independent and distributed modules, both in logic and physical terms. As depicted in Figure 2, and following its enclosed numeration, it is possible to appreciate that biometric data is gathered directly from the subject by using Nexus-10 hardware. In more detail, temperature, GSR and respiration sensors are used.

The BioSignal Collector software was developed in order to access the recorded data and make it fully available for further processing either by database access or online TCP/IP socket connection. In this last category, lies the Emotion Classifier, as it is responsible for user's emotion state assessment – how this process is conducted is fully described in the next subsection. The continuous extracted emotional states are projected into the Russell's model and are filled as inputs for the Aeronautical Simulator's Control Software module. This module, in turn, communicates with FSX, changing its internal variables in order to match the desired quadrant, and as explained in more detail in section 3.3. This module also produces a permanent log file, with information collected from the simulator regarding location and attitude of the user plane. The simulator interacts with the user through immersive 3D video hardware, which allows the user to control the visualization of the simulation.

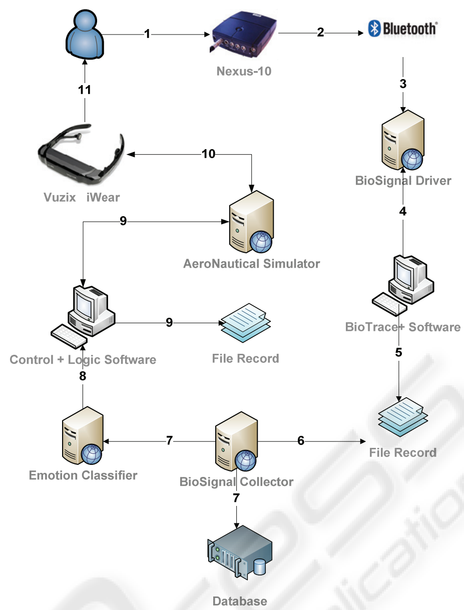

Figure 2: System's Global Architecture.

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, as it can be defined to force a specific quadrant, contradict or maintain the current emotional state or simply tour the four scenarios.

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, and once the biometric data stream is enabled, pinpoint directly in Russell's model what is his 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 in the following subsection.

The three components were considered to have similar impact. For the valence values deviation, only GSR 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 therefore the current emotional state.

3.2.3 Dynamic Scaling

As a consequence of the emotional classification process illustrated in the last two subsections, one issue that emerges concerns either biosignal readings' overflow or underflow considering the user-defined baseline and initial tolerance allowed.

To overcome this 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 biometric channel. 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, where four steps are depicted concerning an overflow situation.

First, c1 – any given particular biometric channel – maximum value is determined by comparing the current reading with the stored value – Equation 1(a). If the threshold 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 channel values shall be normalized accordingly – Equation 1(c) (d). With this approach, together with dynamic calibration and data normalization, it becomes possible to perform real-time adaptations as a result of user peculiarities and signal deviations, assuring continuous values.

$$\text{(a)}\ c_1Max = Math.Max(c_1Max, Sample[c_1Index])$$

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

$$\text{(c)}\ c = Sample[c_1Index] - baseLineSample[c_1Index]$$

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

Equation 1: Dynamic Scaling Formulas.

3.3 Aeronautical Simulation

The main aeronautical simulation module communicates with FSX through the SimConnect API, changing internal variables. The desired emotional quadrant affects the simulation in three dimensions: weather, scenery and maneuvering.

The two quadrants characterized by a state of displeasure are associated with worse climacteric conditions. The two other quadrants are associated with fair weather, producing a more stable flight.

The chosen scenery is an archipelago, a set that can provide both a pleasant flight, with many sightseeing moments, and an irregular one.

All maneuvers are done via the auto-pilot system present in the simulated aircraft. Given the desired waypoint, the heading is calculated, then passed on to the heading control of the auto-pilot system. For the first route, typical auto-pilot controls are active, namely speed, heading and altitude controls. As for the second route, two additional auto-pilot features are applied – maximum bank and yaw damper. The first limits the maximum plane declination during turns, while the second reduces rolling and yawing oscillations, making the flight smoother and calmer.

4 EXPERIMENTAL ACTIVITIES

The experiments were conducted using a wide variety of hardware equipment, for both modules. As for the first one, sensors for skin temperature, GSR and respiration rate and amplitude were used. As for the second module, FSX was used as the simulation environment, providing access to internal variables and a realistic visualization. In order to present the user with an immersive experience, 3D video hardware was used, in the form of virtual reality video eyewear, which provides the user with a three DOF head-tracker, allowing the user to experience the environment as if he was actually there.

The experiment was comprised of three sequential stages. In the first phase, the plane takes off from an airport. The choice of the airport to takeoff from was based on whether the subject suffered from fear of flying. For individuals suffering from pterygophobia, the operator forced either the third of fourth quadrant, providing a calm takeoff and flight, as not to trigger an anxiety attack. For the remaining of the individuals, the operator forced one of the first or second quadrants, trying to obtain increased amplitude of emotional responses. 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.

The experiments were conducted among twenty subjects, 13 male and 7 female, between the ages of 21 and 56. Four of the subjects stated that they had some level of fear of flying, while the remaining did not. Of the subjects suffering from pterygophobia, three of them revealed that they have in fact never flown, only one actually having suffered from the symptoms associated with this phobia.

After concluding the trial, the subjects were then asked to describe the experience, and to review an animation of the evolution of both the simulation and the emotional assessment and to confirm or to refute those assessments. For the case of the four subjects that stated to suffer from fear of flying, they were asked to repeat the experiment two more times, in order to obtain results that could enlighten the possible use of this tool in treating pterygophobia.

5 RESULTS

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: the first concerning single emotions and specific regions on Russell's model, and the second concerning only the four quadrants. For the first method, a success rate of 78% was achieved. If only the four quadrants are considered, this number increases to 87%. Table 1 shows the confusion table with the percentages of automatic assessment versus user self-assessment for each quadrant.

One additional result is that users tend to locate their emotional states in the 1^{st} and 2^{nd} quadrants. Another aspect is that the emotion assessment has a lower failure rate for opposite quadrants.

Table 1: Emotion Assessment Confusion Table.

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

Concerning the simulation, users were asked to describe their experience, and to classify, in a scale of 1 to 5, the immersiveness level. The results show that the majority of the individuals considered the environment to be highly immersive, with an average classification of 4,2.

Regarding the subjects with fear of flying, one outcome that seems to support the fact that this simulation can be used in pterygophobia treatment is depicted in Figure 3, which shows the average emotional response for the three experiments. The 2^{nd} and 3^{rd} experiments show an emotional response that tends to move away from the extreme end of the 2^{nd} quadrant, denoting a reduction in the levels of fear registered during the latter experiments.

Figure 3: Pterygophobia Subjects' Emotional Trend.

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

6 CONCLUSIONS

The distributed architecture proved to be reliable and efficient, and enabled independence between biometric data collection and processing, and simulation computation. It also provided database collection of both raw biometric values and emotional state for future analysis and validation.

The emotional assessment layer reached high levels of accuracy, as the depicted results show. Through the previously detailed validation process, 78% of the emotional states were believed to be correct by the subjects. If classification is simplified to quadrant determination, this value reaches 87%, which supports the conclusion of an effective emotional assessment process. It is worth to mention the on-the-fly classification procedure that nearly suppresses the need to long baseline data gathering and user identification as this baseline evaluation is performed by the user at any given time and can be adjusted. Also, the dynamic scaling was found to be useful, in order to correctly accommodate outsized signal deviations without precision loss.

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

The results seem to suggest that a significant mitigation of the symptoms of pterygophobia was achieved among the subjects that referred at least some level of fear of flying.

In spite of the project's overall success, several improvement opportunities have been identified, such as the inclusion of additional biometric channels, such as ECG, BVP and EEG. This signals integration would be fairly transparent as the current data fusion process and emotional base model support that kind of enhancement. Regarding the aeronautical simulator, it would be interesting to define and test more scenarios with fully automated and dynamically configured take-off and landing.

As a final project summary, one shall point the fact that the proposed system has a dual application as a complete entertainment system with user emotional awareness that continuously adapt the multimedia content accordingly to user's states and a solemn approach as a phobia treatment auxiliary.

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