Sensory Chairs: A System for Biosignal Research and Performance

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ABSTRACT

Music and sound have the power to provoke strong emotional and physical responses within us. Although concepts such as emotion can be hard to quantify in a scientific manner there has been significant research into how the brain and body respond to music. However much of this research has been carried out in clinical, laboratory type conditions with intrusive or cumbersome monitoring devices.

Technological augmentation of low-tech objects can increase their functionality, but may necessitate a form of *context awareness* from those objects. Biosignal monitoring allows these enhanced artefacts to gauge physical responses and from these extrapolate our emotions. In this paper a system is outlined, in which a number of chairs in a concert hall environment were embedded with biosignal sensors allowing monitoring of audience reaction to a performance, or control of electronic equipment to create a biosignal-driven performance.

This type of affective computing represents an exciting area of growth for interactive technology and potential applications for 'affect aware' devices are proposed.

Keywords

Ubiquitous computing, context-awareness, networking, embedded systems, chairs, digital artefacts, emotional state sensing, affective computing, biosignals.

1.   INTRODUCTION

Increasingly computers are becoming part of our everyday lives, not only as our familiar laptops or towers, but built into less inherently digital items, from fridges to water-filters, cars

to door-locks. These 'embedded' computers allow these objects to expand their functionality, to recognise individuals or contexts and behave appropriately. These computers require no guidance from us to fulfil their function, indeed in many cases we may be completely unaware of their presence, interacting with them implicitly through our use of the objects in which they live.

One of the challenges involved in creating objects such as these, is to make them behave appropriately when used in a variety of situations. One approach to creating such context aware objects is to give them the ability to sense the user's emotions or feelings. Emotions are a key part of what it means to be human and frequently influence our decisions and actions over our capabilities for intellect and reason [1]. They are also one of the most difficult areas of our psycho-physiology to understand, especially when trying to program an 'unfeeling' machine to recognise them.

This paper presents an overview of the '*Sensory Chairs*' project in which four audience chairs used in the Sonic Lab performance hall at the Sonic Art Research Centre, Queens University, Belfast, were augmented with a variety of sensors to provide information about their occupants. The chairs require no user interaction beyond their normal function, yet provide physical and biometric data, over a network, to a computer for visualisation, data recording and control of external devices. Basic emotional state inference from the sensor data was also built into the chair software. The chairs were used as an indicator of audience attentiveness or enjoyment and incorporated into a performance.

2.   PROBLEMS OF ESS

Emotional state sensing is currently far from an exact science. There are three core problems with accurately judging the emotions of a human being using indicators from the autonomic nervous system (ANS) [2].

Firstly there is what is referred to as the 'Baseline Problem', finding a condition against which changes in the ANS can be measured. How does one induce a state of emotional 'neutrality' in a subject for study? Individual physiological characteristics also mean that readings may be at the high end

of the scale for one person, with lower readings for another, while both are experiencing the 'same' emotion. Environmental factors such as ambient temperature can also play a part.

Secondly there is the 'Timing of Data Assessment Problem'. Emotions can be fleeting, arising and disappearing in a matter of seconds, Levinson [3] suggests that they may be as short as 0.5 seconds and last up until 4 seconds or beyond. This means that by measuring at the wrong time an emotion might be missed. Other emotions may have a long initial onset, such as anger, whilst some may be much shorter, such as surprise.

Thirdly there is the 'Intensity of Emotion Problem', which addresses the correlation between the magnitude of the physiological response and the 'intensity' of the emotion felt. At low levels of emotion there may be little response from the ANS whilst at higher levels the pattern of ANS activity associated with a particular emotion may be destroyed.

Other issues complicate the graphing and reporting of emotions, such as how was the emotion induced, how was the subject encouraged (or not) to 'express' the emotion and complications from physiological responses not connected to emotional state [4].

Systems which rely on data from audience members also raise questions relating to what we shall call 'sensor ethics'. An audience member may feel uncomfortable being monitored in this way. Perhaps they wish to *pretend* to be enjoying the piece for motives of their own. Perhaps they are uncomfortable as 'performers' or have a medical condition that the sensors might illuminate. For reasons such as these we must approach audience monitoring/participation in the same way as we would for conducting a physiological or psychological experiment.

3 THE SENSORY CHAIRS

3.1 Sensors

Each chair was augmented with four sensors to provide information about their occupants. A key factor in the choice of sensors used and their placement was that they should be passive i.e. require no special interaction from the chairs occupant, simply sitting in a chair is enough to activate some or all of the sensor package. It is unrealistic to expect a potential audience member to learn to 'play' the chair or indeed to have to 'perform' in order to enjoy an event which they have attended, possibly without prior knowledge of the interactive nature of their seating. This is also important in contexts where the chairs are being used to gather data about audience reaction to a performance as one cannot expect 'natural' reactions if the subject has first to be 'wired up' with electrodes or the research is carried out in an 'unnatural' laboratory environment.

Each chair was equipped with an Arduino [5] micro-controller data acquisition board, mounted under the seat and connected to the computer via a USB hub (serial over USB). Max/MSP 4.6 [6] was used to capture and visualise the data from each chair, both as independent streams and an interpolated view of data from all four chairs.

The chairs were fitted with a sensor package consisting of a light dependent resistor (LDR) mounted in the back of the chair, two pressure sensors under the legs-one left, one right, composed of Quantum Tunnelling Compound (QTC)) and a galvanic skin response (GSR) sensor mounted on the arm of the chair. These allowed the system to capture various physical movements (posture in the chair-measured with the LDR, Left /Right movement in the chair-measured with the QTC) as well as biometric data (weight and galvanic skin response-QTC & GSR).

3.2 Gauging Emotion

In order to create an 'emotionally-aware' system the data from the four sensors was graphed according to the affect scale in common use *per* Russell [7]. The X-axis was labelled 'Valence' and its output was a combined product of the pressure and LDR sensor data and was used as an indicator of the occupants 'enjoyment' level. The Y-axis was labelled 'Arousal' and is a product of the GSR readings. The GSR is an indicator of skin conductance, measured across the hand, and increases linearly with a person's level of overall arousal [2]. This was used as an indicator of the chair occupants' intellectual engagement. This divides the graphing window into four distinct sectors or 'affect spaces', as may be seen below, with some common emotions indicated.
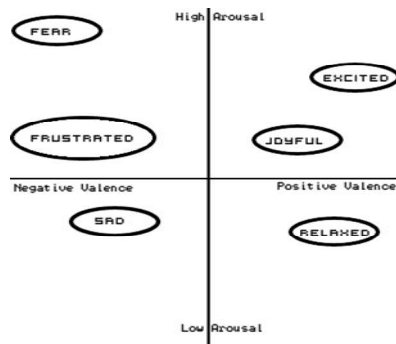

Figure 1: Affect Spaces and Emotions

In order to facilitate off-line research, the data streams from each chair may be recorded into a named text file for analysis at a later juncture. Sensors are sampled at a rate definable by the user into a text file and labelled with the ID of the relevant chair (Table 1).

Table 1. Example of Recorded Data

Index	QTC 1	QTC 2	LDR	GSR	ID
134	909	998	1023	254	ChairB
135	907	998	1023	250	ChairB
136	906	997	1023	249	ChairB

This file may then be imported into a graphing program such as Matlab or Excel for visualisation. The operator may also select the option of recording an audio file in parallel with the data, again for later study in conjunction with the sensor data.

3.3 Experimental Results

The *'Sensory Chairs'* system provides a way of monitoring multiple audience or performer biosignals at the same time and using this data to make basic emotional state judgements. It is also possible to compare this data against the performance which generated it, either as an audio recording or a recording of the performers own biosignal data.

The following are 3 experiments to demonstrate the capabilities of the system and a preliminary examination of the data:

3.3.1 Experiment A

During a performance of experimental electronic music, data was recorded from four volunteers seated in the *Sensory Chairs* system. Audio from the three performances was recorded simultaneously. The participants were unfamiliar with the pieces played and were seated centrally in the performance space.

Subsequent analysis of the data showed notable differences between the magnitudes of individual participants' responses to the performance. Some proved very sensitive to GSR monitoring while others showed more muted responses.

Comparison of the data with the accompanying audio indicated fluctuations in the sensor readings that appeared linked to audio events. During 'calm' or 'soothing' portions of the pieces we noted a lowering in the GSR reading, indicating a relaxed state. Sudden loud sonic events following such portions of audio showed a rising in the GSR indicating a state of alertness. Accompanying these events were spikes in the pressure sensors and LDR sensor indicating movement in the chair, probably in response to the sudden sound.

3.3.2 Experiment B

An interactive audio piece was created specifically for the *Sensory Chairs* system. This was an 'enactive' composition in which the volunteers seated in the chairs generated sonic events based on the biometric data sent from the system. Each chair/volunteer was assigned a specific 'voice' in the piece with rhythmic and melodic events as well as processing controlled by their emotions and movements.

A short questionnaire and informal debriefing afterwards revealed that participants found it difficult to connect a sense of control or ownership to their sounds. This illustrates a mapping issue pertaining to emotional state sensing and biosignals, how does one sonify an emotion or an affective state?

3.3.3 Experiment C

A short binaural audio play was created to test the system, played over headphones comprising a recording of footsteps running towards the listener from behind, followed by a loud gunshot very close by with a high degree of realism.

This produced both a physical reaction in the listener (a jump in their seat) as well as a spike in the GSR reading, although this was very brief and difficult to detect without more sensitive equipment.
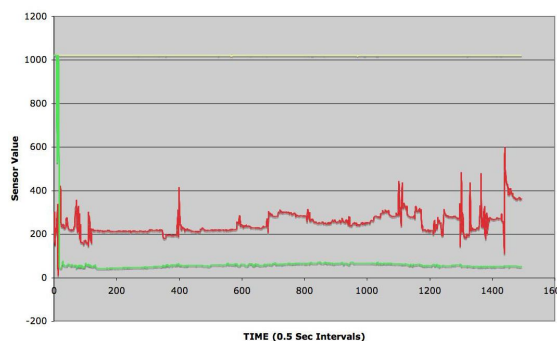

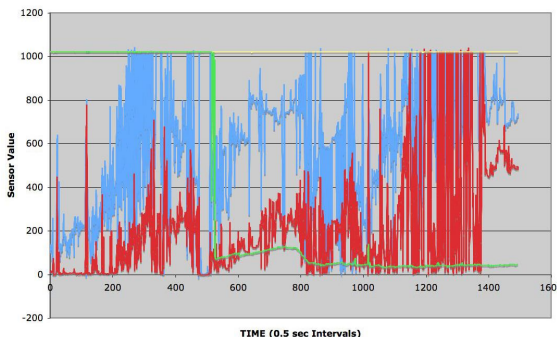**Figure 2: Example Output A-Sensor Data Over Time**

Figure 3: Example Output B-Sensor Data Over Time

Figures 2 and 3 show the recorded sensor data for 2 individuals during the same performance and graphs the output of each sensor (vertical axis) over 0.5 second intervals (horizontal axis). The Red and Blue plots show the readings from the pressure (QTC) sensors, the Yellow the LDR and the Green line is the GSR. Note the values from the LDR remain at maximum for most of the performance indicating both participants leant heavily against the back of the chairs. In Fig. 4 we see the participants GSR reading suddenly drop, this is as a result of the participant having removed their hand from the sensor and then replaced it during the performance.

We may clearly see the difference in magnitude of the sensor readings for each individual across all the sensors. If we compare the pressure (QTC) sensor data (Blue and Red) for both graphs we can see the individual in Fig. 2 remained relatively still in their chair, whereas the individual in Fig. 3 shifted in their seat much more.

Closer observation also reveals similar rise/fall cycles between participants GSR, corresponding with relaxing or sudden events in the audio performance.

4. FUTURE IMPROVEMENTS AND APPLICATIONS

4.1 Possible Expansions

Future generations of the system will see the chairs augmented with other sensors.

An EKG sensor was part of the initial design but it proved impossible to get a reliable signal from electrodes positioned on the arms of the chair. It may be possible to implement an EKG sensor using a more sophisticated circuit design and electrodes than available during this design phase.

An Electro-Myogram (EMG) sensor would allow for detection of muscle activity and electrodes could be unobtrusively placed on the armrests of the chair, in a similar fashion to the GSR sensor.

Electric Field Sensing (EFS) would allow for some gesture recognition capabilities and information about limb and head movements. This would involve placing the EFS under the seat of the chair (to capture leg movements, foot tapping etc.) or on the back of the chair (to capture torso and head movements).

4.2 Future Applications

Beyond the applications outlined so far in the fields of research and performance there are a number of areas where objects embedded with sensors or emotional state sensing capabilities will prove advantageous.

- Affective Gaming - physiological monitoring of gamers allows for adaptive game environments, which can adjust difficulty levels or reward players for completing sections they find particularly difficult, or reward 'courageous' action.
- Communication - increasingly much of our communication is done virtually, via email, videoconferencing etc. Sensor enhanced communication could include some form of visualisation of the other persons emotional state, thought this has obvious privacy implications..
- e-Learning - By examining physiological signals the program can determine a users level of interest, disinterest, frustration etc. and modify its teaching rate or take an new approach in order to keep the user engaged
- Psychological/Neurological research- most research into the psychophysiology of emotions so far has taken place in lab conditions, the sensor enhanced chairs of this paper provide a tool for research in alternative, non-clinical environments, more similar to those experienced in 'everyday' life.
- Information retrieval - 'intelligent' virtual agents that are able to refine search results/data supply based on emotional state e.g. user is 'sad', therefore play uplifting music.

- New Musical Instruments – emotionally aware instruments may allow for richer interaction and performance potential in the next generation of electronic instruments.

5. CONCLUSION

In order to allow facilitate deeper levels of communication between technological devices and their human users, systems must be developed that can interpret their users emotions and moods.

The study of biological and psychological reactions to sound allows us to explore and interpret abstract concepts within psychoacoustics, such as the pleasant/unpleasant effects of sound and emotional reactions to music and performance. Currently little is understood outside of direct neurological and neurochemical effects, observed under laboratory conditions.

Biosignals can provide further depth of interaction between performers and their instruments and compositions, taking the current generations of 'hyper' instruments to the next level.

In the *Sensory Chairs* system we have presented a potential tool for studying emotional reactions to music that may also be used as a biologically driven instrument. We have also presented some preliminary findings of our research into emotional and physical effects of performance.

6. ACKNOWLEDGMENTS

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