Graph Theory: Interfacing Audiences Into the Compositional Process

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ABSTRACT
Graph Theory links the creative music-making activities of web site visitors to the dynamic generation of an instrumental score for solo violin. Participants use a web-based interface to navigate among short, looping musical fragments to create their own unique path through the open-form composition. Before each concert performance, the violinist prints out a new copy of the score that orders the fragments based on the decisions made by web visitors.

Keywords
Music, Composition, Residency, Audience Interaction, Collaboration, Violin, Graph, Flash, Internet, Traveling Salesman.

1. INTRODUCTION
In recent years, technological and aesthetic developments have challenged us to become more engaged and active cultural consumers, helping to create the content we enjoy rather than serving as mere spectators; we curate the playlists we listen to, we compete in the massively multiplayer online games we play, and we collaboratively filter the media we watch. Within this context, traditional concert performance, particularly of classical and contemporary art music, seems increasingly anachronistic: audiences sit in a dark concert hall, often looking at a conductor whose back is turned toward them, afraid to cough or sneeze lest they disturb their neighbors.

Graph Theory aims to bridge this experiential gap. Through its availability on the Internet, it seeks to creatively engage audiences outside of the concert hall; the project then incorporates their activities into the context of a live concert performance. Web site visitors, who need not have specialized musical or technical training, use a visual interface to navigate among short, looping musical fragments for solo violin to create their own unique path through the open-form composition. Before each concert performance, the violinist prints out a new copy of the score from the web site, which linearly orders the fragments based on the decisions made by site visitors.

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2. MOTIVATIONS
The concepts behind Graph Theory emerged out of my interest in involving audiences in my compositional process and my past frustrations in trying to do so. In 2001, I was commissioned to write a piece [7] for the elementary school band, chorus, and orchestra at the Collegiate School in Richmond, Virginia, as part of their "Be A Composer" project. Before starting to write the piece, I spent two days meeting with large groups of students to present my work and solicit their ideas for the music. By actively involving them in my compositional process, I hoped they would be motivated to listen for the realization of their ideas, and they would share the excitement of creating a piece of music.

While composer residencies such as this one can be powerful structures through which to engage and challenge participants, the interface through which the interaction is usually facilitated — language — can prove limiting. In this case, I naïvely asked each group: "What ideas do you have for the piece?" While there was never a shortage of ideas, students had trouble organizing and expressing their thoughts, so their suggestions were not particularly helpful. Most were hopelessly vague (e.g. loud, soft, fast, slow) or extramusical (e.g. animals, stories). Though the students were delighted that they had helped me to write the piece, I felt like I had cheated them out of a truly meaningful contribution.

By structuring participant contributions through a simple web-based visual interface rather than relying on unstructured group conversations, Graph Theory aims to engage each individual participant with the work's musical content and structure.

3. BACKGROUND
3.1 Networked Music
Recent networked music research and practice have focused primarily on real-time, collaborative, networked performance systems. Termed "shared sonic environments" by Barbosa [1], they range from the NinJam [5] software architecture, a networked multi-track audio environment which syncs participants on a common tempo and meter, to Phil Burk's *WebDrum* [3] drum machine, in which different users edit each voice of a looping drum pattern through a simple grid-style interface. These projects are in turn indebted to earlier analog works such as Max Neuhaus' *Radio Net* [11], in which participants from around the United States phoned in whistling sounds that were then mixed and processed in real-time and broadcast over the radio. And several recent works have linked such online environments to live concert performances, including

Tod Machover's *Brain Opera* [10] and William Duckworth's *Cathedral Project* [6].

Like Machover and Duckworth's projects, Graph Theory links an online environment to concert performance, but it does so out of real time, following a paradigm closer to an online discussion forum than a chat. Each user contributes to an evolving musical score rather than improvising with other participants to create music in the moment. Participants need not log on during a live performance in order to influence it, and they need not log on simultaneously with other users in order to collaborate.

In this respect, Graph Theory is influenced by projects such as Splice Music [14], a multi-track audio interface for collaborative remixes built from shared sound libraries; Sergi Jordá's Faust Music On Line [8], a novel collective composition and synthesis interface; and the New York Miniaturist Ensemble's Collaborative Composition Website [12], in which participants can add and remove notes and musical expression markings from a single staff system.

3.2 Dynamic Score Generation

Graph Theory also draws from a tradition of dynamically generated musical scores for concert performance whose visual appearance transforms from one performance to the next. In Earle Brown's *Calder Piece* [2], the music, which is part of a sculpture, literally moves. And recent projects by Art Clay [4] and David Kim-Boyle [9] render digital scores in real time based on the activities of musicians and/or audience members.

3.3 Open Form

Graph Theory's musical structure consists of small musical fragments and paths that link them. Participants navigate among these fragments and within the path constraints to create their own path through the composition.

This structural paradigm is inspired by Stockhausen's idea of open (or mobile, or polyvalent) form, as realized in works such as *Klavierstuck XI* (1956) [15]; by the graph structures common in computer science and discrete mathematics; and by the hypertextual narrative structure of the web itself.

Kaija Saariaho's *Mirrors* for flute and cello, which was released on her *Prisma* CD-ROM [13], provides a more recent musical precedent. It invites users to arrange fragments for flute and cello on a timeline and play them back; different modes allow participants to operate freely or within ordering constraints. The software, though, does not have a networked component.

4. DESIGN

4.1 Web Interface

The web interface (Figure 1), created in Flash in collaboration with designer Patricia Reed, enables users to explore the graph structure and create their own path through the composition. In the top section, they see piano-roll style representations of the current fragment, previous fragment, and possible next fragments. Because the work utilizes only twelve different pitches, with each pitch class frozen in a particular octave for the entire work, the fragments can be easily represented with just twelve vertical steps.

The lower section of the interface features a visual representation of the entire graph structure. Different colors highlight the previous, current, and possible next fragments. The coloring of possible next fragments indicates their relative popularity with previous web site visitors. The color of other fragments on the graph indicates whether they have already been visited during the current user session.

Users indicate their choice for the next possible fragment by clicking either on the piano-roll representation or directly on the graph. If they are unhappy with a decision, they may move backwards to the previous fragment by clicking on it.

A path review button enables users to play through the entire series of fragments they have visited thus far. In this mode, each fragment in the path is played in succession, each a single time. A control panel (Figure 2) enables users to jump to any fragment in the path as they review it; they may then choose to continue exploring the graph from that fragment, discarding any subsequent fragments in their path.

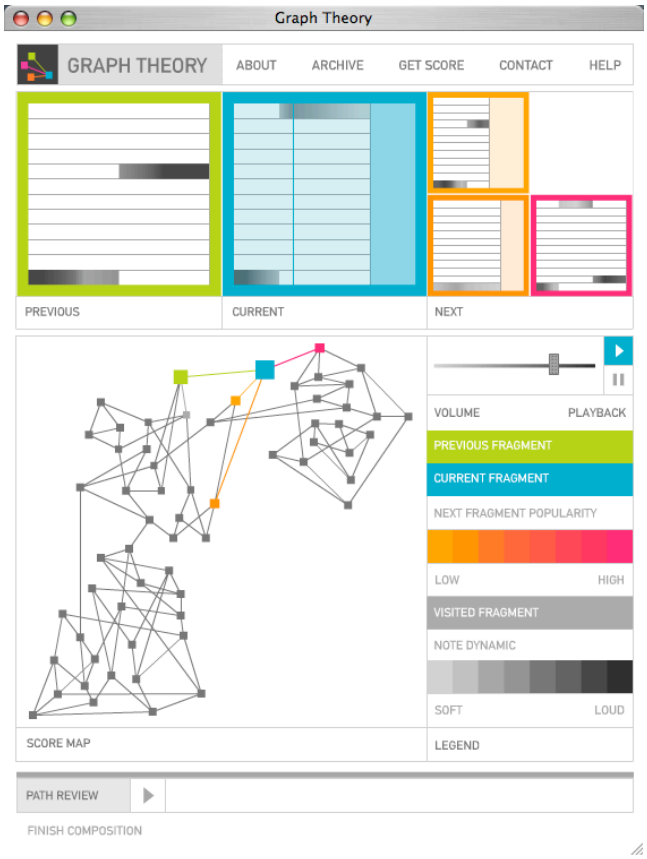

Figure 1. Graph Theory web interface.

Figure 2. Graph Theory path review control panel.

4.2 Score Generation

As users navigate through the musical fragments, each decision they make is logged on a server-side MySQL database. The server also records the number of times a fragment loops before a new decision is made. Each day, then, the server regenerates the PDF score file for the piece (Figure 3), which can be downloaded from the web site for use in concert performances.

The algorithm, implemented in PHP, generates a linear path through the composition. It first assigns weights to the directed edges linking each pair of fragments in the graph; the more "votes" a particular edge has received from participants, the lower its weight. The software then finds the path that visits all fragments at least once but has the lowest total weight. It solves this optimization as a variation of the traveling salesman problem, allowing for a graph that is not fully connected and for the same fragment to be visited multiple times if necessary. A genetic algorithm is used to quickly compute an optimal or near-optimal solution.

In this manner, more popular path segments are more likely to appear in performance scores. And the decisions of recent web site visitors take precedence: a server-side variable configures how far back to look in the decision database when computing weights.

Assembling the PDF score is straightforward. An image file for each of the sixty-one score fragments is stored on the server. The PHP script simply pastes each image fragment into the file in the proper order. Each fragment is labeled with a suggested number of repetitions, based on the average number of times web site visitors let it play before moving on.

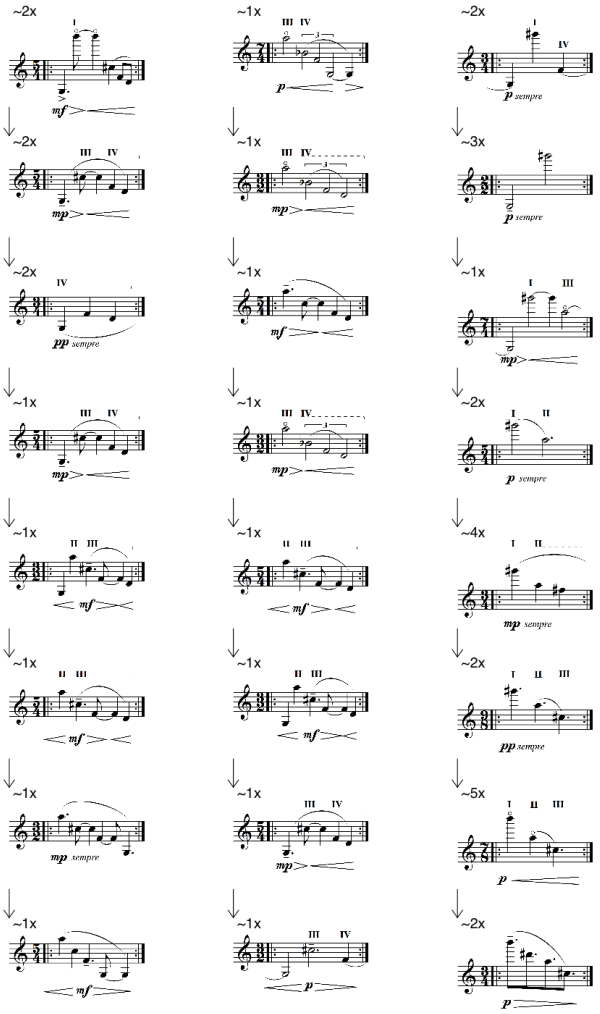

Figure 3. Graph Theory score excerpt.

4.3 Concert Performance

Performers are instructed to practice several different versions of the score as they prepare for a performance of the piece. They then print out the latest version of the score just before the concert and look at it for the first time on stage. This encourages them to be spontaneous in their interpretation and to take liberties with tempo and other expression markings.

While no technology is required in the performance of the piece, presenters are asked to direct audiences to the web site in advance of the concert, and they are also encouraged to place computer kiosks running the web site in the concert hall lobby.

Each performance is recorded and archived on the web site, so that even if participants cannot attend a concert in person, they can still track how the piece evolves and compare the recordings to their own explorations of the music.

4.4 The Music

The sixty-one fragments that comprise the work range in length from 0.6 to 4 seconds, and each fragment contains between 1 and 5 pitches. Linked fragments always differ by only a single added, removed, or changed pitch; each fragment is linked to three or four other fragments on the graph. The rhythmic and metrical content of each fragment were composed intuitively, without systematic restrictions. The music is mostly slow, meditative, and minimal, inspired by composers such as Feldman, Cage, and Pärt.

On the web site, sound is continuous; a fragment loops until the next one is chosen or playback is paused. The fragment recordings, which were created by violinist Maja Cerar and recorded with a click track, are identical each time they play back.

In each 7-10 minute concert performance, the violinist exercises considerable interpretive freedom to modify dynamics, timbre, and tempo, insert pauses, and vary fragment repetitions in order to musically shape series of fragments into cohesive, large-scale musical phrases.

5. DISCUSSION

5.1 Web Site

In informal feedback received from web site users, a number of trends emerged. Many participants enjoyed the visual and aural experience of the score and the ability to control their own path through the composition. However, it was difficult for participants to follow how their own decisions related to those made by other users or to scores performed in concert. Instead, they focused on the individual product they created, and they often wished they could generate audio files or scores based only on their personal paths through the composition.

Future works in this series will further explore this duality of individual and collective creation, and they will also more clearly show participants the role their individual contributions play in the development of the collective musical products, through visualization and auralization of the work's evolution over time. Future works will also link participants via a social network so they can communicate directly with each other, develop versions of the music within social groups, and collaboratively filter user contributions.

And while Graph Theory's simple interactive structure is compelling, user influence remains limited. An enhanced design

could engage participants for longer periods of time, challenge them to contribute in more significant ways to the score, and encourage them to visit the site regularly to see how the score evolves. Participants might gradually modify the connections between fragments, or they could even edit the content of fragments themselves through their collective actions.

5.2 Concert Performance

The three violinists who have performed the work to date all enjoyed the malleability of the score and closely followed how it evolved. One significant problem emerged, though. None of these classically-trained musicians was comfortable playing a new version of the score, sight unseen, in concert performance. When they did try to sight-read a version of the score, their playing tended to be stiff, messy, and unmusical, without large-scale expressive arches and smooth transitions between fragments. Since this performance directive seemed to work against its original aim — encouraging musicality and spontaneity — it was removed from the score. If they wish, performers may now print out a version of the score well in advance of the performance, so that they have sufficient time to practice that particular version.

Graph Theory was written for Maja Cerar, a virtuosic violinist, and so the music is difficult, with fast runs and large leaps in the upper registers of the instrument. Future works in the series will be easier to play, so that they are more accessible to performance by amateur musicians, creating another avenue to participation.

6. ACKNOWLEDGMENTS

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