PESI Extended System: In Space, On Body, with 3 Musicians

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ABSTRACT

This paper introduces a novel collaborative environment in which performers are not only free to move and interact with each other but where their social interactions contribute to the sonic outcome. The PESI system is designed for co-located collaboration and provides embodied and spatial opportunities for musical exploration. To evaluate the system with skilled musicians, a user-test jam session was conducted. Musicians' comments indicate that the system facilitates group interaction finely to bring up further intentions to musical ideas. PESI can shift the collaborative music activity to a more engaging and active experience.

Keywords

Affordances, collaboration, social interaction, mobile music, extended system, NIME

1. INTRODUCTION

The affordances of digital technologies give us ways to look at interaction paradigms that challenge and explore collaborative art practices. Social aspects of emerging technologies have already spread new ideas for social musical experiences, in particular for co-located and remote collaboration in the NIME community [19, 4, 14]. However, further design and implementation of collaborative interfaces for bodily interactions that catalyze social interactions in group music experience, along with systems for identifying these interactions, is needed. A novel collaborative system that is capable of offering solutions for exploration of social actions in group music activity could open up supporting collaborative and creative activities in music practices.

This paper presents *The Notion of Participative and Enacting Sonic Interaction* (PESI) research project that aims to enhance the musical experience in a collaborative music activity, providing embodied and spatial opportunities for musical exploration. PESI accounts for forms of interaction with digital technologies that are embedded in physical and social environments [8]. The design strategies behind PESI seek to answer questions such as: What new design requirements are emerging for interactive systems to provide expert music performances in co-located group music practices? What modes of interaction can transform that music practice into an active and enriched experience? How can the social actions in group music activity be realized as musical intentions affected by spatial parameters?

The PESI system uses mobile phones as tangible and expressive musical instruments, in parallel with an spatial system. This extended system incorporates the mobile instruments and motion tracking technology to create an environment in which performers are not only free to move and interact with each other but where their social interactions contribute to the sonic outcome. We have briefly presented previous versions of the system in [6, 16].

This paper is structured as follows. Section 2 discusses the related work in remote and co-located collaborative interfaces. Section 3 defines the design requirements and specifications. Section 4 introduces the architecture of the PESI system. Section 5 presents our evaluation of the system with three musicians. In section 6 we reflect on our findings and discussions. We indicate our future perspectives and conclude the paper in section 7.

2. RELATED WORK

Many design strategies for physical, social and spatial interaction in collaborative art context have been presented and more inclusive views of interaction for music, including interaction cues that are not directly affecting the sound-producing actions, have been discussed [1, 7, 12]. Within that line of approach, there has been scope for providing a classification of digital music instruments and interactive systems for collaborative music making [2] and the aspect of collaboration has been addressed explicitly [5].

Tooka is an exploration of a two-person musical instrument: a hollow tube with a pressure sensor and three buttons for each player [11]. From an original design meant for novices, it added expressive capabilities, following experiences with trained musicians. Ocarina is a wind instrument developed for the iPhone, which is socially aware: it allows one to hear other Ocarina players throughout the world [20]. Similarly, Daisyphone allows multiple participants to collaborate in the creation of music loops without being in the same physical space [4]. Notions explored in Daisyphone - such as identity, mutual awareness, mutual modifiability, and localization of sounds - have informed the design of the PESI system. MoodifierLive is another mobile phone application for rule-based automatic music performance, allowing for collaborative performances with up to four participants [9]. MoodifierLive explores the potential of mobile devices as all-in-one solutions for both sound production and control. It aims to combine automatic performance and expressive gesture analysis. Malleable Mobile Music

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[19] allows co-authoring of a common music stream, which takes advantage of geo-location and mobility, for as people come closer, their musical contributions become more clear.

Tabletop tools have also been pursued for musical collaboration for electronic music performance [13, 14]. As in the PESI project, Klügel et al. focus on face-to-face interaction in co-located settings, emphasizing visibility of action and the ability to use verbal and non-verbal communication. TOUCHtr4ck is another project that has been presented as a multi-touch tabletop tool for collaborative music making [21]. The authors of TOUCHtr4ck identify three main interaction factors for democratic collaborative music making that are important for our research: awareness of others' actions; modifiability of others' actions; and the distinction of musical expertise.

As the PESI system is designed for co-located collaboration, it brings reflections about space and movements. Nymoen et al. have evaluated the use of a classifier to discover correlations between sound features and movement features [15]. Their experiments have shown that it is possible to study these relationships by feeding movement data to a classifier and selecting the features used for classification (for example, a "shake" feature). We incorporate these ideas into our work and propose an adaptive and flexible interactive environment in which each performer conducts her/himself autonomously. Through the general and broad issues of physical, spatial and social interaction in collaborative group activities, we aim to highlight some key design issues in the PESI research project.

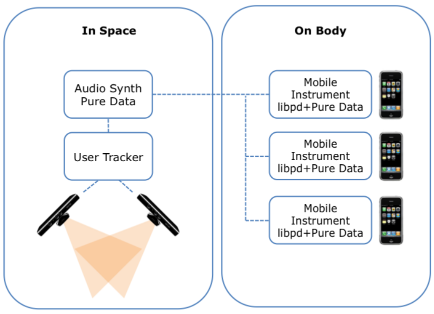

Figure 1: PESI system module diagram.

3. DESIGN REQUIREMENTS

In order to develop the system implementation for such group music practice it is necessary to define certain design requirements and technological specifications. This is to ensure that the system's features are developed on the basis of our initials findings of the previous user-test studies [16] and to maintain the requirements for physical and performance characteristics of an accessible technology.

The system needs to:

- have a robust motion tracking component to extract social interactions and to identify individual performers,
- provide musical instruments that allow bodily movements to emerge with corresponding embodied interactions between performers,
- facilitate collaborations involving more than two performers,
- allow all the modules to be customizable for various types of group music activities,
- maintain easy-to-use, easy-to-learn user requirements,
- provide vital status for networking to allow a low-level latency communication between system components.

4. PESI SYSTEM ARCHITECTURE

4.1 Extended System

To meet the design requirements for a system that allows bodily movements and bodily interactions to emerge between musicians, we implemented the PESI system in two parts - on the body and in space. *On-body* component consists of mobile phones and portable speakers. Performers use the mobile devices to control their individual instruments. Each one wears a pair speakers on his/her body that are directly connected to the mobile device.

In-space, the multi-user tracking and central management unit provides a robust tracking and analysis system that adapts quickly and reliably to any changes in a dynamic, group improvisation performance. It receives a continuous stream of data from the rest of the components. It uses this data to extract actions and to modulate the individual sound outputs. This allows a new layer of sound to be presented based on the social relations among the performers. There are also surround sound speakers set up in the space.

This architecture has been implemented in a highly decoupled modular structure (see Fig. 1). Every component runs independently, and communicates with the other modules through the standard Open Sound Control - OSC[1] protocol. The modular structure in the system allows for dynamic reconfiguration and reusability of the components in order to increase the overall robustness of the system.

4.1.1 On Body

We designed and implemented a mobile phone instrument, running custom software built with Objective-C[2] and Libpd[3] in iPhones. The software receives input from the accelerometer and gyroscope sensors, as well as touch interaction. Performers can choose one out of three different sound modules, each with its own sonic characteristics and interaction-sound mapping settings.

Libpd enables the system to run Pure Data[4] environment as a sound engine on iPhones. The three values of accelerometer and gyroscope for X, Y and Z coordinates arrive as a continuous stream of floats in libpd. This translates actions into sound. The accelerations and continuous pointing are measured constantly along all axes, providing a picture of the performer's hand as it gestures and moves. The mobile phones are connected to two portable speakers that the performers wear on their chests (see Fig. 2). In addition to accelerometer and gyroscope values, touch information is used to provide X and Y coordinates of touch screen input data and binary values to the system. The information retrieved from accelerometer, gyroscope and touchscreen is also sent to the *in-space* component.

The core interaction model allows participants to focus on their interactions with the other participants and with the environment. The objective is to keep the GUI requirements to a minimum level of visual cues, such as the background colour of the screen indicating the choice of sound module and the state of the instrument. In addition to audio and visual feedback, the mobile instrument also provides haptic

[1] http://opensoundcontrol.org/
[2] http://developer.apple.com/library/mac/#referencelibrary/GettingStarted/Learning_Objective-C_A_Primer/_index.html
[3] http://libpd.cc
[4] http://puredata.info/

Figure 2: Mobile instrument with portable speakers.

Figure 3: Motion tracking of three performers using two Kinect sensor bars.

feedback, aiming to respond to certain control actions on the mobile phone. This is explained further in section 4.2.

4.1.2 In Space

The *in-space* component implements a Kinect motion tracking module that constantly computes the spatial position of the three performers and extracts information about their relations, such as relative distances, velocity, acceleration and alignment (see Fig. 3). The tracking module avoids the loss of tracked players due to occlusions or abrupt movements. The *in-space* component is conditioned by the critical requirements of three-musicians performing in a group improvisation. The modular structure of the motion tracking module enables us to add several Kinect sensor bars to the system for a reliable tracking. In its current system structure with three musicians performing, we implemented the tracking system with two Kinect.

The two-Kinect tracker module is built as a client-server architecture. Each Kinect is connected to a computer, that extracts the point-clouds of the users in the scene, removing the background, floor and static objects, and sends it to the central server via the OSC network module. The server merges the data coming from the other processes and computes the significant data that feeds the control system. It performs the following tasks:

- First, it gathers point-cloud information from the different Kinects in real-time.
- Then, it determines the "center of mass" (CoM) of every user by computing the centroid of his/her mesh.
- Finally, it implements an optimization algorithm that finds the best possible fit between tracked player ids and the new incoming CoMs, resulting in a very reliable and reactive tracking system.

The tracker module is built using the OpenNI[5] library with Processing[6] and openFrameworks[7]. It is fully scalable to any number of Kinect and to track any number of users.

The *in-space* network module is centralized in a laptop machine and hosts a local wireless network. It facilitates continuous and vital communication between the *on-body* and *in-space* components. It constantly receives interaction data from the mobile phones and tracking information through the OSC network module. The tracking module permits location of the audio as close to the source as possible, reinforcing the sound produced by the wearable speakers. The sound routed through Pure Data to the speakers in the space is manipulated using the distance information between performers. Therefore, the relative position of each performer regarding each other, and the speed of her/his movement to or from the others, affects the overall sound.

[5]`http://openni.org/`
[6]`http://processing.org/`
[7]`http://www.openframeworks.cc/`

4.2 Audio Synthesis

The mobile instrument has three sound modules. Tilt gesture controls the main features of sound modules in the mobile instrument. Touch input is the key binary data for the audio synthesis as it provides on/off control feature. The overall magnitude of acceleration controls the dynamics of the mobile instrument. When the instrument is tilted along the x-axis, haptic feedback responds to the beginning and the end points in the control range. Haptic feedback is activated through the vibration motor in iPhone. Sonic characteristics of the mobile instrument have been developed further based on the comments and results we gained during our initial user-test [16].

4.2.1 Sound Module Green

The first sound module, *Green*, is designed with 4-point adaptive mapping strategies on a 2 dimensional touch screen interface [18]. The weighted average of the 4-points is calculated based on the closest distance to the touch position. The closest point gains a larger weight. In this module, single touch gesture input is intended to be used to control more than one musical parameter. 4-point weighted sum of the touch gesture results in a variety of outcomes in synthesis based on a squarewave generator and pulse width modulation. In addition to the touch gesture, tilt action changes the frequency variations of the modulating signal. If the hand-held position of the instrument is changed so that the instrument faces down in the vertical position, the sound module cuts the squarewave generator together with pulse width modulation and activates waveshaping synthesis providing frequency and sustain time control through gyroscope and accelerometer sensor-input values. The base harmonic structure of the waveshaping synthesis is specified randomly once the *Green* sound module is activated. Haptic feedback also responds each time to the frequency value changes in the waveshaping synthesis.

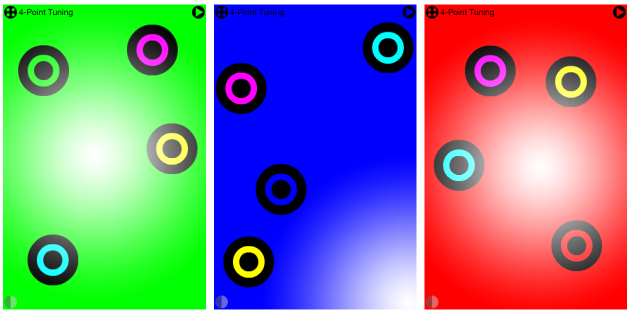

Figure 4: Sound modules can be tuned with 4-point interface.

4.2.2 *Sound Module Red and Blue*

The second sound module, *Red*, is based on granular synthesis, manipulating the size and the duration of the grains. The granular synthesis in this module is the modification of asynchronous granular synthesis described in [10, 17] and it is developed through the concatenative synthesis module introduced in [3]. There are 11 grain-player units in this module. The tilt action in x-axis determines the index of the grains in each of the grain-players and plays back the matching grains in sequence. At the same time, y-axis values set the grain size to be played for each index of the grains in grain-players. The third sound module, *Blue*, is another type of granular synthesis that allows for time-stretching and pitch shifting, which can be classified under synchronous synthesis techniques [10, 17]. In this module, tilt action controls the index of the grains to be played in the grain-players and the touch input data along the vertical axis determines the pitch value for each grain-player.

4.2.3 *Tuning*

Each sound module in the mobile instrument can be tuned through a 4-point tuning interface, which assigns to the sound module with a parameter pre-set (see Fig. 4). The vector values for each point are mapped to parameters which cannot be modified any other way. In the *Green* sound module, these values set certain frequency parameters for two squarewave generators and two pulse width modulation modules. The resulted audio signals are added to the other square wave generators and pulse with modulation modules which are controlled dynamically through touch gesture and tilt action. In the *Red* sound module, the tuning interface sets the synthesis-window-size, analysis-window-size and related overlapping values for the synthesis which equally affect the grain index value controlled through tilt action. Similarly, in the *Blue* sound module, the grain's speed, spread, fade length and scattering values for the granular synthesis can be set with the tuning interface.

4.2.4 *In-Space Sound Module*

When the performer chooses one of the sound modules in the mobile instrument, that particular sound module is also activated in the *in-space* component and produces the audio signals to be processed further. The overall audio synthesis design is aimed for creating a layer of sound cloud that is identical to the individual mobile instrument. The reactivity to distance and speed allows for social interactions to emerge and defines the characteristics of the audio output of the system. When the distance between the two performers is at its closest, then the input audio signals are processed within a larger grain length and density. As the performers get further away from each other, the system produces shorter length sounds with more glitch features. At the same time, if the performer gets closer to the third performer then the frequency response range exponentially increases. The speed of the performer's movements changes the amplitude response of the system.

5. EVALUATION WITH 3 MUSICIANS

We evaluated the PESI system with the *on-body* and *in-space* components in a jam session with skilled musicians, who were experienced in performing experimental music with new interfaces. Our intention was not to test the system features in comparison to any other interactive system. While this jam session is not providing any criteria for the success of technical implementation, it provides us with a clear understanding of the success of our design approach and methods from a musician's perspective.

We invited the musicians Ilkka Niemeläinen, Antti Ikonen and James Andean to participate in the user-test jam session (see Fig. 5). Niemeläinen has been playing music in groups from duos to symphony orchestras for 40 years, playing the guitar and also having 15 years experience using sensor based instruments. Ikonen has been playing mostly keyboards in various bands since 1976, and experimental instruments in Cartes Art Machine between 2002 and 2007. He has experience in playing one-off gigs with ad hoc jam bands from the mid 1980s onwards. Andean's background involves performing in a choir for many years, performing as a classical pianist, and alongside performing with electronics, objects, toys, etc. He has been the member of Rank Quartet, a new music/improv group, for the past three years, and has been regularly participating in other group improvisation contexts with ImproMasters, Helsinki Meeting Point and Improvisation Research Group.

Figure 5: 3 Musicians in a free form improvisation.

We briefly described the control features of the mobile instruments when we met the musicians five days before the user test. We asked them to keep the mobile instruments and play with them to familiarize themselves with the interface. The user testing session took place in our research group's studio and lasted approximately one and a half hours, including the time spent playing free form group improvisation, followed by answering a short questionnaire and a group interview (see Fig. 6). Before the group improvisation we presented the *in-space* component and demonstrated its response to the overall improvisation. We helped each musician to place the portable speakers on their chest. After that, musicians spent more time getting familiar with the PESI system in a warm up session for about five to seven minutes. The jam session lasted approximately 13 minutes and the session was documented through audio and video recordings. Following the experiment, the three musicians answered a short questionnaire, containing close-ended questions (12 Likert-scale questions and a keyword selection question) and also one open-ended question.

6. RESULTS AND DISCUSSIONS

The answers to the Likert-scale questions (from 0-minimum to 5-maximum) were mixed. Taking into consideration the mobile instruments, *on-body* components, the results were mostly positive. The three musicians attributed an average score of 3.3 to the mobile instrument in terms of sound, and of 3 in terms of responsiveness to actions. The answer to the more generic question "how much did you like your instruments?" obtained a more positive result (average of 3.7). The respondents were mostly in agreement - the question with largest disparity of answers was the one related to instrument responsiveness (standard deviation of 1, and of 0.6 for the remaining ones). The musicians gave an average score of 3 as an answer to the generic question "how much did you like the *in-space*?". A similar medium score (average of 3) was achieved regarding the *in-space* component facilitating the discovery of new strategies and ideas during the jam session. Questions about the *in-space* component facilitating the development of musical dialogs with other musicians obtained an average score of 2.7. The responsiveness of the *in-space* component received a similar average of 2.7. The standard deviation was the lowest regarding this question, of 0.6, with the other answers having 1 or 1.2.

The feeling of interaction with others through the combined use of the *on-body* mobile instrument and the *in-space* system obtained an average score of 2.7. Issues relating to overall experience were more successful. Both questions "did it feel like a musical instrument?" and "did it feel expressive?" received a score of 3.3. The highest result was obtained regarding the intention to reuse the PESI system again - an average score of 4.3. The overall rating of the jam session was also positive - an average of 4.

In summary, the results regarding the *on-body* mobile instruments - sound characteristics, responsiveness, overall impression - are positive, with average scores between 3 and 3.7. The results regarding the *in-space* system - responsiveness, facilitation of discovery, facilitation of dialog with others, overall impression - are neutral, with average scores between 2.7 and 3. Feeling of interaction with others conveyed by the PESI system is equally neutral, with an average of 2.7. More generic issues related to experience - resemblance to a musical instrument, expressiveness, intention to reuse, overall impression of the whole - receive higher ratings (average scores between 3.3 and 4.3).

One of the musicians attributed in general lower scores (only scores of 2 or 3, average of answers: 2.6), while the other two gave higher scores (averages of 3.8 and 3.4). The musician who attributed the higher scores was also the one who rehearsed the most (90 minutes, compared to 10 to 20 minutes of the other two musicians). The musicians were also asked to pick five adjectives which best describe the overall experience of this user test, from a list of 20 adjectives, both positive and negative. From these, four adjectives were selected by two respondents: two of them generic ("enjoyable", "friendly") and the other two highlighting the dynamic nature of the project ("interactive", "active"). Other adjectives were only selected by one of the musicians. Mostly they had a positive connotation ("satisfying", "engaging", "delightful", "pleasant", "social"), while one was more ambiguous ("chaotic"). When asked to list the advantages and limitations of using the mobile device for music performance, in an open-ended question, the musicians listed as advantages the size, connectivity, and freedom of movement, besides the sonic and interactive possibilities. In terms of limitations, musicians listed the reduced limited dynamic control, lack of precision in some sound modules, the difficulty in acting outside the planned possibilities, and the lack of interaction with the other hand.

Figure 6: Interview with the musicians after the jam session.

Musicians experienced the capabilities of the system only once they understood how to connect the *in-space* and *on-body* components, and how to skillfully interact with the system, with other musicians and with the space. This observation was further evidenced when we went through the recorded video material of the user-test and the transcript of the group interview. In the very beginning of the jam session, musicians spontaneously shifted their position in the space and played with the mobile instruments in a very controlled situation. In one way musicians spent the first period as a warm-up session, but this time it was also part of the performance and it reflected performance meaning in that practice. That beginning part inspired musicians to further develop musical ideas in relation to the other musicians and to the system.

" You also have certain kind of intentions that you would like to do with the system and then transmit your ideas to the other musicians. With a little bit more rehearsing and trying out a specific intention, it is really possible to do a performance with this extended system."

We believe that our experiment with three musicians shows the suitability of our system for supporting group music activity with an extended system realizing social interactions as musical intentions. Our approach for transforming group music practice into an active experience underlines a novel collaborative system with *in-space* and *on-body* features. The experiment also shows that PESI system implementation meets with the design requirements we presented in this paper.

"RED gives a great, powerful sound with small gestures. GREEN is the one that you get good sound with large hand gestures. It is all about the gesture, because it feels more performatively and sonically satisfying when the gesture relates very clearly to the sound it makes."

"Direct response. It gives a feeling of interaction. It is the RED in that case, most responsive."

"It didn't feel like the system would fail you. I never doubted it. The system was working fine, stable and it was very robust."

While the feeling of interaction with others obtained an average score among the musicians, we think that in some respect, we challenged the social interaction in such group activity by applying our design strategies in the PESI system implementation.

"There are things in this system that I really love and seek to have in any performance. I love things that I can control to a certain degree and not beyond. This is great for that. I know I can trigger it, I can get something in the sound world. It is very pleasant each time and inspiring. Sometimes the system responded the way I was not expecting, but that inspired me to have some other idea to do something else."

7. PERSPECTIVES AND CONCLUSIONS

In this paper we presented a novel collaborative system, its design requirements and architecture. We also discussed the results of an experiment with three musicians. The system itself still remains open for further development. Results from our user-testing jam session indicate that, through some modification of the *in-space* response to the improvisation, and through more intuitive interactions with the *on-body* mobile instruments, we could make the collaborative music activity a more engaging and active experience. Despite being only user-tested once with musicians, the group interview has raised fruitful discussions on the precise details of the system components.

Furthermore, the paradigms of musical interaction and social actions in group activities need to be questioned when we seek design requirements for such a collaborative environment. We introduced a system that we believe can open up new ways of musical exploration in group music activity with a number of musicians. The system brings up the affordances of accessible technologies while creating opportunities for novel design applications to be explored. Our research proposes further development of the system, focusing on movement behavior in long-term interaction between performers. We plan to implement this version and evaluate design and implementation with distinct skilled musicians. We also aim to develop a repertoire to be performed with the PESI system and the performance video materials will be available at `http://sopi.media.taik.fi/research/pesi/repertoire/`.

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9. REFERENCES

[1] S. Benford. Performing musical interaction: Lessons from the study of extended theatrical performances. *Comput. Music J.*, 34(4):49–61, Dec. 2010.

[2] T. Blaine and S. S. Fels. Contexts of Collaborative Musical Experiences. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2003.

[3] W. Brent. Cepstral Analysis Tools for Percussive Timbre Identification. In *3rd Pure Data Convention*, Sao Paulo, 2009.

[4] N. Bryan-Kinns and P. Healey. Daisyphone: support for remote music collaboration. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2004.

[5] N. Bryan-Kinns and P. G. Healey. Decay in Collaborative Music Making. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2006.

[6] N. N. Correia, K. Tahiroğlu, and M. Espada. Pesi: Extending Mobile Music Instruments with Social interaction. In *Seventh International Conference on Tangible, Embedded and Embodied Interaction (TEI), Work in Progress*, Barcelona, 2013.

[7] C. Dobrian and D. Koppelman. The E in NIME: Musical Expression with New Computer Interfaces. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2006.

[8] P. Dourish. *Where the Action Is: The foundations of Embodied Interaction*. The MIT Press, Cambridge, MA, 2004.

[9] M. Fabiani, G. Dubus, and R. Bresin. MoodifierLive : Interactive and Collaborative Expressive Music Performance on Mobile Devices. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2011.

[10] A. Farnell. *Designing Sound*. The MIT Press, 2010.

[11] S. S. Fels, L. Kaastra, S. Takahashi, and G. Mccaig. Evolving Tooka: from Experiment to Instrument. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2004.

[12] M. Gurevich and J. Treviño. Expression and Its Discontents : Toward an Ecology of Musical Creation. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2007.

[13] S. Jordà, G. Geiger, M. Alonso, and M. Kaltenbrunner. The reacTable: exploring the synergy between live music performance and tabletop tangible interfaces. In *Proc.of the 1st international conference on Tangible and embedded interaction*, pages 139–146. ACM, 2007.

[14] N. Klügel, M. R. Frieß, G. Groh, and F. Echtler. An Approach to Collaborative Music Composition. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2011.

[15] K. Nymoen, K. Glette, S. A. Skogstad, J. Torresen, and A. R. Jensenius. Searching for Cross-Individual Relationships between Sound and Movement Features using an SVM Classifier. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2010.

[16] R. Pugliese, K. Tahiroğlu, C. Goddard, and J. Nesfield. A qualitative evaluation of augmented human-human interaction in mobile group improvisation. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2012.

[17] C. Roads. *Microsound*. The MIT Press, 2004.

[18] K. Tahiroğlu. An Exploration on Mobile Interfaces with Adaptive Mapping Strategies in Pure Data. In *Proc.of the 4th International Pure Data Convention*, Weimar, 2011.

[19] A. Tanaka. Malleable mobile music. In *Adjunct Proceedings of the 6th International Conference on Ubiquitous Computing (UBICOMP)*. Citeseer, 2004.

[20] G. Wang. Designing Smule's Ocarina : The iPhone's Magic Flute. In *Proc. Int. Conference on New Interfaces for Musical Expression*, 2009.

[21] A. Xambó, R. Laney, and C. Dobbyn. Touchtr4ck: democratic collaborative music. In *Proc.of the fifth international conference on Tangible, embedded, and embodied interaction*, TEI '11. ACM, 2011.