Who makes what sound? Supporting real-time musical improvisations of electroacoustic ensembles

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ABSTRACT

Coordination between ensembles of improvising electroacoustic musicians is a special case of the larger HCI problem of coordinating joint, real-time activity; one that involves some interesting additional and different challenges. This paper reports on research that has identified two specific real-time coordination problems for ensembles of electroacoustic musicians: "who makes what sound? " and "how is the sound being altered? " Real-time sound visualization is explored as a possible solution to assist musicians in overcoming some of these challenges. The main contribution of this paper is that, counterintuitively, for certain kinds of joint, real-time, coordination activities, temporal representations are important in helping to determine "who did what?"

Author Keywords

acousmatic dislocation, audio visualization, electroacoustic music

ACM Classification Keywords

H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Audio input/output; H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces—collaborative computing, synchronous interaction.

INTRODUCTION

A central problem for HCI is how to use computational representations to support different kinds of joint activity. Group-based electroacoustic music improvisation is a particular form of joint activity that has some specific, real-time characteristics that differ from many other kinds of joint activity. In electroacoustic music, musicians use computers to manipulate aspects of the sound experience: sound clips, samples, and voices are often sculpted prior to a performance and the musician generates the sounds (or even modifies them in real time) through pressing buttons or moving a mouse. One of the key interface problems is that, although there are limitless new sounds that can be generated, the ability to perceive cause and effect is diminished: the sound source is not always tied to the visual cues or the physicality of a material instrument. Couched in terms of traditional instruments and ensembles, the problem is that no longer does the sound of a violin correspond to the movement of a violin bow – and, given the possibilities of electroacoustic ensembles to jointly control the same instrument at the same time, it is not always clear (even to the person making the change) who is responsible for changes to the sound of the violin. This is described by Emmerson as the problem of acousmatic dislocation (Emmerson, 1994) and it poses a number of interesting challenges to musicians when they attempt to coordinate in rehearsals and performances.

This paper presents recent research to develop and evaluate computational visualization tools for group-based electroacoustic music improvisation..

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RELATED WORK

While there are relatively few examples of research specifically focused on tools for the coordination of improvisation between electronic musicians, there is relevant work that can provide some insights into the design of technology tools that can support this human activity. This includes research work that is focused on strategies and tools that help in the teaching process of musical skills as well as research into ensemble coordination.

In terms of the research regarding tools to help musicians learn skills, there is various research into technology-based tools to augment and provide visual feedback to the musicians learning an instrument or to control their voice. Researchers have studied the use of visual feedback through technology-based tools in music education, by providing analysis and visualization of various aspects of the music making activity. There have been attempts to use visualizations to aid people learning to control their voice when learning to speak (Shaw et al., 1996) and sing (Callaghan et al., 2004). Research suggests that visualizations can enable singers to quickly improve pitch accuracy and control over fluctuations with accurate real-time feedback such as waveforms (Welch et al., 1989) or simple visualizations requiring minimal cognitive effort such as highlighting the note equivalent on a virtual keyboard (Wilson et al., 2005). Researchers have proposed similar real-time feedback visualization strategies for learning control of instruments as well. These strategies include displaying waveforms to quickly learn how to make pure tones (Percival et al., 2007), augmented reality systems that teach correct body positioning while playing an instrument (Ng et al., 2007, Ng and Nesi, 2008), and abstract visualizations modulating the size and shape of a two dimensional shape to teach control of loudness and timing patterns (Sadakata et al., 2008).

In terms of the research into tools to help musicians or ensembles collaborate, there is work that looks at various strategies of coordination and timing. When musicians play together, the rehearsals and performances can become very complex whether the instruments are traditional or electronic (Blaine and Fels, 2003). Researchers have also studied challenges of synchronization and timing, which have traditionally been dealt with by negotiating visual cues beforehand to be used later in the performance (Ginsborg et al., 2006, Rasch, 2001, Luck and Toiviainen, 2006). Studies on visualizations in the context of laptop orchestras have proposed onscreen tools to help the musicians and conductors understand the contributions of each musician and the coordination of the music (Smallwood et al., 2008, Trueman, 2007). Researchers have also suggested that visualization tools can improve the creative process and foster mutual engagement (Kinns et al., 2007). There is also research into collaborative bridging tools that enable diverse systems and musicians to collaborate in the ensemble computer music context (Wyse and Mitani, 2009).

The focus on real-time visualizations as an aid to real-time joint activity is a problem that extends beyond the context of musical performances and into the wider realm of collaborative work. Researchers have proposed that visual information is most useful when it is as close to real-time as possible, more effectively supporting situational awareness, and by grounding communication in the collaborative activity, whether that activity involves a medical team in a surgical environment or users collaborating in a virtual space (Gergle, 2006).

RESEARCH PROBLEM

Although there has been much research focused on visualizations that support coordination between musicians working together in ensemble performances and improvement of their skills individually with their instrument, there does not seem to be any research on how visualizations can enable an ensemble to identify specific sonic contributions of each musician during the creative process of improvisation. The remainder of this paper examines this context of real-time joint activity in the creative context including the researchers attempts to provide a technology-based tool to aid the users in their efforts.

METHOD

This process began with observation of live public performances of musicians performing electroacoustic improvisation in order to gain a sense of the type of performances that are typical and to see the musicians using their instruments and other tools in their current practice. Contextual interviews were conducted with the musicians to gather needs and desires for possible visualization tools. The first prototypes were built and presented to the musicians in follow up interviews to gain initial impressions and opinions to guide future refinements. The prototypes were then modified accordingly and evaluated over a period of one week with a final interview to understand the issues encountered. The remainder of this section elaborates this process in more detail.

Understanding the Visualization Needs

The researchers attended three live public performances by two groups, which consisted of three musicians who each have years of experience together playing in public performances. In-person group interviews were conducted with the musicians in order to explore the issues and challenges of collaboration and improvisation in electroacoustic music, as well as to explore possible design ideas for prototype tools that could help in the creative process.

Participants

The musicians were continuously involved throughout this process of design-oriented research, including the observation of live performances, contextual interviews to assess needs, the evaluation of an initial prototype leading to further refinements, and finally, the evaluation of the final prototype in a rehearsal context.

There were two musical groups, for a total of six musicians involved in the study. Each group varied in the tools and techniques used in their improvisation performances. The following summarizes the level of experience and techniques used:

Group A Three musicians, each with over 15 years of experience making electroacoustic music individually and have been playing as a group for two years. They are accomplished musicians of traditional genres of music including jazz, classical, and Asian folk music among others. On the group's website, they describe themselves as, "an ensemble specializing in improvised music, electroacoustics, and realizations of experimental music." They use a combination of physical objects as instruments as well as computer based instruments and sound tools.

Group B Also comprised of three musicians, each with over 15 years of experience with electroacoustic improvisation and have been playing together for two years. They are accomplished musicians coming from traditional music genres including classical, jazz, and electronic music. They use a combination of traditional instruments played in non-traditional ways as well as computer based instruments and sound tools. They use projected visualizations created by one member of the band prior to the show to accompany their audio performances.

INTERVIEWS

The contextual interviews each took place in the practice space or recording studios of the respective bands with the musical instruments available for examination and discussion. One member from Group A was interviewed separately from the group due to travel commitments, however, summaries of the interviews of this group were shared with all members and approved by them. The contextual interviews were conducted in order to: 1) understand more about electronic music in general 2) understand the creative process and coordination issues amongst musicians 3) gain a sense of the issues, which might benefit from visualization techniques to assist the coordination of the members.

Results of Needs Assessment

The most pressing needs expressed by the musicians related to the rehearsal and jam session context when the control of the instrument is retained by the individual as well as when the instrument is shared among multiple musicians. The musicians said that at various times during these sessions, there has occasionally been confusion over which musician made which sound individually and how each musician alters the sounds of the others. This confusion led to a break in the flow of the session and a challenge in recreating the best sounds while avoiding the sounds that are undesirable. Limited visibility between the musicians was also described as a challenge that is faced in the performance context. The three main issues that came out of the needs assessment included the challenge of knowing who makes what sound, understanding how the sound is being altered, and the challenge of coordinating actions. The remainder of the research presented here focuses on the first two issues.

The musicians in Group A described their impression of improvisation of electroacoustic music as something akin to creating rules to a new game each time the game is played. They described how there is no right or wrong way to collaborate and perform, but that there is a perceivable quality that comes with proficiency and well-coordinated performances. They explained that their creative process entails weekly jam sessions in which they explore and share new sounds with each other and as the performance day approaches, they begin to rehearse with more focus. When it comes to the performance itself, they usually have agreed-upon sections to the songs which can last between a few seconds or minutes. The musicians proceed through these together and through visual cues, such as nods or hand gestures. It became clear that the musicians were comfortable with their creative process of rehearsals that lead to loosely structured performances. However, the two main themes that emerged regarding the real time creative process of exploring sounds in the jam sessions and rehearsals was the confusion over who made which sound and a need for a transparent understanding of how the sound is being altered by each musician. These needs became the main focus of the prototypes reported here.

Group B described their process as more completely improvisation with little if any planning of the sections, transitions, or timing – except that they felt that there was an unwritten rule that around 20 minutes or less is a good length for a piece. For this group, the rehearsal sessions are used to become familiar with the style of each other and to experiment with sounds. The public performances are very similar to the rehearsal sessions and they involve the musicians involved in a dialogue and a finely tuned sense of what the other members will play and how they will react. This was described as something that comes with time and experience in playing together and it involves careful listening and learning about the others in the group.

Who makes what sound?

One of the strongest themes to emerge from the interviews was the communication challenge faced when the musicians are playing music together in a rehearsal or in a "jam session", exploring the new sounds and ideas and trying to determine which new sounds could be used in a performance. In this situation, the musicians are together in the same room and the sound of each musician is played through the same speakers. This makes it difficult to know who made what sound in some cases. The musicians in both groups have been reluctant to use headphones or monitor speakers because this segmentation of the sound would alter the sound texture or possibly diminish the effect that each musician could have on the overall soundscape. If the musicians were able to know who is generating which sound, it would help them to be able to recreate the sounds that they have heard and found desirable and to reduce the time it takes to hone in on the interesting combinations. The musicians have described the process of finding new combinations of sounds as "happy accidents" which are recognized by the group during the rehearsal and usually the musicians have to stop and ask each other who made which sound. The musicians in Group A explained that although this might cause a temporary break in the flow, it might actually be part of what makes playing together fun. Group B described their rehearsals as the time and place where they can all do the kind of experimentation it takes to learn which sounds each person is making. They explained that this familiarity with the other band members helps when trying to understand from who the sound is originating.

How is the sound being altered?

Both groups mentioned that they sometimes face challenges in understanding their influence over the sound when the control of the instrument is spread over multiple musicians. In this case, sound signals start from the actions of one musician, which are fed into the computer of another musician. The second musician alters the sounds and then sends the resulting sound to the speakers so that it can be heard. The musicians proposed that it would be helpful for the second musician (possibly both) to be able to see what transformation is in fact being made on the first musician's sound events. A visualization of this transformation could reduce the time it takes to understand how a sound is being made and it also brings a sense of transparency between the musicians that can facilitate more meaningful conversations when the group tries to hone in and improve a sound or progression of sounds.

PROTOTYPES

According to the participants, the most pressing issues they confronted had to do with the rehearsal context – specifically, the problems of "who makes what sound? " and "how is the sound being altered? ". A decision was made to concentrate on designing a prototype that would make the contributions of each musician visible in order to increase the transparency of the sound generation of the group by showing three aspects of the sound in real time. With electroacoustic musicians, their instruments are predominantly made up of complex audio software screens and input devices such as configurable grids of buttons, etc. Instead of trying to provide all of the detailed information from each musician, the research aim was to provide a general tool that could be useful for visualizing any sound signal without having to understand the intricate settings of each musician. The visualization included the waveform of the left and right channel showing the overall volume of the individual musician as shown in Figure 1a) & c), a spectrograph showing the amplitude along the range of audible frequencies as shown in Figure 1d), and a historical graph showing the most dominant frequency as shown in Figure 1b).

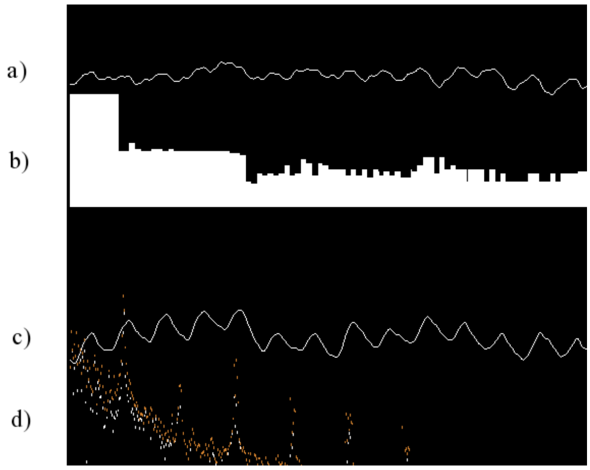

Figure 1: Screenshot of the initial prototype including the a) left waveform b) dominant frequency historical graph c) right waveform and d) combined spectrograph.

The visualization would serve, in a sense, as headphones or monitor speakers, which are used to provide an audio feed that is significantly different than the sound that is delivered to the audience. This technique is effective in many situations, such as, a singer using monitor speakers allowing them to hear their own voice more clearly and de-emphasize the drums so that they can make adjustments to their voice as needed. A musician in Group A explained that in an ensemble setting, the monitors would not help them because the individual contributions usually do not stand alone and they have to be able to hear the sound that the audience would hear in order to make adjustments and to hear the results right away. The musicians identified situations in which they would need the visualization including identifying who was making a loud sound, who was making a high pitched sound, and who is making a repetitive sound. The researchers translated these into the simplest terms of volume, pitch, and time, which were then designed into the prototype features as the waveform, spectrograph, and dominant frequency graph respectively. The aim was to represent those sound events in a way that could be easily noted by the musician by glancing at the visualization.

This prototype could be used in any context; however, for the research reported here, the focus on jam sessions/rehearsals was selected. In this context, the musician is playing in a group with full control over the sound they produce and in a group with shared control over the sound. In both situations, the musician essentially wants to understand what their individual contribution to the overall sound is at any time. One instance of the prototype is run for each output from a musician on a separate screen, for a total of three screens for each group. These screens are then positioned on one side of the rehearsal space in clear view of all the musicians and each prototype instance is assigned to visualize the sounds coming from one musician relative to their position in the room.

Responses to Initial Prototype

The musicians interacted with the prototype, answered questions in a contextual interview, and provided their opinions and ideas about how the tool could be incorporated into their ensemble as well as issues that impact the readability of the screen and usability issues. The interaction with the prototype also stimulated discussion and ideas for new features in future prototypes.

The importance of the temporal issue in music improvisation was found to require a visualization that provided historical as well as real-time information to enable the musician to compare the past with the present. Our attempt to provide that with the dominant history graph did not satisfy the musicians, however, by showing this type of history, they were able to provide detailed guidance for the designers to incorporate the historical display feature in the waveform discussed in more detail in the Discussion section of this paper.

The musicians explained that the visualization was not easy to read and would be difficult to quickly understand what it was showing. Suggestions for refinement to the waveform included repositioning the left and right waveforms to be closer together so that the eye could easily follow both channels as well as showing more history to enable the musician to reflect on the sounds that were just created, but would not require intense concentration on the real-time waveform as is currently necessary. One musician in Group A suggested that it would be good to have some sort of control lever to adjust the amount of history. Refinements to the spectrograph suggested by the musicians included calibration of the X-axis showing the frequencies to more easily identify the notes.

Refined Prototype

Based on the input from the interviews and user responses to the initial prototype, the final prototype was designed, again focusing on the context of jam sessions/ rehearsals providing a visualization tool to help the musician understand the individual contributions to the overall sound being heard. From the evaluation of the initial prototype, it was understood from the musicians that the visualization would be easier to read and understand with some simple changes to the layout and by making the visualizations user-adjustable.

The revised prototype includes the waveform of the left and right channels as shown in Figure 2c) & d) with adjustable history via the slider shown in Figure 2a) and a spectrograph as shown in Figure 2b) that is labeled with frequency marks and with adjustable scale via the slider shown in Figure 2a). The dominant frequency historical graph was removed. The key features of the prototype are now described including the waveform and spectrograph visualization features.

The key features in the refined prototype include an adjustable waveform history, a spectrograph with frequency calibration and adjustable scale, and the ability to toggle between showing and hiding the visualization features.

As in the initial prototype, the waveform starts on the left of the screen and scrolls to the right, however, in the initial prototype, there was only ten milliseconds of history shown at one time. Since the musicians envisioned the visualization as a tool that could be glanced at occasionally, or when they wanted to confirm visually what they were hearing, the amount of history visible needed to be much longer. In the refined prototype, the amount of history visible is adjustable from ten milliseconds to a maximum of seven seconds. The user can position the slider anywhere within the range as desired balancing the amount of visible history with the granularity of detail in the waveform.

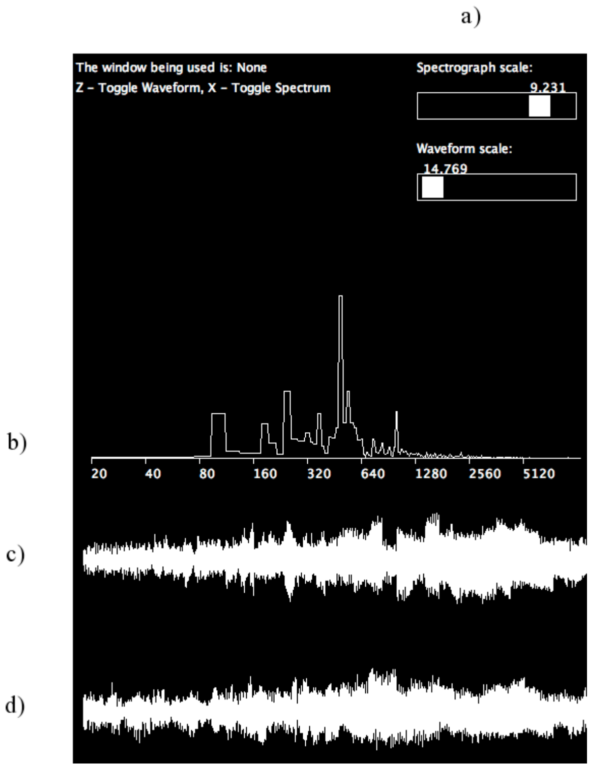

Figure 2: Screenshot of the refined prototype including a) sliders to adjust the scale of the spectrograph and historical scale of the waveforms b) spectrograph with calibration marks indicating frequency c) left waveform d) right waveform

The refinements to the spectrograph addressed the issues of readability identified in the initial prototype evaluation. The user responses suggested that the spectrograph should be calibrated to better understand the frequencies and the scale should be adjusted to focus on the sounds being generated. The horizontal axis was labeled with the frequencies and the scale along this axis was changed to be user adjustable with a slider allowing the focus to show the full audible spectrum or zoom in on the midrange frequencies.

Aside from these substantial changes, there were smaller changes made, which aimed to improve the usefulness of the tool. The spectrograph and the waveform were previously always visible. A toggle feature was added in which the spectrograph and the waveform could be individually shown or hidden by pressing a keyboard button. In addition, the historical graph showing the dominant frequency was removed because the evaluation of the initial prototype suggested that it was a distraction and provided little useful information.

Refined Prototype Evaluation

The refined prototype was evaluated by both groups through individual usage followed by contextual interviews with the researchers. The musicians found the refined prototype useful because it helped them to recreate good sounds and avoid undesirable sounds by quickly glancing at the simple visualization. Although there was initially much resistance by the musicians to acknowledge that there was even a need for sound visualization, once they began to see the usefulness and potential to assist them in exploring new sounds, the musicians expressed support with very positive evaluations. The musicians appreciated that the prototype provided a visualization that was useful on various levels including a summary of the sound that was easily understood in a quick glance, precisely detailed information that helped in pinpointing subtle aspects of sounds, as well as a tool to help in executing new maneuvers, such as coordinating musicians to converge on specific frequencies. As the design exercise proceeded, surprising temporal issues were uncovered which helped the researchers understand why existing tools (level meters, overload indicator lights, etc) have not met the need of musicians.

The findings and implications of the study are now discussed including how the visualization was used by the musicians in rehearsal context and their creative practice, issues of usability, new features and ideas for future prototypes, challenges faced by the researchers, limitations of the research, and comments about future work.

Sound Visualization and the Creative Practice

The prototype addressed the needs of the musicians attempting to understand who makes which sound, how the sound is being altered, and helping in the introduction of new instruments and musicians to the ensemble.

Who Makes What Sound?

In the context of an ensemble of musicians who are all making sounds at the same time, there are occasionally "happy accidents," or very desirable sounds that the musicians would like to be able to recreate. One of the key characteristics of the final prototype is that it took into account the importance of temporal changes in order to help them identify "who makes what sound."

In developing the prototypes, it was noted by the researchers that the level meter that is usually built into amplifiers or mixing boards provides some visual indication of the sound. When asked whether or not the musicians used them, they indicated that they did so in only two situations, including: 1) When setting up the equipment before the rehearsal, they set the levels of the output from their instrument so that it does not overdrive the amplifier, and 2) the use of a level indicator in the form of the overload indicator light on the studio speakers, which flashes to indicate that the output levels are set too high and clipping might be occurring, which is a situation whereas the amplifier is unable to keep up with the demands of the input and introduces distortion to the sound that is produced.

The researchers recognized that a visualization tool similar to a level meter could be useful, and thus a waveform component was incorporated in the initial prototype. It was puzzling that the musicians did not just use an existing level meter. Aside from making it cumbersome for the musician to keep constant focus on a small indicator and various other reasons, the researchers realized that the temporal dimension is a very important factor because of the activity, musicians are busy listening, physically interacting with their instrument, planning their next action, anticipating the next action from the other musicians, and keeping in mind the overall timeline of the performance. When a musician wants to know who makes what sound, there are precious moments that pass as she refocuses attention between the various activities and cognitive processes, therefore a visualization should be forgiving in the sense that it should not demand attention and should provide information within a short time of the sound event to allow the musician to compare what happened a few moments ago with what is happening at the present time. Most level meters show the level at the present moment in time and do not display the history of the level. Some level meters do, however, add the physical characteristic of a slow needle so that when trailing off of a peak in the sound, the needle drifts slowly back down. With our first prototype, there was an attempt to address this issue by displaying the dominant frequency with a rolling history, but this was found to be difficult to read and not entirely useful as it merely provided an indication of the loudest frequency and did not indicate how loud that frequency was. Nor was it intuitive for the musician to understand what the precise frequency was being indicated. In the refined prototype this issue was addressed by including a rolling history into the waveform.

In using the prototype, the musicians confirmed that with the historical tracking of the waveform, there are more chances that when a chance event occurs they are equipped with the information about who projected each aspect of the sound. Therefore, interesting sounds could be more easily recreated and the other sounds could be avoided without causing any significant break in the flow of the rehearsal session.

How is the Sound Being Altered?

When the control of an instrument is shared between more than one musician, there can be confusion over who is responsible for which changes in the sound. By allowing all of the musicians to view visualizations for all other musicians, they can more clearly understand how the sounds are altered as the signals move from the originating musician through the modifications imposed by each musician along the way to the resulting sound that is heard. A musician in Group A explained that this brings transparency to the ways sounds are generated and subsequently, more fruitful discussions can take place among the musicians. He explained that the musicians can more quickly identify why certain sounds are good or bad and adjust accordingly, or at least engage in quick discussions to negotiate and build interesting sounds.

New Musicians, Instruments, and Techniques

When playing with new instruments or when a new musician joins a group, there is a process of learning, adjustment, and experimentation that takes place in order to perform cohesively and with control over the sounds being made. The musicians explained how the visualization prototype could help with this process by showing the range and dynamic of the musicians and by providing detailed information about the sounds being made by the instrument. With the information provided by the visualization, new techniques of precise musical events become possible.

It takes a considerable amount of time for musicians to become familiar with each other and to predict and feel comfortable with the actions of new musicians in an ensemble. A similar learning period is needed when a new instrument is brought into the group. One of the musicians explained that the visualization tool helps the musician to prepare and become more proficient and knowledgeable about his own instrument and sounds, so that when later playing with the ensemble, he would be able to respond to other musicians appropriately and with confidence over a wider range of musical events. Another musician noted that the waveform component of the visualization helped him to know when he was "clipping," or making sounds that exceed the tolerable volume for the speakers or mixer.

Learning the style, range, and dynamic of a new musician who is playing with the group was described to us as a process that takes time in practice. A musician in Group A claimed that the prototype made it visible and clear how the others are playing in comparison to how they are playing. He gave an example of how it can show that one musician is playing at a moderate volume on the high and low ends of the spectrum and that could help to confirm what he is hearing, but it would also enable him to make a decision about how to respond musically. He could then play sounds as an accompaniment in the same range or choose to venture outside of the range. The other musicians agreed that this use of the visualization would likely help when a new band member joins the group, possibly shortening the time it takes to get familiar with the unique style of the new musician.

By providing a very precise visualization of the waveform and spectrograph, the musicians said that the prototype enabled them to do things as a group that they could not do before. One example given was that the group could plan for events in their improvisation in which they would all meet at a particular note or key. One of the musicians who described this technique suggested that the prototype be called "Musical GPS" because it maps the musical space and enables understanding each other and meeting up in precise ways. This use of a spatial metaphor is interesting in this context, suggesting that performers themselves may not realize the significance of the temporal representation in supporting the determination of "who makes what sound".

Challenges

There were a number of challenges faced in this research effort including technical challenges of providing a prototype that would work with any tools used by the musicians, as well as the healthy skepticism and the initial reluctance from the musicians on the need and usefulness of visualizations. These are now described in more detail.

Handling inputs from any instrument

Designing a visualization tool that can handle inputs from any instrument or software constrained the prototype building efforts. Nearly all the musicians use a combination of software tools that is unique. In order for one musician to understand what is happening on another group member's instrument, they must know the screens, equipment and settings intimately. A visualization that represented all of the settings or unique components of each instrument would have been too time consuming to build and would likely be too difficult for the musician to understand and use in the fast pace situation of improvisation performance. It became apparent that processing the raw output from each musician was the most effective way to proceed. Integration of the instruments digitally is something the musicians would like to explore, yet this will require some software integration of each tool, or the use of bridging tools as mentioned in (Wyse and Mitani, 2009).

Separating the prototype from the instrument

The challenge of accepting inputs from any instrument was previously mentioned, but there was also the challenge of creating the prototype in such a way that it would visualize the sound, yet not impede the computers creating the sound. The musicians who were studied and many others who were observed use specialized sound processing cards attached to the computer with a combination of sound processing software that can effectively route various inputs and outputs locally and also to other computers. In some initial tests, it was found that running a visualization tool on the same computer posed challenges in terms of the performance of the system, but also made it necessary to change and complicate the settings within the sound software. It became apparent that the prototype would serve best as a separate system receiving a signal from the musicians' computers using a splitter to ensure that its impact to the existing setup was minimal and would not impact performance of the instrument computers.

Resistance to visualizations

There was a general reluctance on the part of the musicians relating to the topic of visualizations for understanding the music-making process early in the study. The musicians either claimed to be able to hear well enough to discern who makes which sound. In practice, however, it was noticed that each group utilized visual cues from their computers to orient themselves or to confirm what they thought they were hearing. One simple example of this was with Group B in their recording studio, which is outfitted with the latest sound equipment including studio monitor speakers with an overload light, which they would glance at occasionally while making music to ensure they were hearing the true sound without clipping. Another behavior that was observed with both groups is that when they select a new sample or assign a new sound to play, they watch the levels of the sound output. These examples showed that the musicians were accustomed to using visual and aural cues when exploring and playing their music even if they were reluctant at first to the idea of using a new sound visualization tool in their rehearsals.

Limitations of the Study

This research had three main limitations that are worthy of discussion including: 1) a relatively small sample size of musicians 2) the length of the study was a short amount of time 3) the focus of the study was on the rehearsal context and did not explore the performance setting.

The size of the group was large enough to uncover various issues of multiple musicians working together through technology, overcoming coordination and collaboration issues in the creative process. Although the groups had different ways of approaching electroacoustic improvisation, there are likely groups that have other approaches and styles. Including more users in future evaluations and refinements would likely make the tool more robust and useful for more musicians. The length of time over which the study took place was sufficient for the musicians to provide input for the design of the initial prototype and refinements and to become familiar with the visualization and in large part overcome the novelty factor. However, the prototype is still a new component among their tools for creating music as a group and new insights would likely be gained as the musicians appropriate the prototypes over a longer period of time. The musicians did not evaluate the prototypes in public performances for this research. The context of the live performance would certainly add additional pressure and demands on the musicians.

CONCLUSION

The researchers set out with the goal of exploring issues encountered by musicians who engage in electroacoustic improvisation ensembles and to make attempts to address those issues. A sound visualization prototype was developed, refined through involvement of the expert users, and insights were provided in the discussion as to how the prototype was in fact useful to the musicians especially providing support for determining "who did what? " This research informs on the larger HCI problem of joint real-time coordination activities by demonstrating that visual representations, both temporal and real-time can be key to empowering the user to grasp what each user is contributing. While much previous work has focused on ensuring that shared visual information is detailed, up-to-date, and near real-time, we have provided evidence that users in some complex, dynamic collaborative activities also benefit from visual information that serves as a more durable and lasting record. Providing a rolling history of the musical performance alongside the real-time sound visualization empowered the musicians to understand the current, transient state by making available sound event information from the recent past.

In terms of future work, it will be important to explore in more depth the issue of "how to coordinate actions? " – and to develop and evaluate possible solutions for them. However, the research reported here raises a larger question about the coordination needs of electroacoustic ensembles. Although there is currently a great deal of discussion in the laptop orchestra community about the problem of coordination, the participating musicians actually suggested during the detailed interviews that the coordination problems were fewer and less significant than the literature suggests; it is unclear whether this is actually the case or whether musicians who have worked together extensively as an ensemble have "forgotten" (or can no longer recognize) the coordination problems that exist. This is clearly an important issue for further investigation.

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REFERENCES

Blaine, T. and Fels, S. Contexts of collaborative musical experiences. In Proc. NIME 2003, (2003), 129–134.

Callaghan, J., Thorpe, W., and van Doorn, J. The science of singing and seeing. In Proc. of the Conference of Interdisciplinary Musicology, (2004).

Emmerson, S. 'live' versus 'real-time'. Contemporary Music Review, 10, 2 (1994), 95–101.

Gergle, D., Kraut, R. E., and Fussell, S. R. The impact of delayed visual feedback on collaborative performance. In Proc. of CHI 2006, ACM Press (2006), 1303-1312.

Ginsborg, J., Chaffin, R., and Nicholson, G. Shared performance cues in singing and conducting: a content analysis of talk during practice. Psychology of Music, 34, 2 (2006), 167–194.

Kinns, N. B., Healey, P. G. T., and Leach, J. Exploring mutual engagement in creative collaborations. In Proc. C&C 2007, ACM Press (2007), 223–232.

Luck, G. and Toiviainen, P. Ensemble musicians' synchronization with conductors' gestures: An automated feature-extraction analysis. Music Perception, 24, 2 (2006), 189–200.

Ng, K. and Nesi, P. i-maestro: Technology-enhanced learning and teaching for music. In Proc. NIME 2008, (2008), 4–8.

Ng, K. C., Weyde, T., Larkin, O., Neubarth, K., Koerselman, T., and Ong, B. 3d augmented mirror: a multimodal interface for string instrument learning and teaching with gesture support. In Proc. ICMI 2007, ACM Press (2007), 339–345.

Percival, G., Wang, Y., and Tzanetakis, G. Effective use of multimedia for computer-assisted musical instrument tutoring. In Proc. EMME 2007, ACM Press (2007), 67–76.

Rasch, R. Timing and synchronization in ensemble performance. In Sloboda, J., editor, Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition. Oxford University Press, USA (2001).

Sadakata, M., Hoppe, D., Brandmeyer, A., Timmers, R., and Desain, P. Real-time visual feedback for learning to perform short rhythms with expressive variations in timing and loudness. Journal of New Music Research, 37, 3 (2008), 207–220.

Shaw, R., Laplante, P. A., Salinas, J., and Riccone, R. A multimedia speech learning system for the hearing impaired. Multimedia Tools and Applications, 3, 1 (1996), 55–70.

Smallwood, S., Trueman, D., Cook, P. R., and Wang, G. Composing for laptop orchestra. Computer Music Journal, 32, 1 (2008), 9–25.

Trueman, D. Why a laptop orchestra? Organised Sound, 12, 02 (2007), 171–179.

Welch, G. F., Howard, D. M., and Rush, C. Real-time visual feedback in the development of vocal pitch accuracy in singing. Psychology of Music, 17, 2 (1989), 146–157.

Wilson, P. H., Thorpe, C. W., and Callaghan, J. Looking at singing: Does real-time visual feedback improve the way we learn to sing? In Proc. APSCOM 2005, (2005)

Wyse, L. and Mitani, N. Bridges for networked musical ensembles. In Proc. ICMC 2009, (2009).