Glimmer: Creating New Connections

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Abstract. *Glimmer*, a composition for chamber orchestra and audience, uses novelty light sticks, video cameras, computer software, multi-colored stand lights, and projected video animation to create a continuous feedback loop in which audience activities, software algorithms, and orchestral performance together create the music. This paper establishes the aesthetic background and motivations behind *Glimmer* and describes the conceptual framework and technical realization of the piece in detail. Performances of the work by the American Composers Orchestra at Carnegie Hall in New York and by musicians at the Hamabada Art Center in Jerusalem are evaluated with respect to the audience, the musicians, and the resulting music that was created.

Keywords: Orchestra, audience participation, multi-player game, light stick, video tracking, music, algorithmic composition, real-time notation.

1 Introduction

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, classical orchestral performance seems increasingly anachronistic. Audiences sit in a dark hall, looking at a conductor whose back is turned toward them, afraid to cough or sneeze lest they disturb their neighbors.

A feed-forward network (Figure 1) links composers, performers, and audiences, constraining the ways in which these three groups interact. The audience listens to the

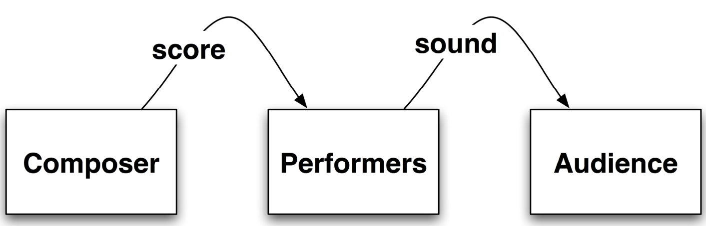

Fig. 1. Feed-forward network linking composer, performers, and audiences in orchestral music

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sounds created by the orchestra, which, together with the conductor, interprets the score written by the composer. But the interaction only moves in one direction. The audience must wait until the piece is over to respond with their applause; during the performance, they have little interaction with the musicians, the composer, or each other. They are spectators rather than participants.

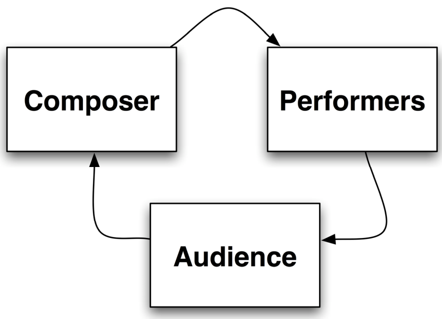

Fig. 2. Feedback loop linking composer, performers, and audiences in interactive performance environments

With *Glimmer*, my recent composition for chamber orchestra, I wanted to transform the usual feed-forward loop linking composer, performers, and audience into a feedback loop that facilitates interaction among these groups during each performance (Figure 2). The audience members become musical collaborators who do not just listen to the performance but also actively shape it. Each person is given a battery-operated light stick that he or she uses over the course of the piece to influence the music. Computer software analyzes live video of the audience and sends instructions to the orchestra via multi-colored lights mounted on each player's stand; there is no conductor. With this design, I wanted to create new connections among composers, performers, and listeners in order to construct a collaborative, shared musical experience, to emphasize the uniqueness and excitement of every live performance, and to encourage audiences to discover their own creativity and to have fun.

2 Background

2.1 Large Audience Participatory Music

Glimmer follows in the tradition of musical works that facilitate real-time participation by a large audience during their performance. In many such works, audience members become performers, creating some or even all of the music. For example, in Jean Hasse's *Moths* (1986), the audience whistles as directed by a conductor and a graphical score to perform the piece [1]. During *La symphonie du millénaire* (2000), an outdoor performance event in Montreal, 2000 audience members rang handheld bells at designated times [2]. And many Fluxus scores specify or imply more open-ended audience participation, as with Tomas Schmit's *Sanitas No. 35* (1962): "Blank sheets are handed to the audience without any explanations. 5 minutes waiting" [3].

In other works, technology involves a live concert audience in new ways while retaining its passive role. Golan Levin's *DialTones: A Telesymphony* (2001) creates music by triggering audience mobile phones to play pre-composed ringtones [4]. And the Concert Companion provides real-time program notes about orchestral repertory via wireless PDAs [5].

A final category of projects invites the audience to contribute input that affects the musical performance, rather than creating sounds that are part of the performance. In Kevin Baird's *No Clergy* [6], computer software stochastically generates successive pages of music notation for each performer in the chamber ensemble, while audience members use laptop computers to access a web interface and vote on parameter values that control the algorithm. McAllister et al [7] developed a performance environment in which individual audience members draw notation on a PDA's touch screen for the musicians to play. And Wulfson, Barrett, and Winter [8] created *LiveScore*, in which gallery visitors adjust knobs on physical controllers to adjust the parameters of a stochastic algorithm that generates music notation for each performer.

The works in this final category rely upon real-time notation systems to dynamically generate visual scores for musicians to read during each unique performance. Such systems provide a powerful tool for connecting musicians and audiences: audiences generate input that drives a software algorithm, and the algorithm generates real-time notation that directs the musicians' performance. Real-time notation systems are in turn indebted to algorithmic composition experiments by Hiller and Isaacson [9], Koenig [10], Cope [11], and others that generated music notation outside of real time. And they draw from the open-form composition structures in works of composers such as Earle Brown [12] and Karlheinz Stockhausen [13].

2.2 Multiplayer Games

Glimmer is also inspired by mass-audience games that use technology to enable large audiences in conventional theatrical spaces to participate without leaving their seats. In projects developed by Cinematrix, audience members hold up the red or green side of a paddle to collectively navigate objects on a video screen [14]. Other recent systems have used video tracking of audience members as they shift left and right in their seats [15] and motion tracking of giant weather balloons which circulate through the seating area [16] to facilitate similar types of interaction.

2.3 Audience Participation in *Glimmer*

In *Glimmer*, as in the real-time notation works and the gaming examples, audience activities influence the actions of the orchestral musicians on stage rather than directly creating the sounds of the piece. I chose this design framework in order to make the audience as comfortable in participating as possible; most were not musicians, and many did not know in advance that they would be contributing to the piece.

I also wanted to give the audience an opportunity to control more than the surface content of the work, not simply choosing from a menu of pre-conceived paths but rather influencing the work at a note-by-note level.

In addition, it was important that the system be conceptually simple. The realities of contemporary orchestral performance — limited rehearsal time, limited time to train the audience, and a contractual limit for the piece to be only ten minutes — made this a necessity.

Finally, as with Tomas Schmit's piece [3], I did not want to direct audience actions via any kind of pre-determined score or sequential instructions. Rather, I wanted to create an environment for them to explore and an opportunity for interesting group behaviors to emerge.

3 System Design

I designed *Glimmer* as a continuous interactive feedback loop that operates during each performance (Figure 3). Computer software analyzes video images of audience activity and transforms the analysis data into real-time notation for the musicians and into video animation for the audience. The musicians play music based on their notation. The audience reacts to the music they hear and the video they see, changing their activities to begin another iteration through the loop. There is no conductor.

In this work, technology is a means to facilitate collaboration, connecting the software algorithms to the audience through video analysis and to the musicians through real-time notation. The software itself translates audience input into notation, quickly performing analysis, decision-making, and communications tasks that would be impossible for humans to do as quickly. But orchestral musicians acoustically create all of the music; there is no electronic sound.

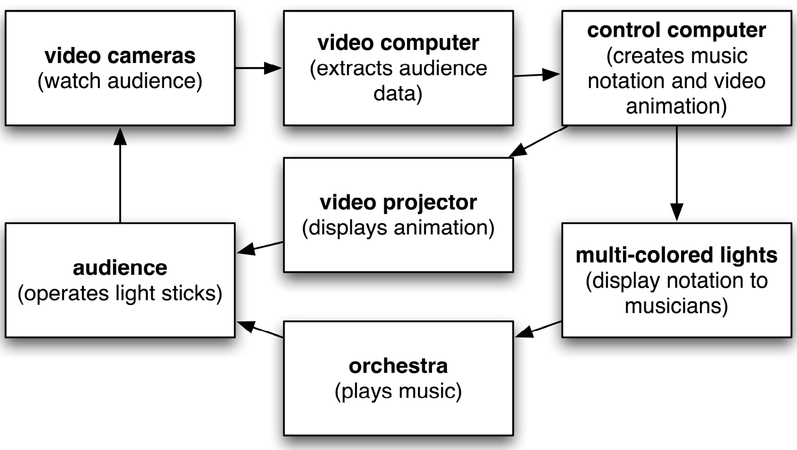

Fig. 3. *Glimmer's* interactive feedback loop

3.1 New York and Jerusalem Versions

The American Composers Orchestra commissioned *Glimmer* for a performance at Zankel Hall at Carnegie Hall in New York in January 2005. It was subsequently performed in March 2006 at the Hamabada Art Center in Jerusalem, Israel.

The original New York version called for a chamber orchestra of twenty-five musicians (strings, winds, brass, and percussion) and six hundred audience members.

Due to the smaller physical layout of the Hamabada Art Center, I revised the piece for the Jerusalem performance to accommodate a fifteen-player string orchestra and two hundred audience members. I also modified the video-tracking algorithm, based on informal audience feedback and analysis data collected in New York. I discuss these revisions and their implications in more detail below.

3.2 Audience Input and Video Analysis

Each audience member uses a four-inch long battery-operated LED light stick to participate in the performance. In the New York performance, the audience was instructed to switch their light sticks on and off; in Jerusalem, they were told to wave them back and forth (Figure 4).

The audience is divided into several groups: seven groups of 75 people each in New York, and five groups of 40 people each in Jerusalem. Each group controls a corresponding group of three or four musicians in the orchestra (e.g. first violins, second violins, violas).

Four consumer-grade video cameras capture images of the entire audience and forward them to a video computer for analysis. Computer software, written with Cycling '74's Max and Jitter, pre-processes each frame, performing color plane extraction, image masking, and threshold noise reduction.

In the New York version, the software then determines the percentage of audience members in each group whose light sticks are activated, performing image dilation and erosion to isolate blobs of adjacent non-black pixels, counting those blobs, and scaling the result by the total number of audience members in the group.

Fig. 4. A group of audience members at the Hamabada Art Center waves their light sticks back and forth to influence the music the orchestra plays

In the Jerusalem version, the software determines the total amount of motion of light sticks in each group, using a feedback filter to create momentary motion trails in the image when sticks are waved. The algorithm then calculates the total sum of all pixels in the frame and scales it based on the minimum and maximum sums found thus far.

In both versions, the resulting data for each group are forwarded over an Ethernet network via UDP to a second computer.

3.3 Data Mapping

On the second computer, software also written with Cycling '74's Max and Jitter translates incoming audience data into outgoing notation and video animation.

Direct Mapping. On a basic level, the light-stick activation percentage for a group controls the dynamic at which that group's musicians play. If everyone in a group turns on their light sticks (New York) or waves them as fast and wide as possible (Jerusalem), their group plays as loud as possible. If everyone has them turned off (New York) or motionless (Jerusalem), the group is silent. As the activation percentage increases, notes also move more quickly from one player in the group to the next.

Competitive Mapping. On a higher level, a comparative analysis evaluates the ability of each audience group to work together to create changes over time. The algorithm rewards groups whose data derivatives are higher: their musicians are more likely to play, they play at a higher dynamic, and they change pitches more often.

The software continuously ranks groups based on these derivatives and uses the rankings to determine which texture is assigned to each group at any time (see below). Groups that are ranked higher are also mapped onto a wider dynamic range in the direct mapping. And when a group jumps into the first-place position, its pitch or pitches change with an accented attack.

Textures. Throughout the piece, each group sustains single notes or clusters of notes that gradually crossfade from one musician to the next: one player *decrescendos* to *niente* while another player *crescendos* from *niente*.

The software defines several different variations on these textures (Figure 5) in which the number of simultaneous sustained notes, the total set of available pitches, and the speed of crossfading all vary. A lookup table maps group ranking to assigned texture.

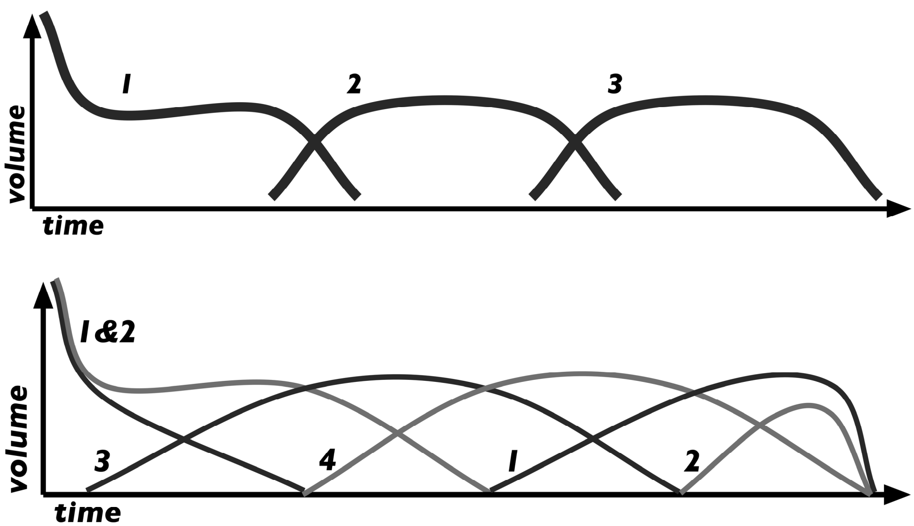

Fig. 5. Visual representations of two different textures used in the piece

Musical Structure. The ranking-to-texture lookup table changes over the course of the piece, giving the music a large-scale structural shape. Each individual change to the table is barely perceptible, so that on a local level, audience-driven events take perceptual precedence over pre-composed cues.

The large-scale arch form begins with just a single group playing a single note at a time, gradually becoming denser until all groups are playing clusters of notes chosen from a large, contiguous diatonic set. In the closing minutes of the piece the texture thins as groups are removed from the piece one by one based on their cumulative competitive rank. One "winning" group is left playing to close the performance.

The music itself is extremely simple, as sets of pitches and timbral combinations are constantly but gradually transformed; works such as John Cage's *Four*[2] for chorus [17] were influential. These simple textures help audience members to easily identify their own group within the orchestra.

3.4 Music Notation and Video Projection

The orchestral musicians do not read from conventional musical notation nor do they follow cues from a conductor. Instead, each player receives real-time instructions from the computer via a Color Kinetics iAccent multi-colored light (Figure 6), which sits on his or her music stand. Each light is controlled independently and changes color continuously.

Fig. 6. A musician at the Hamabada Art Center changes pitches and dynamics based on the color of the iAccent light

The color family of a musician's light — brown, green, blue, or pink — indicates which of four notated pitches to play (Figure 7). The brightness of the light indicates the dynamic at which to play. Short flashes of light prepare musicians for note changes and accents.

A simple video animation (Figure 8), projected onto a screen behind the orchestra, helps the audience more easily follow the relationship between their activities and the music they hear. Each audience group, represented by a rectangle, changes color based on the group's activation percentage and competitive rank, and the first-place group receives additional visual emphasis. As groups are removed from the music towards the end of the piece, their rectangles disappear.

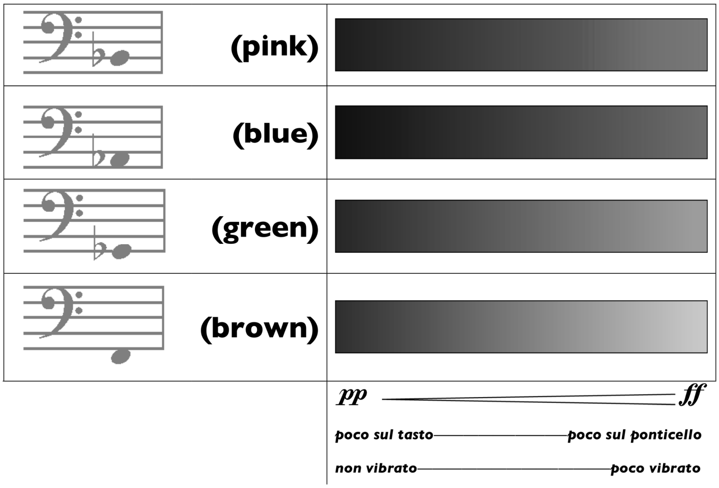

Fig. 7. Excerpt from the cello part mapping color family and brightness to pitch, dynamic, and timbre

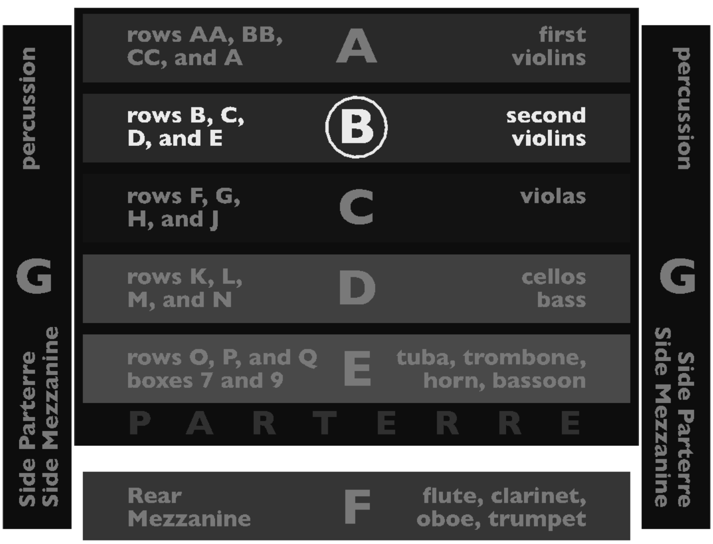

Fig. 8. Video animation projected to the audience visualizes analysis data and first-place ranking

3.5 Reliability within the Orchestral Environment

Decisions about the system design and its technical implementation were heavily influenced by the restrictions of contemporary orchestral performance environments: limited rehearsal time with the musicians, little advance access to the hall, a small budget, and the impossibility of rehearsing the piece with a full audience.

Given these constraints, system reliability was critical. Redundant backup computers ran in sync with the primary machines. Simulation and monitoring software helped to stress-test the system in the absence of a full audience or orchestra. And the system incorporated standard communication protocols and industrial-grade hardware instead of using custom-built components. The Color Kinetics iAccent lights, for instance, were water-resistant, virtually unbreakable, and certified for 100,000 hours of operation. And they responded to UDP messages sent over a standard Ethernet network. While *Glimmer* did not require all of these impressive specifications, these units were simple to integrate into the system, quick to set up on stage, and extremely reliable in performance.

4 Evaluation and Discussion

The American Composers Orchestra asked me to write a piece that used technology and was fun: in these respects, the premiere of *Glimmer* was a tremendous success. The audience enjoyed their role, gasping and laughing at moments of surprise and drama during the performance. They also spontaneously developed creative ways to participate, including a version of the stadium wave in which light sticks were dramatically raised and lowered to show and hide them from the camera's view. And the hardware and software performed nearly flawlessly. The largest problems were human rather than mechanical; for instance, one of the violinists was colorblind.

4.1 Audience Participation

In a successful performance of *Glimmer*, audience members should feel that they contributed something important to the music, and they should believe that the performance would have been different had they not been a part of it.

While some New York audience members did feel that way, recalling specific moments where they made a noticeable difference in the music and in other people's behaviors, others were frustrated that none of their actions seemed to matter. Since *Glimmer*'s algorithms respond to the activity of entire audience groups rather than of individual members, a large part of the problem lay in groups' inability to work together to influence the performance. When many group members switched their lights on and off quickly — but out of sync with their neighbors — their activities simply cancelled each other out. As a result, the on-off percentages of groups varied by a disappointingly small amount over the course of the performance.

Inspired by artificial life and cellular automata procedures, I had hoped that even in the absence of group leaders, interesting behavior would emerge over time. I designed the simple rules that governed the competitive aspect of the piece in order to encourage such behavior, but while the competition added an exciting dimension to the experience, it largely failed to accomplish its original goal. Data collected during the New York

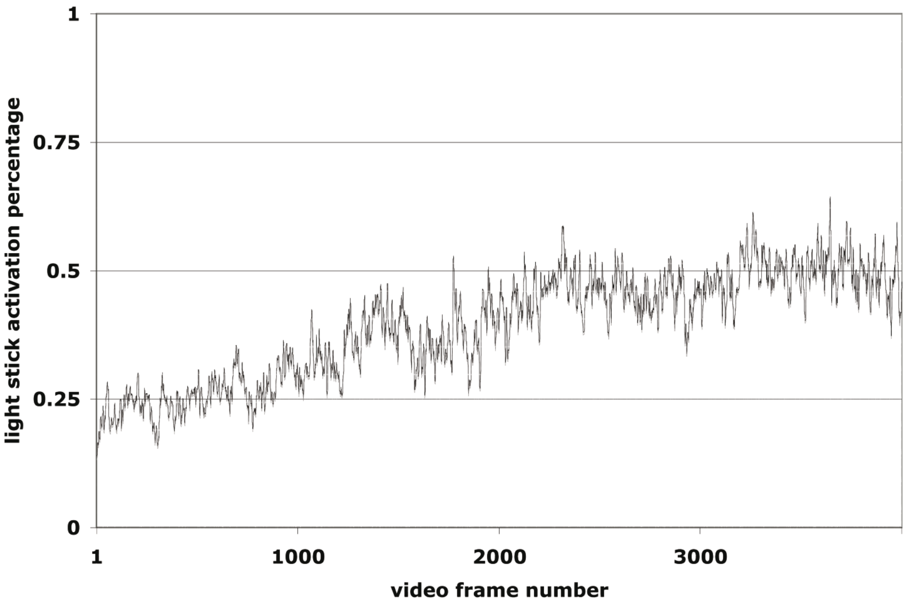

Fig. 9. Audience data collected from the winning group in New York (second violins)

performance (Figure 9) showed that even the most successful groups' activities were analyzed within a narrow portion of the zero-to-one data range and varied by relatively small amounts during the performance.

In informal discussions with audience members, I learned of several reasons why groups had failed to collaborate. Some people complained that the piece was too short for them to develop a group sensibility; they felt they would have done better had the piece been longer, or had it been performed a second time. Others had trouble seeing all the people in their group, so it was difficult to respond to what peers were doing.

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 helped them to communicate a wider range of information to each other — if not to the computer software — through their stick's position and speed, not just its on-off state.

So for the Jerusalem performance, I modified the video analysis software to analyze the amount of stick waving in each group instead of the on-off percentage, and I instructed the audience to participate accordingly. The data collected during this performance was consequently much more encouraging. In several of the groups, including the winning group, a group member spontaneously decided to stand up and direct the activities of his or her peers. This led to gradual, dramatic changes in audience data (Figure 10) as the group worked collectively to influence their musicians and compete against the other groups.

In addition to the change in light stick strategy, many other factors may have contributed to the improved group collaboration in Jerusalem. Each group had half as

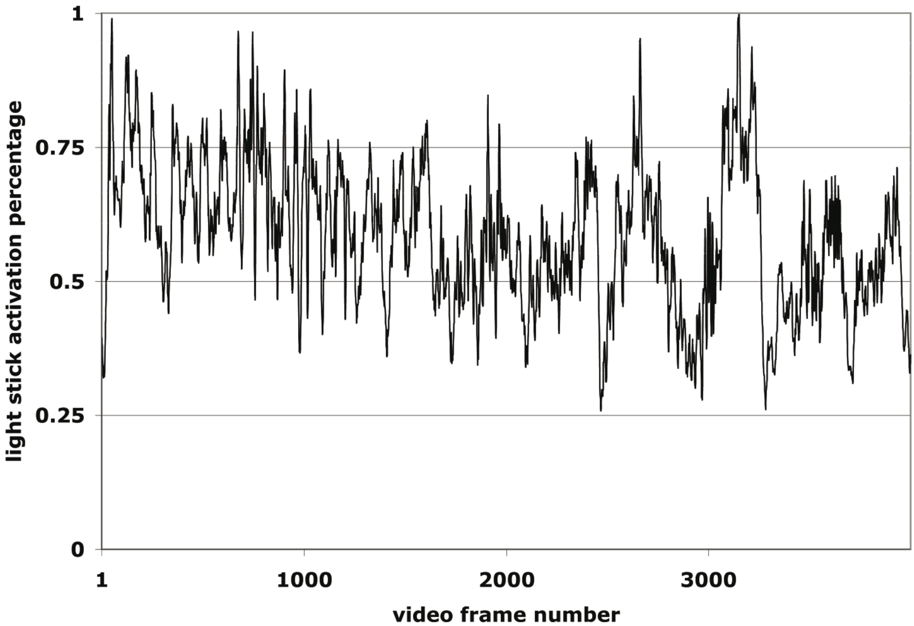

Fig. 10. Audience data collected from the winning group in Jerusalem (cellos)

many members as in New York, and each was seated in a nearly square configuration instead of a narrow rectangular configuration, making it easier for group members to see each other. And the New York performance took place in an established concert hall during an orchestral concert that was part of a subscription series, while the Jerusalem event was in a converted warehouse venue at a concert including classical music, free jazz, and hip-hop.

4.2 The Role of the Orchestra

In *Glimmer*, there is a fundamental inequality between the audience and the orchestra. The audience works within the framework defined by the piece but follows no score, while the orchestra reads its dynamic notation, exercising limited interpretive freedom.

While I was enticed by the idea of giving the orchestral musicians a greater interpretive role, it did not make practical sense in *Glimmer*. In both performances, it was challenging for the orchestral musicians to familiarize themselves with the lighting cues during the single, short rehearsal of the piece. And many of the classically-trained musicians would have been uncomfortable with broader interpretive freedoms or improvisation. Furthermore, the music is constructed so that perceptually salient local events always originate from audience activity. Were musicians to alter these events or add their own, it would be much more difficult for audience members to establish the relationship between the things they did and the music they heard.

4.3 The Musical Result

Stylistically, the music created at both performances of *Glimmer* is similar to my recent through-composed, non-interactive instrumental works: simple, slowly evolving textures, harmonies, and timbres. Yet *Glimmer*'s musical output, when divorced from the interactive environment that created it, is usually not as aesthetically satisfying to me as those other works. While the broad stylistic characteristics may be similar, the surface, moment-to-moment details are not.

In *Glimmer*, these details are determined not so much by the composer or the performers as by the audience members, who know nothing about the piece until moments before its performance. It was important to me to give this level of control to the audience, because I feared that their role would otherwise become superficial and banal. Yet under these circumstances, it would be absurd to expect those details to be controlled with the same degree of subtlety as in through-composed pieces. Opening up the creative process means giving up control, and lowering the barriers of training and commitment to enter that process usually leads to a more exciting process but less exciting results.

Earlier, I stated that *Glimmer*'s success hinged on the belief of audience members that their contributions mattered. For this to be true, the performance cannot proceed exactly as it did in my imagination (or in my software simulations). I should be surprised — sometimes for better and sometimes for worse — by the directions it takes.

While the music in both performances did conform to my broad expectations, there were many moments when the musical details took surprising turns. One passage in the New York performance (Figure 11) was particularly notable, because the subtle musical details combined as effectively as in any non-interactive music I have ever composed. The passage begins approximately eight minutes into the piece, when four, and then just three, groups remain. As the upper winds and brass exit the piece (Gb5 in Figure 11), the first violins leap up a perfect fourth to an Eb6 and the violas leap down an augmented fourth to Gb3. The second violins remain on Db5. The first violins soon move down a step from Eb6 to Db6, melodically resolving the leap, doubling the Db5 at the octave, and momentarily leaving a bare perfect fifth. The crossfade from Eb6 down to Db6 draws out the drama of this melodic and harmonic resolution; it almost sounds like a slow *glissando*. I could not myself have written this passage better, nor could the orchestra have played it better.

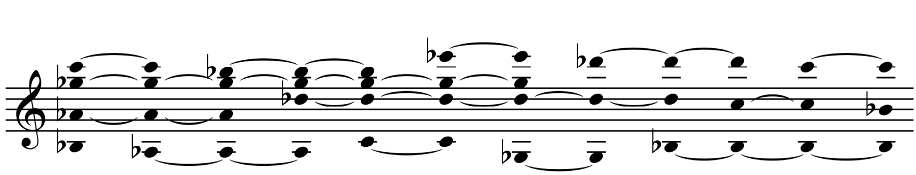

Fig. 11. Reduction of an excerpt of the New York performance

On one level, it is easy to understand how this moment transpired. There is no element of chance in the software; given the same sequence of inputs, it will always produce the same outputs. I can understand exactly how my own pre-composed cues combined with the competitive rankings of the audience to create this succession of events, even though I could not have predicted in advance what would take place then, or even which instruments would be playing.

But in truth, I have no idea why this moment transpired. I wish I could claim that audience members intended it to happen, but such a claim would be naïvely optimistic. Yet I am also reluctant to label it mere chance, because in my hundreds of tests and simulations, nothing similar ever happened. I developed the algorithms, and the audience provided the input, but still, some events were governed with a logic which none of us could control or even follow. Should I be disappointed that this moment did not arise from anyone's conscious, deliberate decisions? Should I be thankful for the serendipity of it and ask no further questions? Or should I be glad that the feedback loop — audience, algorithms, and performers — somehow gave rise to a logic all its own?

5 Conclusion and Future Work

Beyond the improvements made in the video analysis algorithms, light-stick techniques, and audience size at the Jerusalem performance, there are numerous additional incremental changes that could make *Glimmer* more successful, ranging from more informative visual feedback to more varied composition algorithms to a brief practice session for the audience. As other creators of large-scale interactive works have also found, convincing the audience that they have control and teaching them how to exercise it is a large part of the challenge [18].

And in a new work, *Flock*, I am exploring alternative paradigms that seek to address many of the issues raised by *Glimmer*. The work is for a smaller performing ensemble, saxophone quartet, which will be available for extended rehearsal time and is fluent in both classical techniques and improvisatory styles. The performances will take place in small venues limited to 100 audience members and will last a full evening, giving each audience member more influence over the music as well as more time to learn how to contribute. The notation will be displayed on wireless PDA screens rather than through colored lights, communicating information to musicians with text, graphics, and conventional music notation. I am collaborating with a visual artist on accompanying video animations that will be more informative and more aesthetically integrated into the work than with *Glimmer*. And we will solicit more formal feedback from audiences through post-performance discussions and written surveys, giving us more detailed information to consider when improving the work for subsequent performances.

But could any interactive work ever make every audience member 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, practice, or talent; and creating a unique, unified result that satisfies everyone. Works such as *Glimmer* reveal the impossibility of this goal even as they strive towards it. They invite participants to explore an environment, to discover its outer limits and its nonsensical corners, and to discover and express their own creativity as they push against the system's limits.

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The score, performance videos, and source code for *Glimmer* are available at http://www.jasonfreeman.net/glimmer/.

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