# *GRAPH THEORY*: LINKING ONLINE MUSICAL EXPLORATION TO CONCERT HALL PERFORMANCE

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Recent technological and aesthetic developments have challenged us to become more engaged and active cultural consumers who help create the content we enjoy: we curate the playlists we listen to, we compete in the 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 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 training, use a visual interface to navigate among short, looping musical fragments to create their own unique path through the open-form composition for solo violin. Before each concert performance, the violinist visits the web site to print out a new copy of the score, which linearly orders the fragments based on the decisions made by site visitors.

## Background

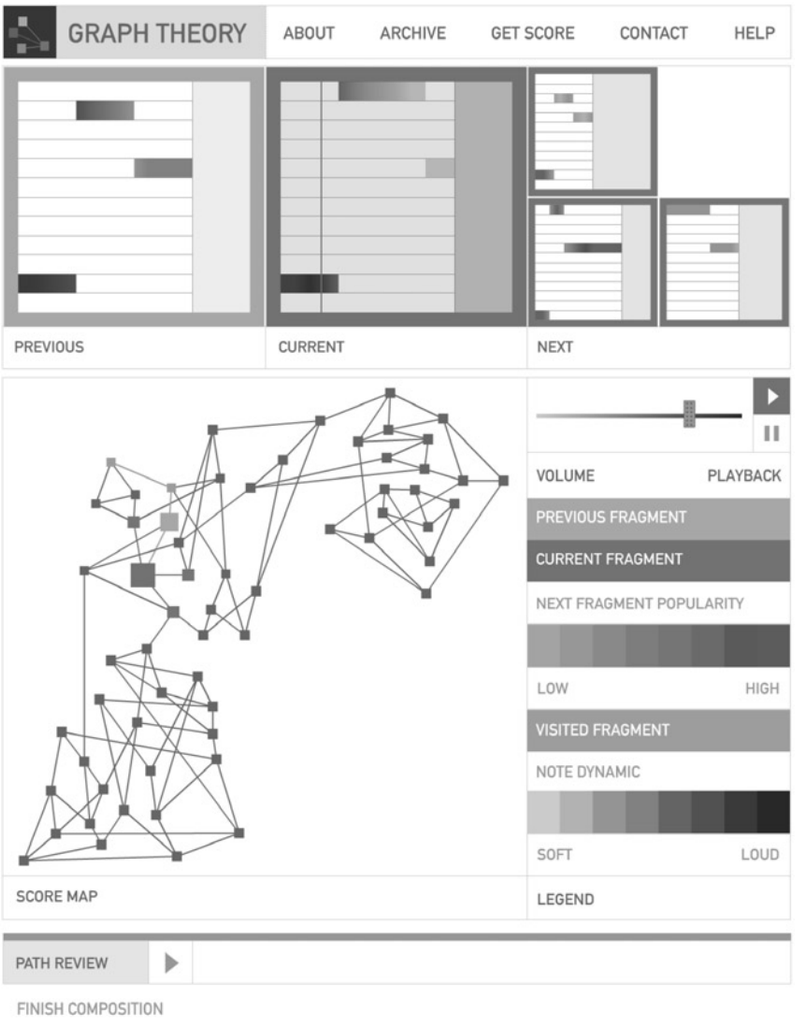
Recent networked music research and practice has often focused on real-time, collaborative, networked performance systems. Termed "shared sonic environments" by Barbosa [1], they range from the NINJAM [2] software architecture, a networked, synced multi-track audio environment, to Phil Burk's *WebDrum* [3] drum machine, in which users edit voices of a looping drum pattern through a step-sequencer interface. And several recent works have linked such online environments to live concert performances, including Tod Machover's *Brain Opera* [4] and William Duckworth's *Cathedral Project* [5].

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 users in the moment. Participants need not log on during a live performance in order to influence it, and they need not participate simultaneously with others in order to contribute to a collective result. In this respect, *Graph Theory* is influenced by projects such as Splice Music [6], a collaborative remix tool; and Sergi Jordá's *Faust Music On Line* [7], a novel collective composition and synthesis environment.

*Graph Theory* also draws from a tradition of dynamically generated musical scores whose visual appearances transform from one concert performance to the next. In Earle Brown's *Calder Piece* [8], the movements of a mobile sculpture influence the music, and recent projects by Clay [9] and Winkler [10] render digital scores in real time based on the activities of performing musicians.

*Graph Theory*'s structural paradigm, in which small musical fragments are reordered, is inspired by Brown's idea of open form [11], as exemplified in works such as Stockhausen's *Klavierstuck XI* [12], in which the performer's wandering eyes select the order of fragments during performance, and Saariaho's *Mirrors* [13], in which users manually order the fragments and play back the results. *Graph Theory* also refers to the graph structures common in computer science and to the hypertextual narrative structure of the web itself.

**Fig. 1. The user interface for *Graph Theory* (2006). (© Jason Freeman)**




## Design

The web interface (Fig. 1) 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 cleanly represented with 12 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, and the hues of possible next fragments indicate their relative popularity with previous web site visitors. The colors of the remaining fragments on the graph indicate whether the user has already visited them during the current session.

Users choose the next fragment by clicking either on the piano-roll representation or directly on the graph; they may move back to the previous fragment if they are unhappy with their decision. 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 a single time.

## Musical Score

As users navigate through the musical fragments, each decision they make is logged on a server-side database. The server also records the number of times a fragment loops before a new decision is made. Each day, then, the server uses this data to regenerate a downloadable score file for use in future performances.

The score-generation algorithm creates 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. 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.

The algorithm also labels each fragment in the score with a suggested number of repetitions, based on the average number of times web site visitors let it play before moving on.

The meditative, minimal music is comprised of 61 fragments that range in length from 0.6 to 4 seconds; each fragment contains between one and five pitches. Linked fragments always differ by only a single added, removed or changed pitch, and each fragment links to either three or four other fragments on the graph. I composed the rhythmic and metrical content of the fragments intuitively, with the goal of avoiding a regular sense of pulse and meter between fragments.

## Performance

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 encouraged to place computer kiosks running the web site in the concert hall lobby. Each performance is also recorded and archived online.

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

In each 7-10 minute concert performance, the violinist exercises considerable interpretive freedom to modify dynamics, timbre and tempo, to insert pauses, and to vary fragment repetitions, musically shaping groups of fragments into larger-scale musical phrases.

## Discussion

In the nine months since *Graph Theory*'s public launch, over 9,000 users have explored the work online, and the work has been presented in five live performances. Many web site 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 understand exactly how their own decisions related to those made by other users or to scores performed in concert. Instead, they tended to focus on the individual product they created, and they often wished they could generate downloadable audio files based only on their personal paths through the composition.

I plan to further explore this duality of individual and collective creation in upcoming works in this series, which will more clearly visualize and auralize the role individual contributions play in the evolution of the collective musical product. I also plan to link participants via a social network so that they can communicate directly with each other, develop versions of the music within social groups, and collaboratively filter each other's contributions.

And while *Graph Theory*'s simple interactive structure is compelling, user influence remains limited. I plan to enable participants to gradually modify the connections between fragments and even to edit the content of the fragments themselves.

I originally wrote *Graph Theory* for a virtuosic violinist, and the music is correspondingly challenging to perform. I would like to make future projects in this series more accessible to amateur performance, creating another avenue to participation in the work.

**Acknowledgments**

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**References and Notes**

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