Constellation: A Musical Exploration of Phone-Based Audience Interaction Roles

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ABSTRACT

With *Constellation*, we explore a system for audience interaction with performers during a music performance. We seek to reconfigure the relationship between the audience and performers by designing a system for interaction during a music performance using mobile devices. Additionally, we aim to augment the listening experience in a music performance by using mobile devices as speakers. *Constellation* was designed and built for the Spring 2015 Princeton Laptop Orchestra concert. We designed four sections to the piece, exploring various roles played by performers and the audience. We conclude by discussing the results and suggesting potential future work.

1. INTRODUCTION

In music performance, the line between the producers and consumers of music is often sharply defined. An audience typically only sees a closed representation of a performer's intentions and remains passive. We wanted to reimagine this relationship. By experimenting with phone-based interaction during a music performance, we change the performance experience and enable meaningful collaboration between an audience of non-musicians and a group of musician performers.

This type of project has been enabled only recently by the proliferation of smartphones and web-based tools. In order to do this successfully, we had to identify meaningful parameters that an audience can control, provide networked communication, and incorporate useful feedback. We divided *Constellation* into four sections, each experimenting with different roles played by audience members and performers. We sought to empower the audience to have control over performers' scores, and performers to have control over audience devices. More broadly, we aimed to experiment with group music-making and take advantage of phone speakers to provide a distributed-yet-individualized listening experience. Our objective was to design an experience that was intuitive, simple, and fun. This piece was constructed in collaboration with PLOrk, the Princeton Laptop Orchestra, which provided ideas, assistance, and a venue to test *Constellation* in practice.

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2. RELATED WORK

Previous projects have engaged with individual parts of these goals. As smartphones have risen in popularity and technical capacity in the past few years, many projects have experimented with phones producing sounds. Building off the idea of a laptop orchestra, Stanford and Ge Wang started MoPho, a Mobile Phone Orchestra, which aims to use phones as "powerful, mobile, and personal musical instruments and experiences" [17]. Others include *Tok!*, a collaborative acoustic percussion game, and *MobMuPlat*, which allows developers to create basic mobile music projects [10, 6].

Several projects have experimented with distributed sound in audiences. A prescient 2001 project called *Dialtones (A Telesymphony)* set up specific ringtones in audience members' phones and called them at specific times to produce distributed sound, without internet [11]. In 2014, Tim Shaw and Sébastien Piquemal created a project called *Fields*, which turned audience phones into an array of speakers, with performers integrated within the audience [15]. *Fields* lays a framework for distributed-sound sections of our piece.

Other projects have experimented with crowdsourcing audience data. *MassMobile*, a project by Jason Freeman, offers a framework for collecting audience input through a specialized application to influence performers; it has been tested in large performance contexts, such as stadiums [18]. *TweetDreams*, a 2011 Stanford project, uses Twitter data to which audience members can contribute to influence a performance [1]. *Moori*, a project by Haeyoung Kim, allowed users to collaborate on shared thoughts and stories in response to a performer through a specific app [8]. In *Constellation*, we combine sections involving distributed sound and audience control of performers, allowing the exchange of roles in a single piece. Fully browser-based interactions like *Constellation* are relatively new, and we experiment with ways to implement these interactions and explore interface solutions to organizing collaboration.

3. INTERFACE DESIGN

Our goal was to design audience interaction experiences that would be novel, natural, and intuitive, with minimal instruction. We also wanted audience visual attention to focus on the surrounding space and performers in addition to their own devices.

We primarily used touch and motion for audience input. Though text communication has been used in past performances, such as *TweetDreams* [1], it requires direct focus on a screen and can be cumbersome. Touch interfaces present numerous advantages:

familiarity, easy association with a discrete set of messages, optimization for smartphones, and reliability across devices. Interacting with *Constellation* through motion followed our goal of making the input intuitive; users are familiar with accelerometer/orientation-based interaction on phones. We wanted individuals to be able to move and physically explore a virtual space while interacting with the piece. The challenges we faced in using motion-based input included measuring and interpreting accelerometer/gyroscope data to meaningfully translate motions into sounds, and communicating the specific range of motions available to a user.

A primary design goal of *Constellation* was to communicate parameters of interaction intuitively and without verbal instructions. This was accomplished through visual feedback, constrained user input, uncluttered interfaces, and use of color. We tied desired user motion to onscreen visual feedback, and kept the screen straightforward and simple. We used bright, discrete colors to distinguish between items, such as control of different musicians on stage. Also, we wanted joining the piece to be as simple as possible (immediately, through a projected web URL).

4. TECHNICAL IMPLEMENTATION

4.1 Audience Device Tools

Constellation capitalizes on recent developments in the field of mobile phones. Recent research estimates that 74.9% of adults in the United States own smartphones; within educated communities that have access to music performances, we would expect a higher percentage [3]. One of our primary technical goals was to build this project as a standalone web browser application that users could open by navigating to a URL. Web browsers as a platform for connection have been utilized by recent works like *Fields* and present numerous advantages over earlier, app-based projects like *MassMobile* [15, 18]. Notably, they require no application downloading and are platform-independent. We also sought to design the system to require no further setup (such as compass calibration or location determination).

Improved libraries for audio processing and networking on phone browsers allowed this goal. The endorsement of HTML5 as an official standard provided wide access to phone sensors, and the Web Audio API allowed for robust, custom audio generation in browsers. The API is supported by the most popular mobile browsers, including iOS Safari and Chrome. It proved a versatile tool and especially stood out because of the wide range of documentation available. We created the sounds of the piece with the Web Audio API, using a blend of oscillators, noise, filters, and envelopes. Bell sounds were developed by analyzing samples from the University of Iowa Electronic Music Studios with SPEAR [9], and recreating the spectra using additive synthesis.

The client web interface was built using Node.js, custom Javascript and custom HTML [2]. The page animations were designed using CSS. Most mobile devices (including iOS and Android) provide accelerometer and orientation data to web applications. Accelerometer data was straightforward to use; however, when using orientation data, Gimbal Lock becomes an issue [7]. We used the library Full Tilt to obtain rotation matrices values to avoid the problem [16].

4.2 Network and Performer Tools

A crucial technical component of *Constellation* was building a network on which to send messages back and forth to devices connected to the project. We used socket.io for our network development, in combination with Node.js and Express, a Node.js web framework [5, 2, 13]. Socket.io enabled us to use WebSocket technology, which facilitated bidirectional communication between clients (phones) and a server [4].

We utilized Max/MSP to develop the tools for performers and the centralized sound generation. Using a local custom python client communicating to Max over OSC, we received and aggregated crowd data. We built sequencers using Max, with a metronome, synthesized sounds, and a colorful, dynamic displayed projection for performers to follow as a graphic score. Additionally, Max handled sound commands that were sent directly to the phones, and displayed text and colors as projection in the hall during other sections.

4.3 Latency

With communication across the Internet among multiple devices, latency between devices is a known control problem. Other experimenters, such as the creators of MassMobile, have observed latency across cellular networks “as long as a second” [18]. This limits precise rhythms; the human ear can recognize rhythmic delays of about 15-20ms [14]. There are strategies to synchronize clocks, such as the Network Time Protocol, but estimating delays across asymmetric network paths is difficult, especially with many devices [12]. We also sacrificed the greater predictability of a LAN for the convenience of existing cellular/wifi connections.

In light of this issue, we built latency into our musical approach. For portions of *Constellation* in which sounds were triggered across all audience phones, we sought to create sound environments that did not depend on precise timing. We took the approach of creating a sonic environment using arrhythmic sounds, like that in *Fields*, which “create[d] interesting sonic textures by embellishing the random latency between devices” [15]. For semi-synchronous sounds, we created sounds with attack and decay envelopes longer than predicted latency. Additionally, we used performers and centralized sound to synthesize asynchronous data, similarly to how the creators of MassMobile timestamped data sent to the server to reconstruct precise timing in Max and produced sound centrally. For certain sections of *Constellation*, we collected crowdsourced data but used Max MSP to create centralized sound, and let performers synchronize by listening to an audible rhythmic pulse.

5. PERFORMANCE

We designed *Constellation* with the intention of showcasing and experimenting with the system as part of a larger PLOrk show. We anticipated 50-100 audience members and a 10-minute performance. Additionally, the show was themed on medieval music, and so we derived inspiration from “Stella Splendens,” a song from the medieval manuscript *Llibre Vermell de Montserrat* [19]. Below, we describe the motivations for each section and how each operated in performance.

We conducted a brief post-performance survey, for which we received 23 responses (a portion of the overall attendees). We asked about enjoyment, feelings of control, understanding of the piece, and comprehension of each section. A video of the performance can be viewed online: vimeo.com/126996846.

5.1 Independent Audience Instruments

To introduce the audience to the idea of their phones as instruments, the first stage was an undirected soundscape in which motion produced noise. After opening the projected url, the visual interface encouraged motion with a circle (labeled with the word

"MOVE") moving on screen in response to orientation of the phone and the background brightening in response to user motion (Figure 1a). Quick user acceleration triggered a burst of noise, filtered and enveloped based on aspects of the motion. During performance, 20-40 seconds after the URL was displayed, the auditorium was filled with a spacious, textured soundscape (Figure 2). Individual noises could be located spatially. In the post-performance survey, all respondents identified how motion created sound, though some individuals interpreted that sound was produced when the circle touched the edges of the screen rather than from only motion.

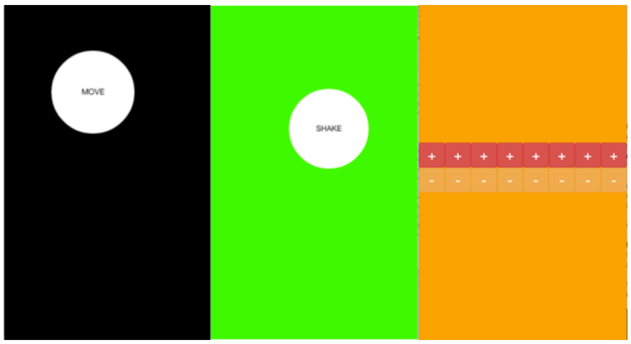

Figure 1 (a, b, c): Screenshots of displays on audience phones during various sections.

5.2 Performers Join Audience Instruments

The second stage of *Constellation* built upon the user interface of the first, adding in pitched sounds and incorporating performer control over the audience. Phone displays transitioned to a series of hues that changed based on how the phone was oriented. The displayed word changed from "MOVE" to "SHAKE" and the intended motion to trigger sounds was similar to that of a shaking a hand-held bell (Figure 1b). Notes produced by phones were tied to specific phone orientations (and colors). We aimed to associate specific notes with colors, and then, by projecting colors, lead audience members to play specific notes. During the performance of this segment, we also incorporated a vocal duo singing portions from *Stella Splendens*, accompanied by synthesizer arpeggios.

In performance, the bells, duo, and arpeggios were musically cohesive, though our interface goals were not met. Our effort to tie colors to notes without written instructions did not bring the desired result in performance. The word "SHAKE" printed on the screen encouraged audience members to shake their phone rapidly (like a rattle) rather than intentionally (like a series of bells). Therefore, rather than a single pitched note, most people created a series of notes as they shook their phone through different colors. Further developing the visual interface and removing the word "SHAKE" could avoid this problem in the future.

5.3 Audience-Crowdsourced Graphic Notation for Live Musicians

Our third segment of *Constellation* experimented with allowing the audience to meaningfully control music played by onstage performers. We created projected 8-beat percussive sequencer grids that could be crowdsourced (Figure 3). We decided upon sequencer grids because, given a consistent beat, sequencers tend to sound rhythmically interesting even given random, changing input. There were five sequencers, each given a specific color. We invited professional and student percussionists to join us to interpret the grids projected on a central screen, with each wearing arm and head bands with one of the colors. On the mobile devices, we assigned each phone to one of the five specific colors/performers, and displayed a series of "+" and "-" buttons (Figure 1c). Together, audience members could vote on the exact sequence that the performers would play.

We also designed one synthesized sequencer, which could be modified by on-stage performers using physical game controllers (Game-Trak "tethers"). Unfortunately, this was difficult to hear in performance; therefore, several audience members reported difficulty understanding the purpose of the performers controlling the tethers.

Musically, the percussionists effectively converted the crafted patterns into sound collaboratively. From an interface perspective, individuals quickly picked up on the piece structure and a steady stream of activity continued throughout the performance. The human quality of crowdsourced control was evident -- at several times, sequencers were fully incremented or fully decremented, forcing drummers to play with either constant sound or unbroken silence. Anecdotally, several participants described the section as game-like and fun. In the post-performance survey, most participants correctly identified how they controlled the percussionists; 4 of 23 respondents expressed some confusion.

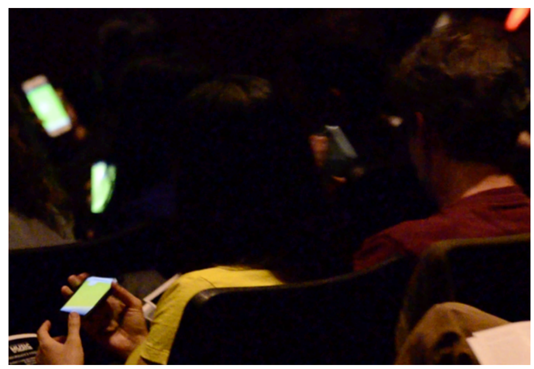

Figure 2: Audience members moving phones to create sounds during performance

5.4 Performers Control Audience Devices

The fourth and final stage of *Constellation* was a return to control of the audience devices by performers--even more directly. We built synthesized notes that could be triggered remotely: a server message would result in keyboard notes echoing from all devices, via local synthesis on each phone. We then tied these messages to instrument input, so that a performer playing a keyboard on stage resulted in synthesizer notes emitted from audience phones. This section was successful; synthesized notes echoed through the space, though at a quieter level than hoped. Several audience members reported that it was fascinating to see direct performer control over audience sound, and that this section could have been extended.

5.5 Overall Audience Feedback

Many audience members described the piece as innovative, musically compelling, and enjoyable. In our post-performance survey, we asked audience members to rate their enjoyment of the piece: the average response was 4.36 out of 5. In response to "Did you feel like you understood the piece?", the average response was 3.50 out of 5, and in response to "Did you feel like you had control over the sounds of the piece?", the average response was 2.95 out of 5.

Figure 3: Projected crowdsourced sequencers with visible onstage performers

6. CONCLUSIONS

With *Constellation*, we explored a phone-based performance with multiple relationships between the audience and performers. We accomplished our goals offering the audience control over the direction of a piece as well as changing the listening experience by using distributed speaker systems and control over audience phones. Technically and musically, our goals were met, though from an interface and control perspective, there was room for improvement. These techniques could be developed and used in isolation or together to create a compelling mobile music experience and turn a typical audience-performer relationship into a complete multi-user instrument.

Future expansion of a project such as this could focus on the following: **(i) Mobile Phone Development.** Ongoing development would enable more complex sounds and processing, as well as easier access to the compass, camera, or microphone. **(ii) User Interaction.** Interaction could be improved with more intuitive interfaces and use of other forms of input. **(iii) Location-Weighting**. Audience locations could be weighted in producing or influencing sound. **(iv) Addressing Latency.** Reducing or eliminating latency could help enable timing-precise music. **(v) Intra-Audience Communication.** Interaction could be expanded by allowing communication within the audience. **(vi) Performance Space.** Because this is a crowd-built piece -- using devices many people carry with them all the time -- it need not be constrained by any needs for instruments or speakers. One could imagine such a piece occurring anywhere that has people willing to participate for a few minutes --on a busy street, in an outdoor park, at a dance, or in any large gathering. Although the sound production power and audio fidelity of these devices is limited, unlocking the potential of distributed sound creation empowers performers to think outside of conventional space constraints.

We look forward to seeing the field develop, and to experimenting with other systems of this form. Until then, it is exciting to appreciate how with only a URL and a phone, any group can become collaborative music-makers. Phones enable a new, powerful way of creating music together.

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