

Speakers, More Speakers!!!^{1,2} – Developing Interactive, Distributed, Smartphone-Based, Immersive Experiences for Music and Art

Anna Forgette, Bill Manaris, Meghan Gillikin, and Samantha Ramsden

Computer Science Department
College of Charleston, USA

forgetteak@g.cofc.edu, manarisb@cofc.edu, gillikinme@g.cofc.edu, ramsdensl@g.cofc.edu

Abstract

We describe a multi-speaker, smartphone-based environment for developing interactive, distributed music and art applications, installations, and experiences. This system facilitates audience engagement through participation via personal smartphones, potentially connecting with traditional computing devices via the Internet without additional software or special configurations. The proposed approach has been inspired and motivated in part by the COVID-19 pandemic and builds on earlier works and technology. It demonstrates a design approach that is more efficient and provides a new avenue for music composers and artists to design highly distributed, participatory, immersive music and art experiences, utilizing various input sensors and actuators available in today's smartphones. These include individual smartphone accelerometers, video cameras, and – of course – speakers. The use of smartphones also provides for relatively precise geolocation through GPS or simple social engineering approaches, such as using dedicated QR codes for different locations (e.g., seats in an auditorium). This allows for composing experiences to be rendered in the same room / auditorium, highly distributed across the Internet, or a combination of both. The paper presents the technological background and describes three case studies of such experiences, in an attempt to demonstrate the approach and inspire new avenues for artistic creativity and expression towards highly immersive, participatory installations / performances of music and art works for the 21st century.

Keywords

Interactive music and art, distributed music and art composition, smartphone-based interface, human-computer interaction, generative music, mobile device control, real-time communication, music performance, audience participation.

Introduction

We present a multi-speaker, multi-screen, smartphone-based environment for developing interactive, distributed music and art applications, installations, and experiences. This environment allows arbitrary network connections to be established among numerous smartphones and other



Figure 1. One of the authors demonstrating our smartphone-based, sound spatialization system in a simulated, multi-speaker laboratory environment.

computing devices (e.g., laptops) to support synchronized delivery and performance of sound and visual materials. This environment also supports design of arbitrary interactive experiences utilizing smartphone touchscreen, video camera, and microphone input, as well as movement captured via smartphone accelerometers (e.g., see Figure 1).

This work has been inspired by the realization that the ongoing pandemic has emphasized a pre-pandemic societal shift in how people communicate and share information – including how they experience, consume, and potentially generate artistic, musical, gaming, and other audiovisual materials via smartphones (such as Zoom, and other related technologies). We believe this shift is here to stay. This has tremendous implications for the average future artist and how they choose to make their work available to vast audiences.³

¹ Funded in part by the US National Science Foundation and the US National Endowment for the Arts (CUE-1935143 and CNS-2139786).

² Also “screens, more screens!!!” – in part inspired by Goethe’s (famous) last words (see <https://www.loc.gov/pictures/item/00652178>).

³ A related example is the shift that streaming services (such as Pandora, Spotify, and YouTube) have made to the delivery, consumption, and – most important – economy of musical compositions and performances.

The average person already owns, carries, and operates at least one smartphone device on a continuous daily basis. These devices are extremely powerful in capturing data and in delivering audio visual material. However, in most cases, due to pre-existing momentum and concerns for protecting copyrighted or otherwise exclusive artistic material, we are all being shielded from using our devices (and the potential they afford) in designing new artistic and musical experiences and performances. Most of us have experienced being asked to silence our smartphones, turn them off, or put them away (as experienced by one of the authors at a recent Brian Eno concert under the Acropolis in Athens, Greece).⁴

We believe the time has come for composers and artists to embrace this new smartphone-based technology – as with other technologies before it – and utilize it meaningfully, in music and art works, installations, and performances.

Our approach utilizes standard and custom-built JavaScript libraries, which allow to seamlessly connect with other pre-existing libraries and tools, including as Ableton Live, Iannix, Isadora, JythonMusic, and PureData, among others, using Open Sound Control and MIDI messages. This flexibility to bring together such powerful and expressive components facilitates rendering of artistic, musical, and other material, designing / building of immersive experiences, installations, and performances, and including audience participation through smartphone input and output.

We demonstrate this approach discussing three such experiences, namely

- a recreation of Iannis Xenakis’s avant-garde piece, “Concret PH”, created originally for the Philips Pavilion in 1958 [1];
- a Zen-like, meditative, music interactive experience, called “Be the Wind”, which renders binaural wind-chime and other restorative sounds, in a distributed fashion with participation from the audience; and
- a fractal-based, sound spatialization piece, called “On the Fractal Nature of Being”, which invites audience members to interact via movement – collecting accelerometer and video data from their smartphones – to generate a dynamic fractal design on a main screen and an evolving, generative soundscape, utilizing musical input from live instruments interspersed through the audience.

While the current paper focuses mainly on designing smartphone-based, participatory music and art experiences / installations, it should be emphasized that this work also applies to designing other kinds of art experiences, including kinetic sculpture, dance, and theatrical experiences and performances, among others.

Background

Audiences in most traditional art and music performances in the West are often considered as mere “receivers” of the performance [2]. In other words, they are not expected to contribute in any way to the creative act occurring before them. Yet, the very presence of an audience in the space does have an effect on the performance. For instance, there are always some low-level forms of participation involved in artistic endeavors (moving around a gallery space, filling in gaps in information, applauding, etc.). This observation led new media theorist, Lev Manovich to argue in “The Language of New Media” that all art is, indeed, interactive [3].

In music, even something as simple as physical gesture can be an integral part of music ensembles and allow for interaction among music participants [4]. The level of interactivity though varies and is usually confined only to the music performers.

Computing systems have opened new avenues for designing explicit interactivity within newer artistic and musical experiences. There are many examples, such as Waite’s Church Belles [5], whose focus is to explore how to provide an effective means of audience participation and interaction.

Another development is peer-to-peer systems, which have found success in this area. Peer-to-peer systems gained popularity between 1999 and 2001 with the wide proliferation of the file-sharing system Napster [6]. The wide acceptance and understanding of the system led to the creation of interactive music works using Napster and related technologies. One such example is the system built by Tanaka, which allowed collaborative music composition on personal digital assistants (PDAs) across short distances [7].

Interactive music creation and performance has continued to evolve, and, as technology has improved, musicians have been able to interact over greater distances. Network Music Performance (NMP) systems, which allow real-time music performance from different locations, are great examples of this as they break the traditional localized geographical barriers of music performance and composition [8]. For instance, Benson et al. discuss SoundMorpheus, a system supporting distributed musical performances, via Myo-armbands to capture motion, and control aspects of music performance, via user arm movements and interaction [9].

An interesting development is the *Web Real-Time Communication* (WebRTC) protocol and related APIs. This has made it possible to design meaningful artistic collaborations across great distances. Such systems include Lind’s Soundtrap [10], a music studio which allows for digitally collaborative music composition; and Ramsay and

⁴ A perfect, yet missed opportunity, as Brian Eno with Peter Chilver have been creating avant-garde experiences for music and art, distributed as smartphone apps, for over a decade.

Paradiso’s GroupLoop [11], a web-based collaborative audio feedback control system, among others.

The WebRTC protocol and APIs have permitted peer-to-peer systems to become more user friendly, providing functionality for audio, visual, and data sharing from device-to-device across networks, thus breaking geographical barriers. An interesting example comes from Chaves, who describes the overarching goals of such a system, stating that he wishes to create “[a] networked performance in which a ‘wireless imagination’ engages the listening subjects in different spatial, temporal, and social poetics” [12].

In terms of using smartphones for building music and art experiences, the work of Brian Eno and Peter Chilvers’ Bloom [13], among others, stands out. This innovative and truly inspired (and inspiring) smartphone app uses a game-like environment to encourage users to make music and visual art, in the form of raindrops, by tapping on the smartphone screen.

Dekel and Dekel’s MoGMI [14] also demonstrates the ability to transform the smartphone into a musical instrument, this time using physical gestures and accelerometer data, as the control mechanism.

The smartphone has also been used to gather accelerometer data in Jean, Broll, Stein, and Lédeczi’s work [15].

Many installations, such as Manaris, et al. “Diving into Infinity”, use body movements, tracked by Kinect and other related sensors, as the means of interaction with an artistic piece [16].

Of all related work, CoSiMa’s Soundworks environment is one closer to what we are presenting herein [17]. Soundworks supports artists in developing smartphone-based experiences, which allow users to collaborate and generate various sounds via touch and the movement of their smartphones. However, having experimented with the framework, we found it to be difficult to install and use, mainly due to the lack of documentation. Still, this is a piece of inspiring, pioneering work in this area.

Finally, Carson’s *immaterial.cloud* [18] brings elements of all this technology together, allowing users to break geographical barriers and collaborate with one another on a musical piece using WebRTC’s data connections. The architecture of our environment is similar to that of Carson’s but extends it in important ways, making it more generic, modular, and thus more easily adaptable to new applications. This allows the development of more varied, complex experiences, by creating a well-documented, easy-to-understand environment.

System Architecture

Our system allows the development of smartphone-based interactive music and art installations. One of its main advantages is that it supports an arbitrary number of audiovisual channels (i.e., intentent, individual

experiences), which can be as large as the number of available smartphones (and networked laptops, tablets, etc.).

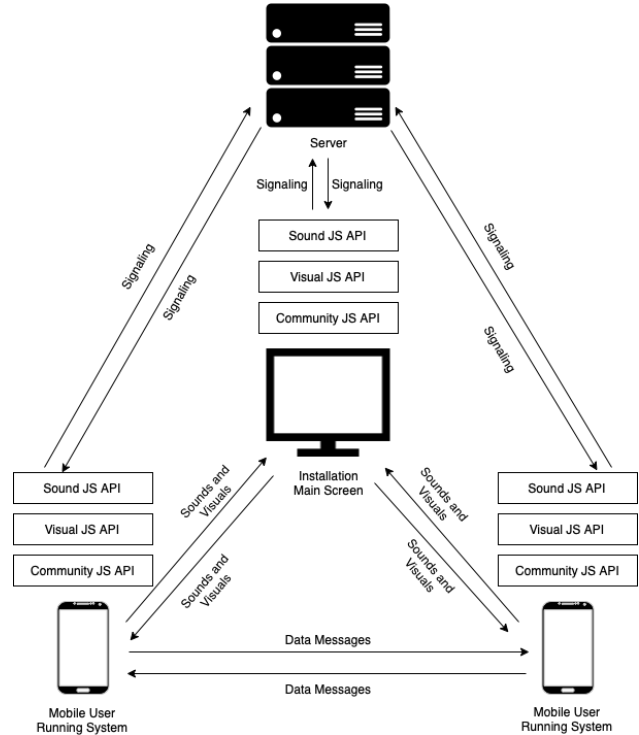


Figure 2. The various components and APIs comprising our system architecture.

This is accomplished by providing individual URLs, created specifically to serve different (or identical) resources, such as sounds or images, to the participating devices.

When conceptualizing our system architecture, our goal was to provide a means to engage users in interactive digital music and artistic experiences and performances. Based on earlier work, and current technological capabilities (e.g., WebRTC, WebAudio, etc.), it became clear that a web application would provide the best framework to support everything we were seeking.

In particular, web applications make music and art experiences easily accessible to participants’ smartphones (and other related devices, including tablets and laptops) **without having to download** any specialized software. This is by far the most enabling aspect of this design decision; users just need to point their devices to a particular URL (which may be different for different users to provide multi-channel, or even multi-role, engagement with the experience itself). Accessing a URL is a common task that all users of smartphone devices know how to accomplish – i.e., typing a URL, and scanning a QR code.

This approach also supports granular / cloud sound stochastic experiences, where the actual location of the sound is not as important, but instead the variety / multiplicity of sounds is what “creates” the experience.

Moreover, this system design allows for mixed-types of experiences, i.e., where there is a special role – via a dedicated URL known to only one person – who can act as an on-stage performer / DJ / maestro of experience, deciding which sounds to be played at a particular time, adjusting timbres, volumes, and potentially sound panning / spatializations / diffusion patterns, thus providing overall navigation of the experience as it unfolds, based on a particular composition, or experience design.

System Elements

Our system architecture consists of two main components – a server, and various client modules.

- The server component stores various pieces of code and assets (sounds, visuals, etc.) comprising the experience. It is usually very minimal, with the only goal of serving the right content to the right client (in the case of a multiple user-role experience, such as maestro on stage vs. audience participants), or the same content to all clients (in the case of a single user-role experience). Additionally, it supports messaging for bi- or multi-directional communication between user clients, allowing for a wide variety of interaction / participation designs.
- As mentioned above, the user client component is able to run on mobile (or other) devices within the safe space (no downloads) of modern web browsers. This module generates / renders the artistic and musical component of for the experience / performance, receives input (if any) from the user, and communicates with other components, as orchestrated by the experience design.

The server and client components communicate with each other through (wired or wireless) Internet connections. This is accomplished via the WebRTC protocol. As mentioned earlier, this allows users to interact with one another, and to render audio and visual artifacts in real time (as allowed or dictated by the composition or experience design).

Implementation

The server component is built in Python or JavaScript. The user client component is built in HTML5 and JavaScript. This infrastructure is truly lightweight and does not require any installation or special configuration, as it comes preinstalled in all major web browsers.

When the participant / user visits the corresponding website established for the experience, the client software begins to run inside the browser's secure environment (also, see next section discussing security of the approach). The client opens a WebRTC data connection via the server to all other clients (user devices) connected to the server. This allows for controlled interaction / communication / synchronization between all devices and the server, while running the particular experience. The types of messages

exchanged, and their frequency depends on the artistic experience design.

Currently, it is expected that the artistic experience designer is well-versed in both art and programming. However, our approach makes both development and deployment much easier than with earlier approaches, as it standardizes and hides unnecessary complexity behind well-defined APIs. This is similar to the approach used in the JythonMusic environment [19], an environment for music and art experiences developed in Python, which has also been a design inspiration for our system.

Our system improves on JythonMusic, as it makes running experiences (as well as communication / synchronization between devices) transparent to the end-user (i.e., no software to download, and no specific configurations to be performed prior to running the experience).

This is a significant advantage / improvement, as it makes such experiences much more usable, accessible, and potentially more appreciated by average end users, who simply enter an experience by browsing to a website. Everything else automatically happens, as they navigate the user interface provided to them by the experience. In a later section, we discuss three such experiences, as examples / case studies.

APIs for Building Experiences

At the heart of this new artistic experience design framework, we incorporate several JavaScript libraries / APIs, some of which are pre-existing, and others have been created by us to handle / hide unnecessary complexity and make designing music and art experiences easier, compared to existing systems. Since the system is implemented in JavaScript, a developer may incorporate additional libraries / APIs (not mentioned here) to access additional desired functionality. Below, we present our system's APIs based on the functionality they provide.

Connectivity

- *Community.js* – this is a custom API which allows user clients to register themselves, when they come online, and connect to other clients. It provides functions to register a client via a custom ID, to get a list of registered clients (users) from the server, to broadcast to all clients (or some of them, having a certain ID pattern), to send messages to a specific client (using an existing client's ID), and to receive messages from another client.

This API utilizes part of a cloud-hosted Community server, for client registration. Once registered, however, users may initiate connections to other users and communicate directly and securely (without overburdening the cloud server). This is particularly important for musical experiences where timing and low latency are important. This approach allows

for truly distributed, potentially massive experiences to be designed and deployed.

This functionality has been implemented utilizing the pre-existing *PeerJS* library,⁵ which simplifies WebRTC peer-to-peer connections and allows users to broker data, video, and audio stream connections to other remote users.

Designers of various performances/experiences are able to specify how to best connect users, and what type of data messages to send through these established connection channels, in order to create compelling and interesting participatory experiences.

Sound

For adding sound capabilities, we utilize the following:

- *AudioSample.js* – this is a custom API which allows user clients to use existing sound samples as instruments. While there are other more powerful, lower-level APIs (mentioned below), we developed this one for convenience, as it handles the majority of design situations we have experienced.⁶ It provides functions to load an audio sample (supports a variety of formats, including MP3, WAV, and AIF – 16, 24 and 32 bit PCM, and 32-bit float formats), to play the complete sound or a subset of it, to loop the complete sound or a subset of it, to stop the sound playing, to pause, and then (as needed) resume the sound playing, to set the pitch (in MIDI – 0 to 127) of sound, to set the frequency (in Hz), and to set volume, panning, etc.

For additional functionality, we have explored the following pre-existing libraries: *Howler.js* – a web audio library which provides functionality for playback of multiple sounds, control over fading, rate, volume, and seeking, in addition to 3D spatial sound or stereo panning.⁷ *Tone.js* – a web audio library for creating synthesized music interactively.⁸

Visual

For visual design, we mainly utilize *p5.js*, a porting of the MIT Processing system into JavaScript. *p5.js* is used already by artists to create interactive, 2D and 3D graphical applications (including drawing shapes, creating complex animations, accessing / reacting to mouse and touch events, loading images, etc.).⁹

Interaction

For user interface building, we utilize regular HTML5 UI building functionality. We also use *NexusUI.js*, a collection of HTML5 interfaces and JavaScript functions to assist with building of interactive web audio instruments in the browser.¹⁰ Finally, we use *Hammer.js*, an open-source library for capturing and recognize gestures made by touch, mouse, and pointer events. This provides functionality to recognize the various user touch events, including *tap*, *double-tap*, *press*, *pan*, *swipe*, *pinch*, and *rotate*.

In terms of additional input, we can also access accelerometer, microphone, and camera data through available Web API functionality. This allows to design a wide variety of interesting and versatile smartphone interactive experiences.

Security of Installation

Finally, and perhaps most importantly, our approach is extremely secure, through the strong, intented layer of security protection provided by modern web browsers. This creates a *barrier* between:

- a. the physical device hardware (and its contents, such as existing photos or personal contacts); and
- b. the software rendering the actual artistic or musical experience.

This is very important and cannot be overstated.

Any extra access required / desired for the experience (such as accessing the user's camera¹² or the device accelerometer, for example) must be explicitly approved by the device user. The browser security enforces this, and there is no way around it.

This way, the artistic experience designer can separate themselves from hacking concerns and from maintaining their software according to the latest security updates and directives; instead they may focus on artistic concerns and content creation (sound, images, interaction, etc.).

Managing security is delegated to the developers of modern web browsers, which are updated by the end user as part of maintaining the security of their own device(s).

To summarize, this division of concerns (artistic vs. security / software maintenance) is significant.

⁵ See <https://peerjs.com>.

⁶ This is motivated by the 80/20 design rule, i.e., identify a set of functions (20%) that handle 80% of use cases, delegating the remaining, rarer ones to more complicated approaches, thus gaining in convenience and ease / simplicity of use.

⁷ See <https://howlerjs.com>.

⁸ See <https://tonejs.github.io>.

⁹ See <https://p5js.org>.

¹⁰ See <https://nexus-js.github.io/ui>.

¹² Which is very different from accessing the device's camera roll / existing photos, for example.

Case Studies – Artistic Experiences

This section discusses briefly (due to space limitations) three artistic experiences designed using our system.

Iannis Xenakis, “Concret PH” – A Retelling

Iannis Xenakis was a pioneer in using early computers to create music. He coined the term *stochastic music* (from the Greek word *stochos* (“στόχος”), or target), to describe music that evolves over time within certain statistical tendencies and densities, and has points of origin and destination. Xenakis created stochastic music to react to chaotic, purely random properties of 12-tone, or serialist music [1]. He believed that the listener may be aesthetically overwhelmed by the complexity of serialist music (which, while deterministic in its rules of creation, by definition, over time sounds utterly chaotic (i.e., uniformly distributed), as if generated using a random number generator in modern computer programming [19].

Xenakis proposed that mathematics of probability could be used to produce a compositional technique that is more controllable. This compositional technique could then be used to produce more aesthetically pleasing music, as he went on to demonstrate [1].

Reconstructing the Piece

This is a recreation of Iannis Xenakis’s avant-garde piece, “Concret PH”, an early and influential example of stochastic music. It was created to be played at the Philips Pavilion in the 1958 World’s Fair in Brussels [23].¹³ Unfortunately, the Pavilion was soon demolished, so there is no way to experience this piece as was originally conceived.

“Concret PH” (and stochastic music in general) may sound random at the local level - i.e., at the level of a single symphonic orchestra musician or, in our case, at the level of an individual’s smartphone speakers. However, when listened to as a whole at the global level - i.e., the sounds of the whole orchestra or, in our case, the sounds emanating across all the speakers of smartphones in the audience – the music exhibits movement and direction through unfolding waves, or areas of concentration in pitch, volume, and panning (among others). Although the music may initially sound random, when observed over time and more carefully, it exhibits some of the same qualities as listening to, say, falling rain, which has Zipfian (or power-law, non-random) proportions [20]. It should be noted that these proportions are also observed in more traditionally composed music (such as classical and jazz music, for instance) [21, 22].

The piece is performed mainly via audience smartphones, with an additional main screen presence (see Fig. 3). It unfolds over time and is relatively short (about 3 minutes).

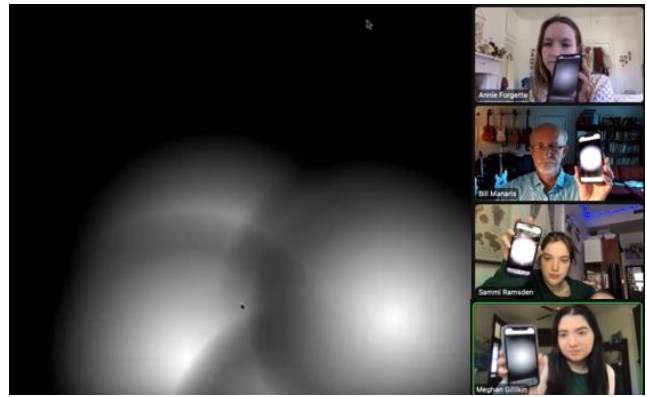


Figure 3. The four authors testing “Concret PH” (right). Sound and visuals are disturbed among all connected smartphones, including a main screen experience (left).

In the original, Xenakis used a recording of burning charcoal, partitioned into one-second fragments, and then pitch-shifted and overlaid, to create a semblance of harmony or polyphony, thus generating a granular, ever-unfolding continuous sound texture. The piece was performed through approximately 400 loudspeakers in the Philips Pavilion arranged (due to technical limitations of the time) in five clusters and 10 channels (sound routes) [23].

In our reconstruction, we use all participating smartphone speakers in the audience. We reconstructed the piece by sampling the background sound from the original (as found on YouTube¹⁴), and recreating the aural density using Python code written in JythonMusic.¹⁵ This produced a score, which was then manually inserted in the JavaScript client code of our framework to drive the sound of the participants’ smartphones.

Our reconstruction utilizes a probability density function controlled by the number of available (or connected) smartphones, adjustable in real-time. This forces the sonic outcome to remain approximately the same, regardless of how many smartphones are participating. The piece can be experienced with as little as one smartphone, or distributed over numerous smartphones – as many as connected to the experience, gradually approximating the sonic characteristics of the original. Our experience also utilizes the *visual* JavaScript API (described above) to visualize each sound playing from individual smartphone speakers, as well as the global, communal soundscape created by the culmination of all the smartphone speakers (see Figure 3).

The smartphone piece was premiered at the University of Maryland, College Park, USA on April 8, 2022. Participants were asked to move freely through the space, while their smartphones produced sound and visuals. In some regards, the ability to move freely resembled the

¹³ This building was designed by architect Le Corbusier, who employed Xenakis as an architect and mathematician at the time.

¹⁴ Concret PH, in stereo – <https://youtu.be/XsOyxFybxPY>.

¹⁵ See <http://jythonMusic.org>.

movement of people inside the Philips Pavilion in 1958. A recording of the performance, captured via a 3D binaural microphone, is available here - <https://bit.ly/concretPH1>.¹⁶

“Be the Wind” – A Case Study

This experience is similar to the Xenakis’s “Concret PH”, except it adds user interaction. Instead of the audience passively listening to sounds unfolding over all participating smartphones, audience members can also decide when sounds are generated by tapping on their smartphone screens (see Figure 4).

Unlike “Concret PH”, which was influenced by Xenakis’ 1944 Greek Civil War experience, where he almost died in an explosion from a British tank shell, the goal of this experience is to be restorative in nature.

Through integration design and choice of sound materials, users are encouraged to engage in a slow, deliberate, meditative experience. The sound material consists of high-resolution, binaural audio recordings of a high-quality wind chime (tuned in C minor), as well as a field recorded sound of a running river and various recordings of bird calls.

Using these audio samples, the score is constructed in a way similar to “Concrete PH” using a probability density function. Users may contribute sounds to the collective experience by tapping on their smartphone, or they may simply sit back and listen to other people’s sound contributions. Harmonies emerge, and go away, as people contribute material. This smartphone experience will be premiered at the Music Library of Greece in May 2022. A recording of it will be available at <http://manaris.org/research>.

“On the Fractal Nature of Being” – A Case Study

Fractals are a fascinating natural phenomenon. Their mathematical intricacies and iterative or recursive self-similarity remind us of the complex underlying interconnectedness of the world around us. This immersive, smartphone-based artistic experience aims to capture the essence of fractals and evoke reflection on the intricate and meaningful ways in which we are all interconnected.

Similarly to “Be the Wind”, this piece involves a peer-to-peer network, connecting each smartphone in the audience to a larger main screen in the installation space. The audience members have the opportunity to alter and change the main screen by interacting with their own individual device. The system utilizes the built-in accelerometer capabilities of the smartphones to gather data on how each audience member is moving. Camera data are also collected from the smartphones to capture the most prevalent colors in the areas surrounding each user.

Using a recursive fractal design, natural images are displayed on the main screen. At the smallest recursive



Figure 4. Interacting with “Be the Wind.” Users tap on smartphone to generate a specific wind-chime pitch, utilizing binaural recordings of a high-quality wind chime tuned in C minor (*left*). Images chosen from a set of restorative, natural images are displayed on both the smartphone and shared experience (*right*) .

level, each main screen image is controlled by an individual user’s smartphone input. As a user moves their device, their corresponding image moves on the main screen, matching their movement, and causing a chain reaction of movement within the fractal design, which shifts and “breathes”.

Additionally, the color of each image on the main screen reflects the main color “seen” by each smartphone camera. As a user moves their device, and the camera captures different colors, the corresponding image on the main screen changes to match that color. This change is then propagated in real-time to all higher-level images, thus reflecting the colors captured from each camera in the audience, and creating a fractal collage that is an ever-changing representation of this communal experience.

In terms of sound, the piece utilizes live instruments, including a piano, a theorbo, a cello, and a bassoon. These instruments are performing improvised musical material from a series of harmonies emanating from 371 Bach chorales (based on earlier work presented in [24]). The participants’ smartphones utilize elements of the sounds generated from these live instruments (recorded earlier), distributing them in real-time throughout the performance space.

The piece is controlled using several density functions similar to the one used in Xenakis’ “Concret PH”, utilizing excerpts of recordings from the live instruments. Together, the sounds create a cloud structure that navigates the harmonic progression of the piece. Live instrument performers and smartphone participants come together through interaction, movement, and deep listening. The piece lasts approximately 12 minutes. It will be premiered at the Music Library of Greece in May 2022. A recording will be available at <http://manaris.org/research>.

¹⁶ Courtesy of Ian McDermott, University of Maryland.

Conclusion

During at least the last decade, artists and musicians have begun experimenting with various online delivery mechanisms and smartphone technologies. At the same time, computer game designers have engaged fully with such media, resulting in numerous, highly popular / successful online games and game platforms, such as World of Warcraft (WoW), Minecraft, Fortnite, and many others. Such experiences have allowed people from across the globe to come together and experience joint game play.

We propose that similar experiences may be created with appropriate musical or artistic goals, as the technology is readily available to support this. This involves a multi-speaker, smartphone-based environment, which supports the development of interactive, distributed music and art applications, installations, and experiences. This approach allows audience members to become themselves performers, simply by entering a URL into a browser, or scanning a QR code. The goal herein has been to report on how such a platform can support the design and deployment of evocative artistic experiences combining sound, visual art, meaningful and accessible user interfaces.

This is especially important now, given the complicated nature of designing artistic and music compositions and live performances during a global pandemic (with country-wide lockdowns in various nations or cities, and the canceling of medium- to large-crowd events, including exhibits and performances in museums, theatres, and music halls / auditoria, at the time of this writing). While this has seriously affected traditional music composition and art installations and performances, we hope that the work presented herein (as well as approaches similar to it), will provide a viable, innovative alternative, in terms of economies of scale, and delivery platforms / physical spaces, to deliver artistic and musical content well into the 21st century.

Acknowledgements

This work has been partially funded by the US National Science Foundation and the US National Endowment for the Arts (CUE-1935143 and CNS-2139786). Nick Moore has provided significant assistance in various ways, including testing of the experiences reported herein.

References

1. I. Xenakis, *Formalized Music: Thought and Mathematics in Composition*, Indiana University Press, pp. 273, 1971.
2. S. Kattwinkel, *Audience Participation: Essays on Inclusion in Performance*, Greenwood Publishing Group, pp. 54-67, 2003.
3. L. Manovich, *The Language of New Media*, Cambridge, MA: Massachusetts Institute of Technology Press, pp. 335, 2001.
4. A. R. Jensenius and C. Erdem, "Gestures in Ensemble Performance", in *Together in Music: Coordination, Expression, Participation*, Oxford University Press, pp. 119-128, 2021.
5. S. Waite, "Church Belles: An Interactive System and Composition Using Real-World Metaphors", *Proceedings of the 2016 conference on New Interfaces for Musical Expression (NIME 2016)*, pp. 265- 279, July 2016.
6. A. Oram, *Peer-to-Peer: Harnessing the Power of Disruptive Technologies*, O'Reilly Media, Inc., pp. 448, 2001.
7. A. Tanaka, "Mobile Music Making", *Proceedings of the 2004 conference on New Interfaces for Musical Expression (NIME 2004)*, pp. 154-156, June 2004.
8. C. Rottondi, et. al., "An Overview on Networked Music Performance Technologies", *IEEE Access*, vol. 4, pp. 8823-8843, 2016.
9. C. Benson, et al., "SoundMorpheus: A Myoelectric-Sensor Based Interface for Sound Spatialization and Shaping", *Proceedings of the 2016 conference on New Interfaces for Musical Expression (NIME 2016)*, pp. 332-337, July 2016.
10. F. Lind and A. MacPherson, "Soundtrap: A Collaborative Music Studio with Web Audio", *Proceedings of the 2017 Web Audio Conference*, August 2017.
11. D. B. Ramsay and J. A. Paradiso, "Grouploop: A Collaborative, Network-Enabled Audio Feedback Instrument", *Proceedings of the 2015 conference on New Interfaces for Musical Expression (NIME 2015)*, pp. 251-254, May 2015.
12. R.M.P. Chaves, *Performing Sound in Place: Field Recording, Walking and Mobile Transmission*, Queen's University Belfast, pp. 225, 2013.
13. B. Eno and P. Chilvers, "Bloom", *Generative Music*, 2012, <http://www.generativemusic.com/bloom.html>.
14. A. Dekel and G. Dekel, "MoGMI: Mobile Gesture Music Instrument", *Proceedings of the 2008 Mobile Music Workshop*, pp. 13-15, May 2008.
15. D. Jean, et al., "Your Phone as a Sensor: Making IoT Accessible for Novice Programmers", *Proceedings of the 20th International Conference on Information Processing in Sensor Networks*, pp. 390-391, 2021.
16. B. Manaris, et al., "Diving into Infinity: A Motion-Based, Immersive Interface.", *Proceedings of the 21st International Symposium on Electronic Art (ISEA 2015)*, pp. 692-2015.
17. N. Schnell and S. Robaszkiewicz, "Soundworks – A playground for artists and developers to create collaborative mobile web performances", *Proceedings of the 2015 Web Audio Conference*, January 2015.
18. T. Carson, "Immaterial.cloud: Using Peer-to-Peer Technologies for Music.", *Proceedings of the 2021 Web Audio Conference*, 2021.
19. B. Manaris and A.R. Brown, *Making Music with Computers: Creative Programming in Python*, Chapman & Hall/CRC Textbooks in Computing, pp. 502, May 2014.
20. A.R. Jameson, et al., "Improved Estimates of the Vertical Structures of Rain using Single Frequency Doppler Radars", *Atmosphere*, 12(6), 699 (2021).
21. B. Manaris, et al., "Zipf's Law, Music Classification and Aesthetics," *Computer Music Journal* 29(1), MIT Press, pp. 55-69, Spring 2005.

22. B. Manaris, et al., "Armonique: Experiments in Content-Based Similarity Retrieval Using Power-Law Melodic and Timbre Metrics", *Proceedings of the Ninth International Conference on Music Information Retrieval (ISMIR 2008)*, Philadelphia, PA, pp. 343-348, Sep. 2008.
23. Lombardo, et al., "A Virtual-Reality Reconstruction of Poème Électronique Based on Philological Research", *Computer Music Journal*, Summer 2009, 33(2), pp. 24-47.
24. B. Manaris, et al., "Harmonic Navigator: A Gesture-Driven, Corpus-Based Approach to Music Analysis, Composition, and Performance", *2nd International Workshop on Musical Metacreation (MUME 2013)*, *Proceedings of AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment (AIIDE'13)*, Boston, MA, pp. 67-74, Oct. 2013.