AUDIENCE-PARTICIPATION TECHNIQUES BASED ON SOCIAL MOBILE COMPUTING

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ABSTRACT

Mobile devices, such as smartphones and tablets, are becoming indispensable to everyday life, connecting us in a powerful network through services accessible via web browsers or mobile applications. In conjunction with recent explorations on physical interaction techniques for making music on mobile devices, the mobile platform can be regarded as an attractive solution for designing music performances based on audience participation. Using smartphones to enable audience participation not only offers convenience, but also tends to induce engaging and interactive social experience. In this paper, we first take a look at two separate phenomena of interest to us: the rise of mobile music and the design of audience participation performance paradigm. Then we present techniques for enabling audience participation based primarily on using smartphones, as experimented by the Stanford Mobile Phone Orchestra. We evaluate these techniques and consider the future of social music interactions aided by mobile technology.

1. OVERVIEW

Mobile technology is opening doors to music making for non-professionals, blurring the distinctions between composer, performer, and audience. But beyond enabling musical self-expression, mobile devices also have the potential to connect people in a social context, thereby realizing a powerful group experience. In Section 2, we briefly summarize how physical and social interaction techniques on mobile devices have been explored. In this context, we are motivated to combine the musical and the social nature of mobile computing, to explore new possibilities in music performances that are based on audience participation.

Of course, having the audience participate in music performances is not a new concept. Audience participation implies that the audience members also take on the role of a composer or performer to certain extent, either by directly producing sound themselves, or by communicating their intentions using an aided tool to indirectly affect the sound. Designing for audience participation is artistically interesting as it adds an uncertainty factor to the performance. It is also technically challenging, as it requires technology to coordinate communications between a large group of people. In Section 3, we describe past works involving audience participation, to understand their designs and implementations.

With the proliferation of modern smartphones and server-based cloud computing architecture, it is now possible to envision a scenario in which audience takes out their phones and immediately participate in the performance, without the need to download special software or to pre-configure the hardware. This minimal setup from the audience's side is not only convenient, quick, and cost-effective, but it also lowers the psychological barrier to entry for participation, as the audience can use their own *personal,* familiar devices. In a related way, mobile devices transform what could otherwise easily turn in to a dry human-to-machine communications to be a more engaging human-to-human social activity. In Section 4, we describe our experience with this 'social engagement' concept of designing for audience participation, using techniques that are based on existing mobile technology and cloud computing.

We conclude in Section 5 with an evaluation of our approach to using social mobile computing to enable audience participation. Ultimately, our hope is to offer everyone accessible pathways to participate in the physical and social activity of music making.

2. THE RISE OF MOBILE MUSIC

Mobile technology, and in particular personal smartphones, offers a convenient and rich set of tools for music performance. Structured mobile phone ensembles have been founded across the world to explore physical interaction techniques that smartphones afford, leveraging especially their onboard sensors, network, and audio capabilities [23, 25]. Essl and Rohs have provided a formal analysis of sensor capabilities in mobile phones, showing how they can facilitate interactive performances on mobile devices [11]. Moreover, in the past year, we have seen development of an API (Mobile Music Toolkit) that promotes and facilitates the process of creating musical instruments and experiences on mobile device [3], and a meta-environment (urMus) for designing sound and media synthesis systems on smartphones [10].

Beyond enabling self-expressions in music through physical interactions, mobile phones can facilitate performances based on group collaboration by connecting performers in a wireless network. For instance, CaMus[2] (2007) by Rohs and Essl leverages built-in cameras on mobile devices and Bluetooth technology to allow multiple phones to collaborate in a performance [27]. Other mobile phone instruments, such as Sound Bounce [8] and interV [25], use OSC [30] to enable gesture-based communications between the players performing together using mobile phones.

Our hope is to test the limits of the collaborative potentials of music performed using mobile phones, beyond ensemble performance into the domain of audience participation.

3. TOWARDS INTERACTIVE AUDIENCE PARTICIPATION

There are numerous examples of works—both musical and non-musical—that involve audience participation. In the field of entertainment and computer graphics, Loren and Rachel Carpenter in 1991 devised a system to allow audience members to control an onscreen game using red and green reflective paddles [5]. This demonstration inspired other computer vision based techniques for allowing audience members to control onscreen activity, such as by performing left-right leaning movements in their seats, or by directing laser-pointers at the screen [21]. While these examples do not incorporate audio, they contain important social elements that connect the participants, either cooperatively or competitively.

If we take on a broader definition of "audience" to include "large-group interactions", we find numerous projects exploring electronic musical interfaces for such a purpose. In one study by Feldmeier and Paradiso (2007), inexpensive wireless motion sensors are used to create an interactive music environment for large groups in a dance and entertainment setting [14]. The sensors given out to a crowd detect participant's motion (based on acceleration) to dynamically determine musical structure, sonic events, and/or lighting control. While the system is able to gather data over a theoretically unlimited audience size, it does not allow different sensors to be distinguished from one another. Blaine and Fels (2003) [4] and Weinberg (2005) [29] provide a thorough background on large group interactions and interconnected musical networks.

In this paper, we are more interested in enabling audience participation in a more traditional and restricted sense than simply "large group interactions"; in this paradigm, there is a clearer separation of roles between the audience and the composer/performers, with an expectation that the audience are naïve participants who follow directions to partake in the music-making activity, but to nonetheless consume the resulting experience. In many musical works with real-time participation by a large audience, the audience directly generates sound without an aided technology, such as by using whistles, as in Jean Hasse's *Moths (1986)*[15], or by ringing handheld bells, as in *La symphonie du millénaire (2000)* [6]. Other works involve a more indirect influence on the composition, such as by voting on a possible ending of a piece, as in Thomas C. Duffy's *The Critic's Choice (1995)*[9], or by deciding when to advance to next musical motive, as in a performance of Terry Riley's *In C* (1964) [1]. For a more complete survey and description of these works, see [13].

Our goal is to explore ways in which personal mobile devices can be used to enable a highly interactive and engaging participation from the audience during a musical performance. Below are three influential works from the past decade that are particularly relevant for us. The first relies on mobile phones as the primary tool for involving a large number of audience members in a performance. The second example serves as an atypical instance of involving audience *not* for artistic or experiential reasons, but for a scientific purpose. The final example takes special attention to the challenge of achieving a highly engaging experience for the audience members.

3.1. Mobile Phones as the Primary Interface

One of the earliest and most relevant examples of using audience's own mobile phones to involve audience in a music performance is *Dialtones* (2001) [19]. According to its report, Dialtones is a large-scale concert performance whose sounds are wholly produced through the carefully choreographed dialing and ringing of the audience's own mobile phones [20]. To achieve choreographed sound, the piece requires a preparation time prior to the performance: audience members register their phone numbers and are given seat assignments, and new ringtones are downloaded to their devices.

In *Dialtones*, the audience members, through their personal phones they are holding, serve as receiving points for audio that is sent from and controlled by the main performers. This approach is in some sense the opposite of what we hope to achieve in our designs of performances in which the audience would also *initiate* communications using their phones. Regardless, what is remarkable about this work is the sheer scale of having a 200-person audience participate in a powerfully spatialized sonic experience.

3.2. Performance with a Purpose

A perception study conducted by McAdams, Vines, Vieillard, Smith, and Reynolds in 2004, though it does not involve use of personal mobile phones, offers valuable insights into having the audience perform specific tasks in a live concert setting [22]. The tasks involved continuously rating familiarity and emotional force of the performed piece, using a custom-designed 'response box' equipped with a slider connected to a potentiometer.

The primary goal of this study was to acquire perception data from the audience members for conducting a scientific study of musical structure and emotional force in a real music-listening environment. This study inspires us to experiment with the idea of "perception study as a performance art" (and vice versa). Taking a step towards artistic direction, we ask: what would it be like to provide a real-time visual and auditory feedback on the audience's responses as part of the performance, such that the audience members become aware of each others' cognitive-emotional states, and are thus further influenced by one another? One of the pieces we design (described in Section 4.3) explores this possibility by using a web application running on a mobile browser.

3.3. Attempts to Engage a Large Audience

In the aforementioned studies, we often find a trade-off between the number of participants and the level of interactivity allowed by the performance. For instance, Levin's *Dialtones* or the perception study by McAdams, *et al*. involve a large audience (on the order of hundreds of people), but the communication link between the people and the main performers is limited and uni-directional. In *Dialtones*, the flow of control signals is from the small group of musicians (who perform the phones *en masse* by dialing the audience) to the audience members. In the perception study performance, the flow of signal is in the opposite direction only, from the audience to the response box. Consequently, the audience members cannot affect the musical trajectory of the performance, nor are they able to engage with each other.

Jason Freeman pays particular attention to these challenges in composing and designing *Glimmer* (2004), a piece for chamber orchestra and audience participation [13]. In this piece, each audience member is given a light stick that can be turned on and off, and during a performance a computer analyzes live video of the audience and sends instructions to the orchestra. The system is designed as a continuous interactive feedback loop: the audience members not only initiate actions that trigger changes in music, but also respond to the music they hear and the video they see to affect their own activities. This design reflects Freeman goals for his composition, "to give the audience an opportunity to contribute not merely surface content to the work, nor to simply choose from a limited menu of pre-conceived paths, but to influence the work at a lower level" [13]. This attitude is consistent with our own hopes and goals for designing our audience-centered performances.

Furthermore, Freeman makes an interesting observation from the performance of *Glimmer* on a phenomenon that he did not necessarily anticipate:

> "But most importantly, audience members enjoyed waving their light sticks around much more than switching them on and off, even though they knew that such activity had little effect on the music. Not only was it more fun to do, and not only was it more pleasing to watch, but it also gave them the *feeling* of more communication with and control over their peers. They were able to communicate a range of information to each other — if not to the computer software — through their stick's position and speed, going beyond mere onoff signals." [13]

Perhaps experiencing this kind of social communication between the audience members is a byproduct of active engagement, almost even an *emergent property* of a successful audience-participation design paradigm. In the following section, we make note of such (unintended) social engagements that occur in the pieces we have implemented.

4. MOPHO EXPERIMENTS

In summer and fall of 2010, the Stanford Mobile Orchestra experimented with various techniques to design and implement performances that center on audience participation, culminating in a concert on November 18, 2010. Figure 1 shows the context of the concert. All of the pieces used one or more of the techniques described below to enable audience participation, using Apple iPhones and iPads as the primary hardware.

4.1. Sampling Audience

One technique of enabling audience participation is to have the audience members generate sound that becomes part of the composition. The process of sampling can be performed prior to the performance, as in *Madder Libs* (2010) and *Converge 2.0* (2010), or during the performance, as in *Orkestra* (2010).

Figure 1. MoPhO 2.0: Audience Participation Concert

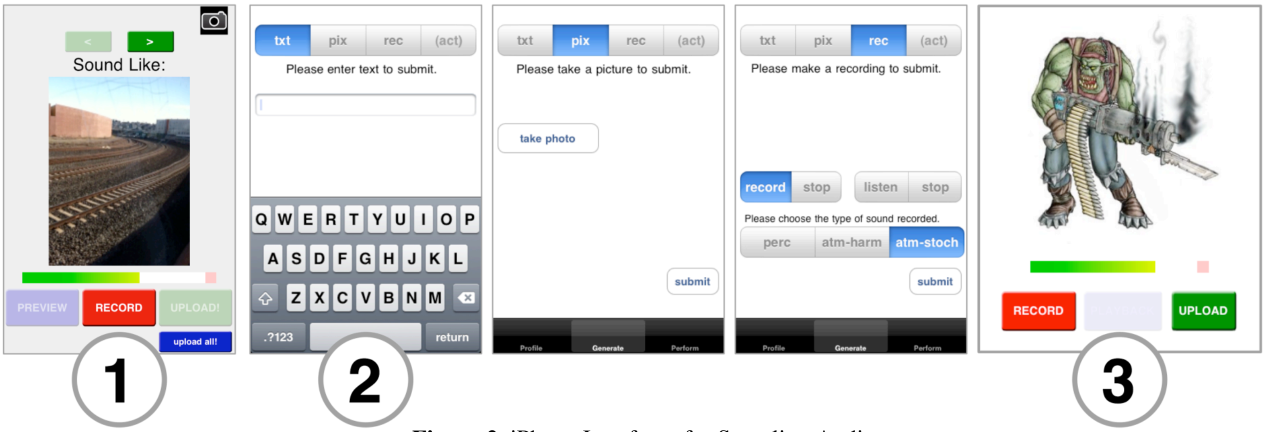

Figure 2. iPhone Interfaces for Sampling Audience:
Madder Libs (1), *Converge* (2), and *Orkestra* (3) use an iPhone interface to sample audience members.

In *Madder Libs* (2010) by Nick Kruge, audience members capture video clips of themselves emulating different instruments, to be incorporated into a larger composition (analogous to how, in Mad Libs, users come up with words for descriptions and enter them in a story). Prior to the performance, a station is setup for audience members to record and submit video snippets using an iPhone application (see (1) in Figure 2), which uploads the data to a server. Then, the snippets are downloaded from the server onto a visual grid on an iPad, and during a performance, the performer triggers mini-videos shown on different grids using a touch gesture, bringing together the diverse video snippets into a single musical piece (see [18] and Figure 3).

Figure 3. Performance Interface used in *Madder Libs*

Converge 2.0 (2010) by Jieun Oh and Ge Wang also uses a pre-sampling method, allowing the audience members to contribute to the compositional source materials. It is a crowd-sourced audio-visual composition that brings together contextual autobiographical moments, captured and submitted by a group of participants, into a coherent narrative. In the weeks prior to the performance, participants use their mobile phones to capture their life moments using the medium of text, image, and sound (see (2) in Figure 2).

These submissions are either uploaded to a server or emailed to the organizer, to be compiled and scored into an audio-visual composition. Figure 4 shows a snapshot of the *Converge* visualizer used during a performance.

Figure 4. Visualizer used in *Converge* Performance

In both *Madder Libs* and *Converge 2.0*, there are three distinct levels of communications. The first level involves the participating audience members expressing themselves using mobile technology powered by a cloud-computing architecture. The second level involves the "master performer" (often a centralized computer and/or the main performer) communicating back to the audience during a performance by shaping the sampled materials into a coherent whole. The third level involves audience-to-audience reception of the performance, which, if successful, generates empathy: audience members become socially engaged upon realizing that what they are seeing and hearing has been expressed by people like themselves. For instance, one audience member described how the performance of Converge led her to vicariously experience those moments that were captured and submitted by others, in such a powerful way that she felt very sad.

The technique of sampling audiences can also be conducted *live* during a performance. In *Orkestra* (2010) by Nicholas Bryan, a subset of audience members perform a vocalization of grunting (and similar) sounds, which are recorded and uploaded, using a mobile phone (see (3) in Figure 2), to a central computer. The sound clips are then spatialized in 8-channel surround speakers through a live-coding performance by the main performer. The vocalizations are made one audience member at a time, and upon each sampling, the new sound is superimposed in a highly rhythmic pattern of intensifying sounds.

Because the volunteering and recording phases are all part of the actual performance, everyone in the performance space can hear the initial source material in addition to the processed sound. In this manner, live-sampling the audience contributes to a higher level of engagement between the audience members, as the group attention moves around the room and becomes directed at the one person under the spotlight who is performing impromptu. In *Orkestra*, the audience members laugh and chuckle upon hearing particularly dramatic or unexpected vocalization of grunting sounds.

Again, this social response can be regarded as the aforementioned third-level of communication between the audience members, a phenomenon that is not necessarily planned out or intended, but rather is an occurrence that emerges as a result of having the audience deeply engaged in the performance.

4.2. Leverage Social Networking Services

Another technique for enabling audience participation is leveraging existing social networking services. The last decade has experienced a huge growth in the popularity and development of social networking services, with *Facebook* (www.facebook.com) and *Twitter* (www. twitter.com) being key examples. These online services based on social relationships have become pervasive. *Facebook*, for instance, has more than 500 million active users, collectively spending 700 billion minutes per month on *Facebook* [12]; As of September 2010, *Twitter* had more than 145 million registered users [28]. These numbers illustrate how inescapable social networking services have become in our daily lives.

But even more pertinent to the topic of audience participation enabled by social mobile computing is the growing significance of the mobile platform experienced by these services. More than 200 million active users of *Facebook* access its service through their mobile devices [12], which translates to roughly 40% of all active users; Similarly for *Twitter*, 46% of active users make mobile a regular part of their *Twitter* experience [28]. Using the application programming interfaces (APIs) provided by these social networking services, it is now possible to design people-centered collaborative music that leverage existing social networking services, accessed using the audience's own mobile devices during performance.

Indeed, *Tweet Dreams* (2010) by Jorge Herrera, Luke Dahl, and Carr Wilkerson demonstrates this possibility. In this piece, audience members use their personal mobile devices to tweet. Tweets containing search hash tags, as decided by the performers and projected on the screen, are sonified and visualized into a dynamic network. Refer to [7] for details. Figure 5 shows tweet visualizations used in a performance of *Tweet Dreams.*

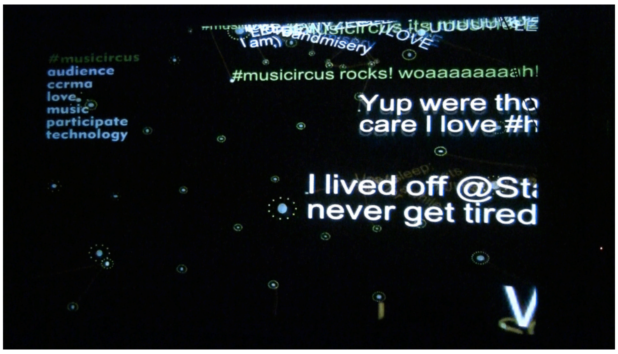

Figure 5. *Tweet Dreams* Visualization

Again, this compositional design inspires interactive audience-to-audience communication. During a performance of this piece, a tweet "the guy next to me smells" was pulled up and sonified. This generated an atmosphere of panic mixed with humor, inspiring more people to express their sentiments to the crowd. Someone replied by tweeting, "Keep your shoes on at the #musicircus."

4.3. Interactive Web Applications

A third major technique experimented by the Stanford Mobile Phone Orchestra is interactive web applications. Web technologies, such as Dynamic HTML and Ajax, have greatly transformed the ways in which people use browsers, introducing a new model of computing in the "cloud" through web application. This shift in paradigm—from computing locally using one's own computer to offloading computation and storage to a server infrastructure—offers exciting new possibilities for computer music research. Web applications not only offer convenience of use and universal access but, more importantly for our purpose, also open doors to collaboration and social interactions. Especially in consideration with the tremendous growth in popularity of consumer mobile devices with built-in browsers, the mobile web provides us with an ideal setting to enable audience participation in music performances in a manner that is software-free (beyond an internet browser) and less dependent on the hardware (that is, in comparison to building device-specific applications).

Popular web applications for music ranges from music recommendation services such as Pandora (www.pandora.com) and Last.fm (www.last.fm), to communities of sharing creations in audio, such as Freesound Project (www.freesound.org) and ccMixter (ccmixter.org). Though these applications provide a great interface for consuming and sharing music, most of the large-scale music applications are not focused on the actual process of creating or performing music.

Projects that do focus on such aspects of music are being explored in a smaller scale, primarily in academic settings. One example is CODES, a web-based environment for cooperative music prototyping, targeted towards novices to support music writing and facilitate cooperative musical activities [24]. Another example is CARO 2.0, a system that focuses on expressive

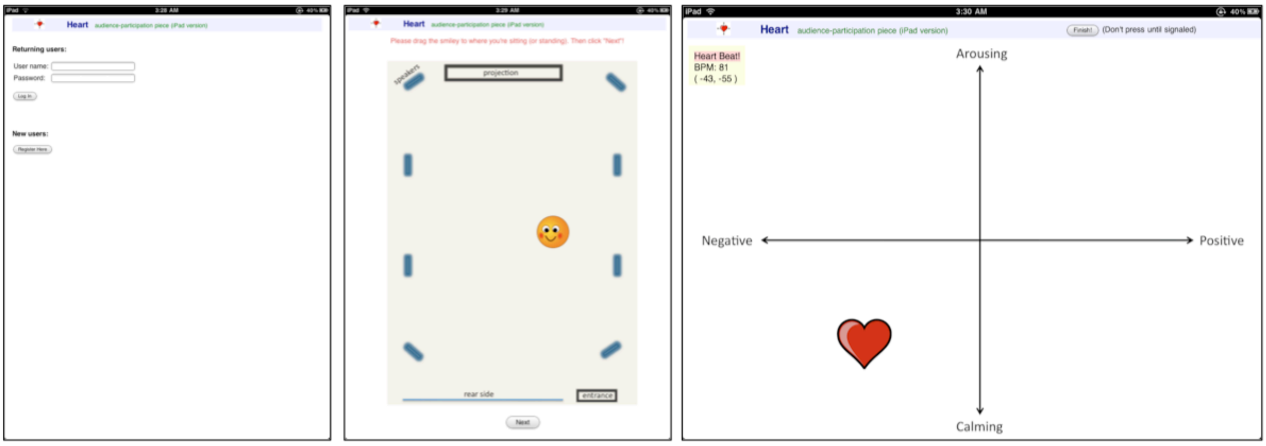

Figure 6. iPad Control Interface for *Heart*:

First, participants log in to the system (left). They drag the smiley face to their location in the performance space (center). They tap on the heart icon and drag it along the 2-dimensional grid based on their introspected emotional state (right).

performance of music and allows composing and sharing music that others can play and modify [26]. *Hide & Speak* and *Tone Bender* are prototypes for web-based collaborative games have been built for acoustics education and psychoacoustic data collection [17]. "Interactive Music Systems for the Web" by C. Kim reviews and lists several other interactive music systems on the internet [16]. While these web applications focus on various aspects of creating or performing music, they are generally not intended for use in a live performance involving simultaneous participation from many people.

Thus, we designed *Heart* (2010, by Jieun Oh) to be a web-browser based piece that enables real-time audience interactions. Its implementation relies heavily on Ajax and JavaScript event handling for iOS, and uses Ruby on Rails framework running on a web server to dynamically generate web pages through which audience can interact. To the best of our knowledge, it is the first instance of using a web application for enabling audience participation in a live performance setting.

During the performance, a subset of audience members use iPads to communicate their self-monitored heartbeat rates and emotional states while listening to a chosen song (see Figure 6). The rest of the audience engage in the performance by listening to the music and observing the visualization projected to the front of the performance space. (In the November concert, 13 people participated, and *Bohemian Rhapsody* by Queen was chosen as the song stimulus.)

The participating audience members' responses—communicated as tapping and drag gestures on a mobile browser—are immediately sent to the server, stored in a database, queried for certain properties, processed to obtain aggregate statistics, visualized in a browser, and projected to a large screen for the rest of the audience. This series of events happen continuously and semi-realtime, with latency of about a second or lower from the initial touch gesture to its visualization.

Three important implementation techniques used in designing *Heart* are (1) Ajax, (2) database tables, and (3) web-native visualization methods. Ajax sends and receives data from the server without having to refresh the browser page, allowing us to create an interactive user experience, much like a desktop application. Database tables, conveniently setup for use through the Rails framework, allow consistent storage and quick retrieval of collected responses from the audience. They are particularly useful in conducting perception-based

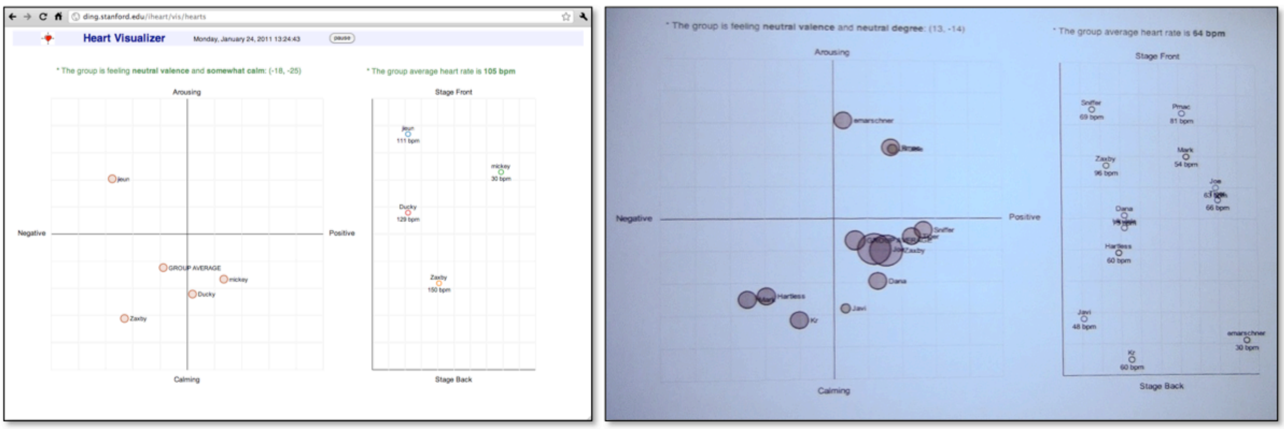

Figure 7. *Heart* Visualization through a Browser:
simulated performance with 4 participants (left) and actual performance involving 13 participants (right)

"performance experiments" for keeping a record of a large amount of data, and at the same time offering an immediate feedback to the audience by performing SQL queries. Finally, visualization of interaction data is implemented using Protovis [2], web-native approach that does not require any additional plug-ins. Thus anyone in the world could observe the audience responses by navigating to the hosting URL (http://ding.stanford.edu/iheart/vis/hearts) during the performance. Figure 7 shows the visualizer used in *Heart* performance.

In this manner, *Heart* provides the technical plumbing needed for achieving bidirectional communication between the audience and the server. But more importantly, we were pleasantly surprised to see that even the audience members who were not directly participating using the iPad interface seemed engaged in the performance: actively following the visualizer, they paid attention to how the emotional states of the participating members were changing across the structural boundaries of *Bohemian Rhapsody*, and laughed upon observing synchronized group behaviors.

5. EVALUATION

Freeman articulates what is one of the greatest challenges in designing performances centered on audience participation:

> "But could the work ever make all 600 audience members feel truly indispensable to its performance? Large-audience participatory works cannot promise instant gratification: giving each person a critical role; requiring no degree of experience, skill, or talent; and creating a unified result which satisfies everyone." [13]

While fulfilling all three requirements remains extremely challenging, leveraging social mobile computing—as experienced by the various works designed by the Stanford Mobile Phone Orchestra—may be the right direction towards implementing a fully gratifying performance experience that Freeman and we dream of. Beyond offering a rich set of physical interactions for controlling and interacting with music, personal mobile phones introduce a much lower psychological barrier to entry to participation as audience members get to use their own, familiar device. Mobile technology has become an inseparable part our life—almost a natural extension of ourselves, and accompanying it is a powerful social fabric governing our lives which, when brought to the performance setting, introduces a new level of engagement centered on social interactions.

Implementing a communication pathway between the audience and the "master-performer" is a *technical necessity* for designing an audience-participation performance. In contrast, inducing a social intercourse among the audience during the performance is an *artistic by-product* that makes the performance experience all the more engaging, conforming to our original motivations for designing audience-centered performances.

These experimental pieces tended to yield a socially engaging experience that is difficult to achieve without having the audience-participation model. In fact, this social element can be regarded as an *emergent property* of having a group of people behaving extemporaneously under a common goal of music-making.

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