ShEMP: A Mobile Framework for Shared Emotion, Music, and Physiology

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ABSTRACT

Categories and Subject Descriptors

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces—*Collaborative computing, Organizational design, Synchronous interaction*; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Input devices and strategies*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Audio input/output*; H.5.5 [**Information Interfaces and Presentation**]: Sound and Music Computing; C.2.4 [**Computer-Communication Networks**]: Distributed Systems—*Client/server*; J.5 [**Arts and Humanities**]: [Performing arts]

General Terms

Algorithms, Design, Experimentation, Measurement

Keywords

Collaborative music, group emotion, mobile computing, physiological interfaces

1. INTRODUCTION

How can we measure the quality of a creative experience? In what ways do the emotions of participants affect or are affected by creative collaboration? Is the perception of a musical performance altered depending on whether it is experienced individually or as a member of a group? These are among the questions under consideration by partners, including the authors, in the Social Interaction and Entrainment using Musical Performance Experimentation (SIEMPRE) project. Here we introduce ShEMP–a software framework through which we can explore these questions in greater depth. ShEMP, a mobile framework for Shared Emotion, Music, and Physiology, in conjunction with MobileMuse, an unobtrusive sensor package for mobile physiological signal acquisition, leverage the distributed yet locative properties of mobile devices to allow the design of ecological experiments outside of the laboratory to investigate collaborative creativity and shared experience of musical performances. This paper provides a brief introduction to several notable advances made in recent and current SIEMPRE experiments that have been particularly motivating to the development of ShEMP. This is followed by an overview of the design of ShEMP and a discussion of the suite of technologies it employs. We then elaborate on an initial battery of experiments to be executed presently, for which the framework was designed.

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2. BACKGROUND

For the last two years, the Social Interaction and Entrainment using Music Performance Experimentation (SIEMPRE) project has focused on measuring interpersonal creative interaction on the backdrop of music performance. The experiments designed and executed thus far have focused on these the experience of musical performance and experience in the following interconnected areas ([5]):

- Musician/musician interactions
- Conductor/musicians interactions
- Music/listener interactions
- Musician/listener interactions

Within these scenarios, our attention is drawn to four different foci: *entrainment*, and *emotional contagion*, *co-creation*, and *leadership*. The first of these, entrainment, is described by Clayton, Sager, and Will ([1]) as "a process whereby two rhythmic processes interact with each other in such a way that they adjust towards and eventually 'lock in' to a common phase and/or periodicity." This takes shape on multiple levels and in various situations: from a listener's foot tapping in tempo with music or their respiration and heart rates coming into synchronization (albeit often much more slowly) with the beat of the music, to an organisms internal physiological processes' entrainment to one another, or to those of another organism within a group. Indeed, as Clayton, Sager, and Will note, humans' internal rhythmic processes can and do entrain to both other internal rhythms as well as to those of other humans through music performance and shared experience of music. This potential for entrainment through social interaction by way of music is of particular interest to SIEMPRE.

Closely linked to entrainment is emotional contagion. In their seminal work on the subject, Hatfield, Cacioppo, and Rapson ([3]) describe the phenomenon of emotional contagion as one in which a particular emotional episode in one individual can evoke stimuli that act upon other individuals to bring about similar or complementary emotional responses. While the related phenomenon, empathy, requires cognitive and autonomic facility, Hatfield et al. argue that emotional contagion is an automatic and involuntary process. Converse to empathy, they further define contagion as a process in which humans automatically mimic and synchronize the behaviors of another, and as a result, converge emotionally ([2]). Emotional contagion not only strengthens emotional bonds between people, however; the presence and awareness of emotional contagion in interpersonal interaction affects meaning and significance in communication, aid in understanding social interaction, and facilitate empathy and sympathy, for instance. It is this significance that places emotional contagion as the second focus of SIEMPRE's research into interpersonal interaction.

Several studies under the SIEMPRE umbrella are concerned with musical co-creation. This is not necessarily completely bound up in musical performance by expert musicians, but includes the idea that audience and performer alike work together to shape a performance. On the one hand, performance process is informed not only by the training and preparation of the musician, for instance, but also by their awareness of and response to input, active or otherwise, from the audience. On the other hand, co-creation also occurs where novice musicians work together to create music for only themselves to experience. In either case, and in all those in between, co-creation serves to bind the group socially and serves as another means for social interaction.

The final focus within interaction that concerns SIEMPRE is leadership. Here again, a common paradigm in musical performance parallels that of everyday human interaction. By varying manipulating the leadership role, we can examine not only how changes to leadership affect group interaction in general, but also the specific implications these changes may have such already discussed phenomena as synchronization and entrainment, and the emotional understanding of the audience and performers.

3. RECENT RESULTS AND MOTIVATIONS

With this as the focus, SIEMPRE partners have designed and executed a wide array of experiments.

Overview of notable experiments and results here... Recent work and/or motivations from CCRMA and Javier...

Several studies, particularly those with a focus on audience experience of music–be it a live performance, a video recording of a live performance, audio of a studio recording, or otherwise–note the importance of observing the audience experiment in as ecological a manner as possible (see [4], for example). Furthermore, it is at least presumable that a good deal, if not the majority, of an individual's time spent experiencing music is when they are either alone, or among a small group of people–not in either a concert hall or laboratory. Issues of ecological validity aside, it is at least important to consider implications on the aforementioned research foci when audiences (of one or more) experience music individually.

4. FRAMEWORK DESIGN

4.1 Software

Your space, Spencer.

4.1.1 Digital Signal Processing

In order to allow the hardware to interface with a variety of devices, signal is passed over a standard 1/8" (3.5mm) TRRS audio plug, as the 1/8" TRRS audio jack has become all but the standard on consumer mobile devices. However, as standard wiring uses only the sleeve of the TRRS plug for input, it was necessary to devise a way to receive multiple input signals over a single channel. On the mobile device (currently iOS devices are supported), the signal is received as an audio input stream. Within Apple's AudioUnit framework, the passes through a DSP chain in order to split the multiplexed signal back into its original constituent signals.

The signal is first lowpass-filtered ($Fc = 7.5$kHz) in order to remove noise introduced by pulse-width modulation from the sensor hardware. The signal is then multiplied sample-by-sample with sine waves at the frequencies of the component carrier waves established in frequency-division multiplexing in the sensor circuit. In order to address frequency and phase jitter introduced by pulse-width modulation and timer imprecision from in the sensor micro-controller unit, a phase-lock loop is established between the filtered incoming signal and software oscillators controlled by the demodulation routine. These multiplications produce sine waves with a positive DC offset at double the frequency of the initial carrier waves for each component signal. These signals are then further lowpass-filtered ($Fc = 25$Hz) to remove said sine waves and leave only the slowly varying DC offset as the final demodulated output for each signal. These demodulated outputs are then exposed to other components of the framework for recording, streaming to an external server, sharing with other devices, or visualization within the user interface.

4.2 Hardware

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 electrocardiogram. The MobileMuse board houses four discrete sensors. 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 and it is 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, independent hand gesture might introduce interesting options not presently available with a mobile device's onboard accelerometer or gyroscope. At minimum this enables two-handed gestural control. Furthermore, an independent accelerometer provides a means of minimizing motion artifacts, an issue to which EDA sensors are particularly susceptible.

As shown in the block diagram in Figure 5, all of the sensor signals are amplified, processed, conditioned and then fed into the ADCs of an ATMega328PU processor. The choice of this process enables use of the MobileMuse as a custom Arduino board with all of the advantages this creates—most importantly, ubiquitous software availability. The ATMega processor firmware frequency-division multiplexes the sensor signals in order to create one single audio data stream for ease of transmission over the sleeve of the TRRS plug. The signal is then reconverted to an analog stream using the pulse-width modulation (PWM) output of the processor fed through an onboard DAC. Finally, magnetic isolation is used to remove any shock risks and to eliminate line noise.

5. PROPOSED EXPERIMENT

Emotion in Motion ***on the go...***

6. POTENTIAL ISSUES

Anyone feel free to chime in here...

7. CONCLUSIONS

8. ACKNOWLEDGMENTS

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9. REFERENCES

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