MobileMuse: Integral Music Control Goes Mobile

R. Benjamin Knapp
Sonic Arts Research Centre
Queen's University Belfast
University Road
Belfast BT7 1NN
Northern Ireland, UK
b.knapp@qub.ac.uk

Brennon Bortz
Sonic Arts Research Centre
Queen's University Belfast
University Road
Belfast BT7 1NN
Northern Ireland, UK
bbortz01@qub.ac.uk

ABSTRACT

This paper describes a new interface for mobile music creation, the *MobileMuse*, that introduces the capability of using physiological indicators of emotion as a new mode of interaction. Combining both kinematic and physiological measurement in a mobile environment creates the possibility of integral music control—the use of both gesture and emotion to control sound creation—where it has never been possible before. This paper will review the concept of integral music control and describe the motivation for creating the MobileMuse, its design and future possibilities.

Keywords

Affective computing, physiological signal measurement, mobile music performance

1. INTRODUCTION

The relationship between emotion and music has become an obsession for researchers and popular culture over the past several years. With popular books such as *Musicophilia* [11] and *This is Your Brain on Music* [8] topping the best seller lists, it is evident that this topic has indeed a very broad appeal. The field covers topics ranging from musicology to psychology, and from social science to computer science. This paper will focus on one subset of this broad field—the concept of using direct physiological measurement of emotion to augment the existing kinematic and locative sensors in mobile phones to create a new form of group musical interaction. While research on the introduction of emotion as a component of human-computer interaction, so called *affective computing*, has been ongoing for many years (a good collection of articles can be found in [10]), the concept of integral music control, the capability to use both gesture and emotion in controlling musical instruments has been around a comparatively short time [3, 4, 9]. The concept of using emotion in a mobile music making environment takes integral music control outside of the standard performance environment and introduces new possibilities of musical interaction. This paper will review the concept of integral music control It will then describe the creation of a new interface, the *MobileMuse*, that enables integral music control as a new means of creating music in a mobile environment.

2. INTEGRAL MUSIC CONTROL

Integral Music Control (IMC) is defined in [3] as "a controller that:

1. Creates a direct interface between emotion and sound production unencumbered by a physical interface.
2. Enables the musician to move between this direct emotional control of sound synthesis and the physical interaction with a traditional acoustic instrument, and through all of the possible levels of interaction in between."

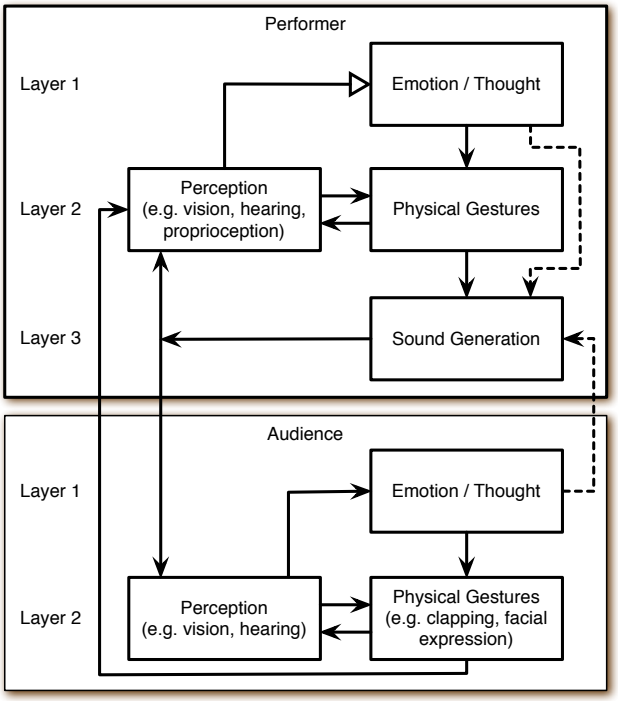

Figure 1: The three layers of performance feedback using IMC. Layer 1 represents the internal emotion and thoughts of the performer. Layer 2 is the physical interface layer. Layer 3 represents the consequence of the gesture—the creation of music. Performance feedback with the audience is also possible. The dashed line represents a new path of direct measurement of emotion. (From [3])

Figure 1 shows the standard technique of controlling sound generation: a thought creates a gesture which then controls a sound generator. Both the sounds and the proprioception of the physical interaction of creating the sound are then sensed by the performer creating a direct feedback loop.

The concept of integral music control opens up the possibility for the addition of direct measurement of emotion as another means of interaction.

2.1 Measurement of Emotion

To measure the emotional state and emotional changes of the performer, various physiological indictors of emotion can be used to achieve as accurate a measurement as possible while not interfering with performance. These signals include:

- *Galvanic skin response (GSR)* (Skin impedance)—Measured with electrodes on the finger tips
- *Electrocardiogram (ECG)* (Heart rate and heart rate variability)—Measured with electrodes built into a chest strap
- *Respiration (Amplitude and frequency)*—Measured with strain sensors built into an elastic chest strap
- *Electroencephalogram (EEG)*—Measured on the occipital (rear) portion of the head with electrodes attached to a head band
- *Facial electromyogram (EMG)*—Measured with sensors built into the same EEG head band

It should be made quite clear that these physiological indicators are not only measures of emotion. Indeed, as described in [10], there are many reasons other than emotional changes why these physiological signals might vary. However, the primary alternative reasons for variation such as changes in environment and changes in physical activity, do not apply in standard musical performance practice (even mobile) and consequently the reliability of these physiological signals as an indicator of emotional change is presumed to be high. As seen in Figure 1, the direct measurement of the audience's emotional state can also be used to interact with and even co-create with the performers. Members of the audience are, of course, not able to wear the large array of sensors worn by the performer. However, the audience can be connected to custom circuitry that measures GSR and ECG signals (see Figure 2). These two signals are chosen because of their capability to indicate changes in emotional state while still being easy to apply and relatively unobtrusive.

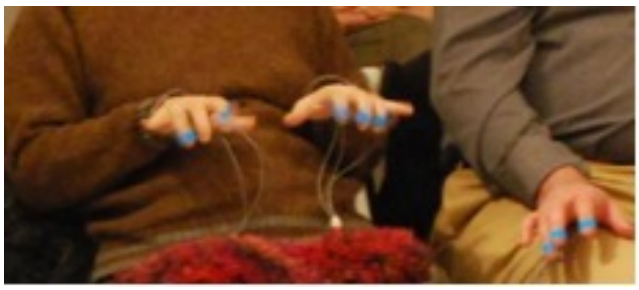

Figure 2: Sensors worn by audience members measure GSR and ECG. Heart rate and heart rate variability are then derived from the ECG.

2.2 IMC Systems for Live Performance

To implement true integral music control in live performance, a system is selected for the performer such as the *BioMuse*, which is composed of body worn sensors (both kinematic and physiological), that enable unencumbered movement during live performance. Figure 3 shows the data path for a complete performance configuration. Data from the BioMuse sensors worn on the performer, sensing both motion and physiological indicators of emotion, are transmitted through a Bluetooth link to a PC running the real-time signal processing software, EyesWeb. The processed data are then sent to Max/MSP via Open Sound Control (OSC).

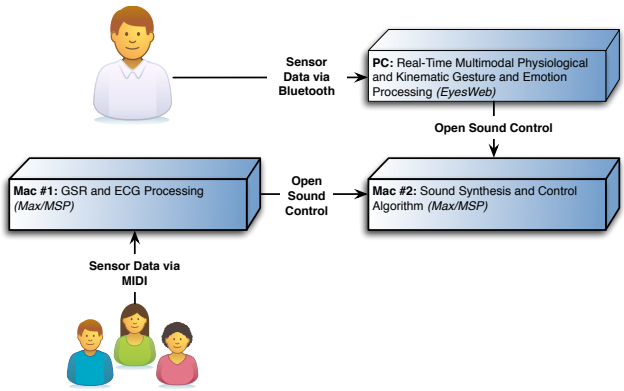

Figure 3: Data Flow for Sensor Acquisition and Processing.

The processed audience emotion signals are digitised and sent via MIDI to an Apple Mac running Max/MSP. All of the data from all of the audience members are sent via OSC to another Mac running Max/MSP. The reason for this separation of processing tasks into two computers is due to the DSP requirements of the primary sound synthesis Max/MSP patch. Separating the processing into two computers enables the creation of a dedicated GUI for the audience computer that allows real-time monitoring of the data and removal of any noisy data streams. Typically, in any performance there are always one or two audience members that remove their sensors or in some way manipulate the sensors so that their data are not useable.

3. MOBILE MUSIC CREATION AND THE MOTIVATION FOR A MOBILE IMC

Gaye, Holmquist, Behrendt and Tanaka define mobile music as "a new field concerned with musical interaction in mobile settings, using portable technology...[that] goes beyond today's portable music players to include mobile music making, sharing and mixing." [2] While not precisely mobile music as defined by Gaye et al., the concept of using mobile devices within an artistic context began, arguably, in 2001 in Golan Levin's work Dialtones [7], wherein audience members' mobile phones provided the sole sounding medium for the piece. As the ubiquity of mobile phones has grown worldwide (in June 2010, for instance, the number of mobile phones in Saudi Arabia grew to nearly double the country's actual population), so have the artistic community's pursuits of mobile music grown from niche diversions to full-scale areas of output and research. Performing ensembles have formed around the creation and concertising of new mobile music (e.g. [12]), and the sheer number of music generation and virtual instrument mobile applications that became available last year alone all point to the fact that mobile music and locative media as artistic (as well as entrepreneurial) endeavours are burgeoning phenomena.

The preponderance of currently available implementations of mobile music creation using mobile phones use only locative information, gestural information and/or other data gathered from the built-in sensors of the phones themselves.

Would there be advantages or new possibilities with the introduction of physiological assessment of emotional state in this new environment? Clearly, musical pieces that use audience emotional state measurement as a means of interaction, such as *The Reluctant Shaman* [5] or *Stem Cells* [6], would no longer need the custom hardware shown in Figure 2 to be installed before each performance. If there were a way to measure emotion using a mobile phone, then audience members could simply download the mobile phone application before coming to the concert (or even at the concert venue), connect the interface to the phone, and then participate in the performance.

While performers using IMC typically use more elaborate sensor configurations as described previously, a new type of less encumbered (both physically and spatially) mobile performance interface could also be imagined that would enable entirely new forms of interaction. Indeed it would be possible to implement the concept described in [4] and shown in Figure 4 to combine the physical gestures and emotional state of multiple performers before they are categorised and processed into control parameters. This would enable individual as well as composite measurements of gesture and emotional state. Both forms of networking can be combined to create a mesh of integrally networked IMCs. Thus, for example, a mobile performer's emotional state could be assessed by the IMC, combined with other performer(s) to create an overall combined emotional state.

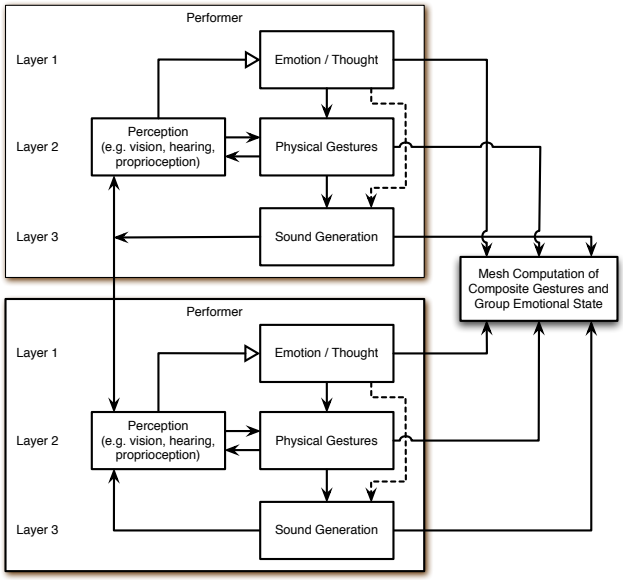

Figure 4: The networking of multiple IMC's using an integral control path as part of a distributed mobile environment. In this mesh, any performer's physical gestures and emotional state can be composited with any other's. (From [4])

4. THE MOBILEMUSE

In creating a device that could measure physiological indicators of emotion and interface to a mobile phone, two questions needed to be answered:

1. *What is the interface?* It is clearly desirable that any mobile IMC should be able to connect to any handset, not just one particular model. To fulfil this requirement, the answer to this first question is that the interface should be a standard TRRS audio jack. Rather than using the custom connectors that vary from mobile phone to mobile phone, this enables easy interfacing with most modern models. Indeed, this choice enables ubiquitous interfacing to most computing equipment (e.g. Macs and PCs) as well.

2. *What physiological signals would be used?* The answer to this question is subject to the same requirements as when measuring audience emotional state. It should be very easy to wear, but should also measure the key physiological indicators of emotion. Thus, as with the audience measurement hardware shown in Figure 2, GSR and heart rate were chosen as the physiological signals to be used for emotional state estimation.

4.1 Implementation

It was decided that the entire sensor system must fit on a single finger. In order to accomplish this, heart rate is measured using standard pulse oximetry techniques rather than a full ECG as was done for the audience of the IMC shown in Figure 2.

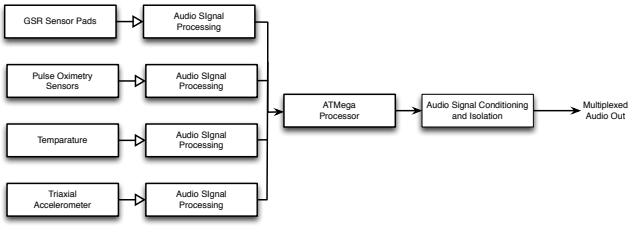

Figure 5: Block Diagram of the MobileMuse

As shown in Figure 5, four sensors are integrated into the MobileMuse. Upon further consideration, and because of the ease of design, a temperature sensor was also added to the interface. Skin temperature change (in relationship to the environment) has been shown to be indicative of long term mood [1] and it was thought that this might prove beneficial in assessment of emotional state. A triaxial accelerometer was also added to the circuit for gestural control. While this might seem redundant, it was thought that independent hand gesture might introduce interesting options not presently available with the accelerometers built into the phone. At minimum this enables two-handed gestural control.

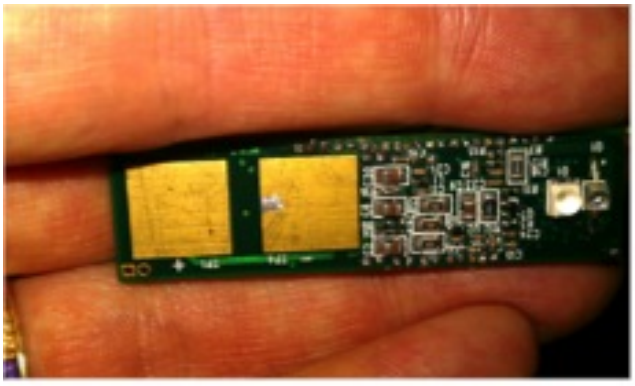

Figure 6: First implementation of the MobileMuse: The two large pads are for GSR measurement and the two LEDs on the far right are for pulse oximetry.

As shown in the block diagram in Figure 5, all of the sensor signals are amplified, processed, conditioned and then

connected to an ATMega processor. Choosing this processor means that the MobileMuse can be used as a custom Arduino board with all of the advantages this creates—most importantly, ubiquitous software availability. The ATMega processor is used to frequency-division multiplex the sensor signals in order to create one single audio data stream. The signal is then reconverted to an analog stream using the pulse-width modulation (PWM) output of the processor and subsequent signal conditioning. Finally, magnetic isolation is used to remove any shock risks and to eliminate line noise.

4.2 The iPhone App

The first requirement of the mobile phone application is to demodulate the frequency-division multiplexed signals coming from the MobileMuse. As shown in Figure 7, a simple application was created to implement this demodulation and display the waveforms and the composite estimate of emotional state derived from the physiological signals.

Figure 7: The MobileMuse application interface.

5. POSSIBLE APPLICATIONS

The MobileMuse enables a broad range of musical possibilities. Performers in a standard stage-based environment can now interact with audience members both locally and around the world. The MobileMuse audio interface enables stage performers to use low-cost wireless audio transmitters to connect to computers running sound creation software. Other BioMuse sensors can be connected to the MobileMuse in audio combiner mode so that any physiological or kinematic sensor can be connected via a standard audio interface. As with all mobile music creation, the concept of audience member and performer has lost all meaning. The emotional state of mobile listener/performers creates a feedback loop between listening and controlling the music being heard. This introduces one of the exciting possibilities of the MobileMuse which is to extend the realm of mobile music creation to the area of shared experience. As people across a mobile network listen to a music stream, watch a video, or even dance together, the emotional state of each listener or the composite emotional state of many listeners can be displayed visually or can introduce sonic changes representative of an individual or group as a whole. Of course, as discussed previously, there are always confounding factors in deriving changes in emotional state from physiology, e.g. one could be exercising or moving from indoors to outdoors. However, in the typical mobile performance scenario and with the performer's awareness of these issues, these factors can be largely mitigated.

6. CONCLUSIONS

The use of mobile phones as a new means of music creation and a new way of using location as a component of performance is fast becoming standard practice. This paper has introduced the concept and design of the MobileMuse, a new interface that enables direct measurement of physiological indicators of emotion to be used as a new means of interaction with a mobile phone. By bringing affective signal processing to a mobile platform, MobileMuse situates itself perfectly to marry three diverse arenas of artistic exploration that have, by and large, never been joined—mobile music, locative media, and affective creative practice.

7. REFERENCES

[1] T. Baumgartner, M. Esslen, and L. Jäncke. From emotion perception to emotion experience: Emotions evoked by pictures and classical music. *International Journal of Psychophysiology*, 60(1):34–43, 2006.

[2] L. Gaye, L. E. Holmquist, F. Behrendt, and A. Tanaka. Mobile music technology: Report on an emerging community. In *Proceedings of the 2006 Conference on New Interfaces for Musical Expression*, pages 22–25, Paris, France, 5–7 June 2006. NIME, IRCAM–Centre Pompidou.

[3] R. B. Knapp and P. R. Cook. The Integral Music Controller: Introducing a Direct Emotional Interface to Gestural Control of Sound Synthesis. In *Proceedings of the International Computer Music Conference (ICMC)*, pages 4–9, Barcelona, Spain, 5–9 September 2005. ICMA, Phonos Foundation, Pompeu Fabra University and the Higher School of Music of Catalonia (ESMUC).

[4] R. B. Knapp and P. R. Cook. Creating a network of integral music controllers. In *Proceedings of the 2006 Conference on New Interfaces for Musical Expression*, pages 124–128, Paris, France, 5–7 June 2006. NIME, IRCAM–Centre Pompidou.

[5] R. B. Knapp, M. Dowling, and G. D. Ford. The Reluctant Shaman. Premiered at the 2008 International Computer Music Conference (ICMC), August 2008.

[6] R. B. Knapp and E. Lyon. Stem Cells–Reimagined. Premiered at the 2009 International Conference on Music and Emotion (ICME), August 2009.

[7] G. Levin. Dialtones (A Telesymphony), June 2001.

[8] D. J. Levitin. *This Is Your Brain on Music: The Science of a Human Obsession*. Dutton Adult, 2006.

[9] M. A. O. Pérez, R. B. Knapp, and M. Alcorn. Díamair: Composing for choir and integral music controller. In *Proceedings of the 2007 Conference on New Interfaces for Musical Expression*, pages 289–292, New York, New York, USA, 6–10 June 2007. NIME, Harvestworks and LEMUR.

[10] C. Peter and R. Beale, editors. *Affect and Emotion in Human-Computer Interaction: From Theory to Applications*, volume 4868 of *Lecture Notes in Computer Science: Information Systems and Applications, including Internet/Web, and HCI*. Springer Berlin / Heidelberg, Heidelberg, Germany, 2008.

[11] O. Sacks. *Musicophilia: Tales of Music and the Brain*. Vintage Canada, 2008.

[12] G. Wang, G. Essl, and H. Penttinen. *Oxford Handbook of Mobile Music Studies (forthcoming)*, chapter The Mobile Phone Orchestra. Oxford University Press, London, England, UK, 2009.