Bio-Feedback Based Simulator for Mission Critical Training

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Abstract. The paper address needs for training and simulation tools needed to address a multitude of threats to national security. In order to most effectively prevent terrorist threats, government agencies need to be able to train for extreme event scenarios that are very difficult to realistically replicate. A crucial aspect of the training challenge is to provide scalable, real-time hands-on training capability that includes not only visual demonstration and description of possible threats but also the capability for the individuals to interactively practice specific threat scenarios and be evaluated on their performance. This paper describes a bio-feedback system incorporated into the training simulator for the mission critical practices.

1 Identification and Significance

One of the major goals of human computer interaction (HCI) studies is to develop adaptive, smart computer systems, which are reconfigured based on user response. Such systems use biometric identification such as facial recognition, fingerprint recognition and eye tracking in order to customize access to the system. However, such systems do not adapt to the user need based on their psycho-physiological conditions. This paper describes development of non-invasive touch based system, which will allow tuning a computer based training system to the user emotional and stress levels.

The system is based upon the fact that during the operation of a computing device, the user stays in almost permanent manual contact with an input device, such as a mouse, tracking ball, joystick or for more advanced version of the simulators integrated with motion or eye tracking devices. This paper will describe the incorporation of sensors to monitor the physiological conditions, such as galvanic skin response (GSR), electric skin resistance (ESR), and temperature. Based on the sensory response, the computer system would be able to determine stress level and emotional condition of the user, visual-somatic response and adjust itself to provide better training and determine if the user is suitable to the task assigned.

P.M.A. Sloot et al. (Eds.): ICCS 2003, LNCS 2659, pp. 1074–1080, 2003.

There are many practical applications for such a system. For example, it could allow parental control of minors, allowing them to play computer games at an emotionally safe level. The described system can enable user interface developers to better monitor the human response to a prototype. Also, the system will enable game developers to dynamically adjust the difficulty level based upon the player's condition. The system can also be integrated into a car steering wheel along with an onboard computer to monitor the motorist's condition during the trip and prevent him/her from falling asleep at the wheel. But one of the most important applications of the system is to monitor the work related stress and enable failure prevention in mission critical tasks in nuclear stations, hazardous chemical, oil factories and other high risk areas.

Today's governments face the monumental challenge of addressing a multitude of threats to national security. In order to most effectively prevent terrorist threats, government agencies need to be able to train for extreme event scenarios that are very difficult to realistically replicate. A crucial aspect of the training challenge is the ability to provide a large number individuals amongst numerous agencies with a scalable, real-time hands-on training capability that includes not only visual demonstration and description of possible threats but also the capability for the individuals to interactively practice specific threat scenarios and be evaluated on their performance.

At present, such systems do not exist in the market. However, active research is being performed by several groups, such as, IBM BlueEyes team [1, 9], MIT Media Lab [2] and other organizations [1]. The major advantage of the described technique compared to those reported in literature is the monitoring of visual-motor reactions and attention distributions, both very important parameters for training simulator and game developers. For example, the "Emotional mouse", the experimental system developed at IBM is limited to measuring six emotional states – anger, disgust, fear, happiness, sadness and surprise.

This paper describes a system which is significantly more advanced than those being investigated. The system will have a significant impact on the human computer interaction development in the next decade and will lead to more expressive communication with machines.

2 Overview

Paul Ekman's facial expression work demonstrated that there is a correlation between a person's psychological state and a person's physiological measurements. Based on this work he developed Facial Action Coding System [3]. Later, Dryer [4] determined how physiological measures could be used to distinguish the various emotional states. He also demonstrated that people consider a computer system as having personality [5], and a system having a similar personality as the user leads to better collaboration [6]. In his experiments Johnson [7] used video cameras to determine users psychological state and concluded that there is a correlation between patterns in user behavior and users psychological state.

Wendy Ark [9] in her work reported that during normal computer use (creating and editing documents and surfing the web) people spend about 30% of their total computer time touching their input device. In addition, it has been demonstrated that the major physiological parameters, associated with physiological state, are Galvanic Skin Response (GSR), Electric Skin Resistance (ESR), General Somatic Activity (GSA), temperature (TEM), heart rate (HR) and blood pressure (BP) [3, 4].

Based on the prior art we decided to integrate a bio-sensing device into motion or eye tracking hardware and make it in a way, that it actively monitors the above listed variables — GSR, ESR, GSA and HR.

3 Technical Characteristics

The major objective was to develop a scanning device, which would be able to monitor the real time psycho-physiological state of the trainee. We term such a system a 'bio-sensor'. The bio-sensor will enable the study of

- Psychosomatic and psychotherapeutic issues related to the HCI
- Psychological state and personality traits of the subject
- Characteristic peculiarities
- Mental performance level
- Central nervous system state
- Functional abilities of central regulation and peripheral blood circulation of cardio-vascular system
- Psychological tension and stress level

In order to complete these tasks three major objectives need to be achieved (Figure 1). First algorithms to process analog signals from the sensors should be developed. Second, a set of psycho-physiological tests has to be developed to collect and analyze data. And third, an interface should be developed for both report generation and other software integration.

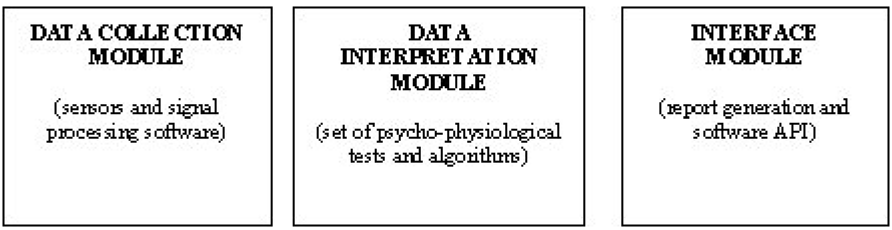

Fig. 1. Major modules of the system

Each of these three modules is described in more detail below.

3.1 Data Collection Module

The data collection module consists of two parts – hardware sensors and control software. A data collection module has following characteristics:

- Include sensors of photo-plethysmogram and GSR
- Tunable discretization frequency up to 1k Hz
- Bandwidth of bio-amplifiers not less then 0.1-1000 Hz
- Electric shock protection
- Power supply from computer

Control software properties:

- Real time signal filtering
- Spectral and autocorrelation analysis algorithms
- Bio-amplifiers bandwidth control
- Signal intensity control
- Automatic detection of photo-plethysmogram parameters

3.2 Data Interpretation Module

This is the main analytical module of the system. The goal of this module is to manage data collection and to extract meaningful information from the data. It should provide a set of tests and analysis algorithms, which will study different aspect of HCI. The main functions of the data interpretation module will include:

- Chrono-cardiography analysis based of variation principle
- Simple and complex visual-semantic response study
- Attention distribution test
- Associative test
- Response speed test
- Stress level determination

3.3 Interface Module

In order to be a useful tool the system has to be able to generate reports and communicate to other software. This brings us to the third objective – to generate an easy to use report generation system and application programmer interface (API). Report generation system should be able to display graphical physiological data and test results as well as being able to save results and provide access to stored user data. The API should be easy to use and allow third party software developers easy access to collected data and diagnostic results.

4 Conclusion and Future Work

Development of a smart adaptive computer system has been one of the major challenges of computer science in the last decade. Several different tools and methodologies have been developed in order to obtain some physiological feedback from user. One of the most well known applications of such systems is the polygraph or “lie detector” which is now widely used in criminology and human resources and cardio-systems in gymnasiums. Several other techniques have been used for biofeedback in psychotherapy.

The main concept of this work was to develop an easy to use system, which includes a bio-sensing device and software package integrated with modern training simulator hardware, which will determine users psychological conditions using biofeedback. Data from the IBM research team working on “emotional mouse” (Table 1-4) shows strong correlation between emotional state and physiological data. The next step that we are planning is to extract not only the emotional data but also the stress level, activity level and attention level.

We are planning to integrate different sensors in to the motion or eye tracker hardware. First, we will use infrared detectors in order to obtain photo-plethysmogram of the computer user. This signal is depending on blood flow in fingers and allows the detection RR intervals (time between two consecutive heart pulses). Performing statistical analysis and filtering of the RR intervals, we will obtain heart rate and heart rate variability (VF) [10]. A high value of VF indicates that the user is falling asleep and a low value of VF indicates that the user is overloaded or tired. Average RR value for human is 900-1000 milliseconds (equivalent of heart rate 60-70), and average value of VF is 4-5%. Based on this data, the system will be able to warn when the user is too tired or about to fall asleep or getting too stressed to adequately complete the mission.

Another analytical technique that we are planning to incorporate into our system is the analysis of video-somatic reaction. This technique is excellent for action based computer game developers. The system will collect reaction time of the user and apply mathematical models similar to the one used to determine a heart rate variability. This will allow us to correlate to the psychological condition of the user. In this case, we will measure average response time and its variability. The advantage of this method is that no hardware modification is required.

Combination of heart rate variability, video-somatic reaction based methods and emotional state determination technique similar to one described by IBM [9] will allow error minimization and generate a system which will be able to help make a computer which will be more adjustable to users psychological state

Table 1. Difference Scores. (Source: IBM)

		Anger	Disgust	Fear	Happiness	Sadness	Surprise
GSA	Mea	-0.66	-1.15	-2.02	.22	0.14	-.1.28
	Std.	1.87	1.02	0.23	1.60	2.44	1.16
GSR	Mea	-	-53206	-61160	-38999	-417990	-41242
	Std.	63934	8949	47297	46650	586309	24824
Pulse	Mea	2.56	2.07	3.28	2.40	4.83	2.84
	Std.	1.41	2.73	2.10	2.33	2.91	3.18
Temp	Mea	1.36	1.79	3.76	1.79	2.89	3.26
	Std.	3.75	2.66	3.81	3.72	4.99	0.90

Table 2. Standardized Discriminant Function Coefficients. (Source: IBM)

	Function			
	1	2	3	4
GSA	0.593	-0.926	0.674	0.033
GSR	-0.664	0.957	0.350	0.583
Pulse	1.006	0.484	0.026	0.846
Temp.	1.277	0.405	0.423	-0.293

Table 3. Functions at Group Centroids. (Source: IBM)

EMOTION	Function			
	1	2	3	4
anger	-1.166	-0.052	-0.108	0.137
fear	1.360	1.704	-0.046	-0.093
sadness	2.168	-0.546	-0.096	-0.006
disgust	-0.048	0.340	0.079	0.184
happiness	-0.428	-0.184	0.269	-0.075
surprise	-1.674	-0.111	-0.247	-0.189

Table 4. Classification Results. (Source: IBM)

		Predicted Group Membership						Total
	EMOTION	Anger	Fear	Sadness	Disgust	Happiness	Surprise	
Original	anger	2	0	0	0	2	1	5
	fear	0	2	0	0	0	0	2
	sadness	0	0	4	0	1	0	5
	disgust	0	1	0	1	1	0	3
	happiness	1	0	0	0	5	0	6
	surprise	0	0	0	0	1	2	3

Acknowledgments. We would like to thank Vladimir Bryskin and the staff of the BioLab Inc. for the help in the work and the information and ideas provided to the authors

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