TouchSound: An approach to multi-user music performance on touch tables

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ABSTRACT
This paper presents a novel approach to music performance on touch tables. The chosen approach aims at improving the existing FeelSound system in such a way that pleasant music (as opposed to abstract sounds) can be produced. A small qualitative evaluation has shown that TouchSound delivers improved performance over FeelSound. Users are able to produce music, even when lacking previous musical experience. A multi-user experiment has shown that TouchSound is capable of supporting a multi-user music performance. Future usage of TouchSound could be envisioned in an experimental, explorative setting, both for novice musicians and musical experts.

1. INTRODUCTION
The art of music performance has been practiced by mankind for many thousands of years. For the greatest part of this period, music was performed on analogue instruments which limited the sound that could be produced to the physical properties of the instrument being played. Only the quite recent introduction of electronic instruments made it possible to produce virtually any sound with a single instrument. Still, most of the electronic instruments had an interface comparable to that of analogue instruments (electric guitar, keyboard) or an interface entirely consistent of the technical inner parts of the instrument (modular synthesizers). Furthermore, most traditional interfaces do not provide a possibility for multi-user performances.

The introduction of multi-touch devices has triggered the construction of a whole new range of interfaces for music performance. However, most of these interfaces are either unsuitable for multi-user performance or are only able to produce very abstract sounds.

This paper describes a novel kind of interface which aims to overcome the problems of existing touch table music performance interfaces. Hence, the overall goal of this research project has been defined as: *"To create an application which enables a multi-user electronic music performance on a touch table"*.

To confirm whether the overall goal of the research project has been reached, a number of sub-questions have to be answered:

- Are musically inexperienced users able to produce music with this system?
- Are musically experienced users able to produce music with this system?
- Is the system able to support a multi-user performance?

2. PREVIOUS WORK
Since multi-touch surfaces have become popular and widely available, a number of music applications have been developed which make use of multi-touch technology.

Crevosier et al [1] developed *Sound Rose*, an interactive audiovisual installation which uses acoustic sensing (ultra-sonic sound) to create an audiovisual experience based on movements of a user's finger on a surface. This system is only capable of tracking one touch at a time (therefore not having multi-user capabilities) and creates rather abstract sounds instead of music.

A far more advanced music performance system has been developed by Kaltenbrunner et al [2]: an interactive collaborative instrument called *reacTable**. This instrument works by placing tokens with specific functions on a table surface. Beneath this table's surface, a video camera tracks the objects placed onto the surface and a projector, also located beneath the surface, draws animations onto the surface, reflecting the state of the system. Turning and moving the tokens influences the music being played, as the functions of the tokens are mapped to components of a virtual modular synthesizer. While this system supports multi-user control (any user can manipulate the tokens), it relies on tokens rather than touches for its input.

Inspired by the reacTable*, Fikkert et al. [3] developed *FeelSound*. Rather than tokens, users of FeelSound can use their hands to produce music. This system uses the mu3 framework, also developed by Fikkert et al. [4]. By drawing lines on a DiamondTouch[1] touch table surface, musical patterns are constructed which can be sequenced into a composition. FeelSound is a multi-user system and different instruments are available to the users. Users are not bound to a single instrument, but are free to use any of the available instruments.

ReactOgon [5] is another system which provides a tangible interface for music performance. Like reacTable*, this system gives a user the possibility to produce music by placing physical tokens on a touchable surface. However, ReactOgon maps the tokens on a hexagonal structure projected onto the table's surface. This hexagonal structure is called the *harmonic table* and is a mathematically clever way of placing musical notes on a grid. The idea is that it allows even inexperienced musicians to produce pleasant musical sounds.

3. APPROACH
The developed system is a follow-up to FeelSound, but also gets its inspiration from ReactOgon. Its aim is to provide the same sort of interface as FeelSound: drawings get converted to musical samples. However, this new system should overcome FeelSound's main shortcoming, the inability to produce pleasant music, by using the harmonic table structure like ReactOgon does.

3.1 Harmonic table
3.1.1 Layout
The harmonic table is a layout structure for musical notes, just like the ordinary keys of a piano. The keys of a piano are arranged in a strict ascending order, when moving from left to right. Essentially, this layout is one-dimensional, as you can only move up or down the scale.

The harmonic table is a different structure and offers a two-dimensional scale. It is represented by a hexagonal matrix in

[1] See http://www.circletwelve.com

which each cell represents a single note. The layout of this table ensures the same properties apply to each cell in the matrix. For any cell A in the matrix:

- The cell to its left[2] yields the note which is a semi-tone lower than A's tone. The cell to its right yields a semi-tone higher note. (For example, D#-E)
- The cell below A yields the note which is a quant (7 semi-tones) lower, the cell above the note which is a quant higher than A's tone. (C-G)
- Diagonal lines through A result in either augmented or diminished chords (A-C-D#)
- Triangles with a vertex on A result in either major (C-E-G) or minor triads (C-D#-G)

Figure 1 shows these examples on a part of the harmonic table (the green cells together form each of the examples).

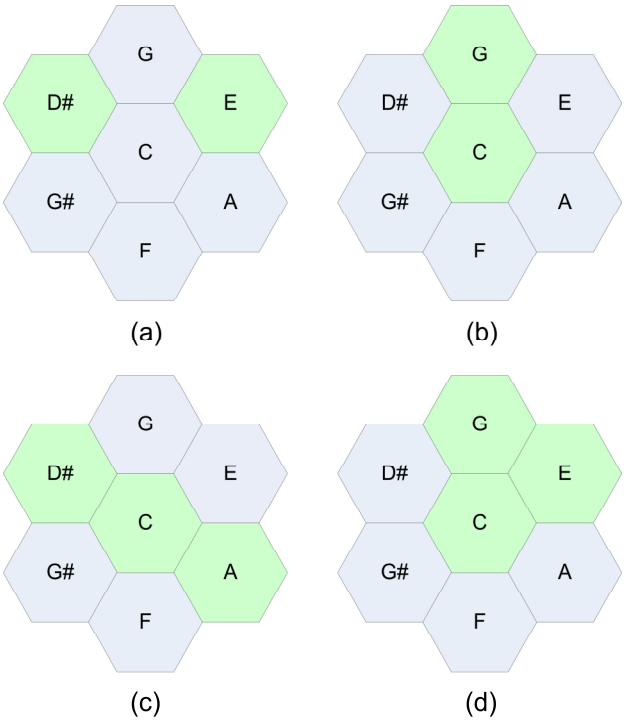


Figure 1: Harmonic table examples: (a) semi-tone, (b) quant, (c) diminished chord, (d) major triad

The layout of the harmonic table also has another advantage: it makes it possible to have a relative large range of notes available in a compact space. This is an advantage to many traditional instruments (like a trumpet, guitar or violin) which often provide only a fraction of the range of notes available with a harmonic table.

3.1.2 Relevance

The layout of the harmonic table is based on the musical concept of harmony, which comes from the Greek word 'harmonía': joint, agreement. The layout of the harmonic table is adjusted to suit chord progressions which are commonly used in western musical tradition [6]. In contrast to traditional note orderings, like the linear increasing order on a piano, the notes on the harmonic table are ordered to have commonly used chord progressions close at hand.

The harmonic table's layout also ensures that similar shapes always produce similar sounds. For example, a triangle of neighbouring notes will always produce a minor or major triad. Although being slightly more difficult figures, augmented and diminished chords will also have a consistent shape, regardless of their position on the harmonic table. This means the harmonic table is able to create a consistent mapping of shape to sound and vice versa. If you draw a shape, you will know how it sounds. If you hear a sound, you will know what shape represents it.

Psychological and perceptual research has shown the relevance of cross modal perception: the phenomenon that images can be related to sounds and vice versa [7]. This, in combination with the fact that similar shapes produce similar sounds, makes the harmonic table especially useful for novice musicians: chords and melodies can be constructed from easy-to-remember drawings and figures.

3.2 System design

3.2.1 Overview

This paragraph contains a brief description of the system's general functionality. A high-level class diagram of the system, showing its most important aspects, is shown in Figure 2. More specific information about the system's parts will be given in the following sections.

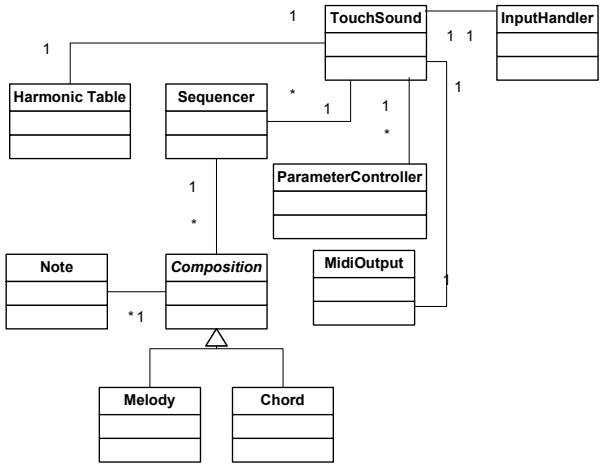


Figure 2: High-level class diagram

The TouchSound application consists of a multi-touch, multi-user interface (UI, see Figure 3) which outputs MIDI signals that can be turned into music.

The connection between a multi-touch device and TouchSound's UI is being handled by the mu3 framework, developed by Michiel Hakvoort[3]. The main part of the UI is the Harmonic Table, which allows users to create short clips of music, called *Compositions*. Compositions come in either of two tastes: *Chords* or *Melodies* (see paragraph 3.2.2). These Compositions consist of individual notes and can be used to build a larger piece of music, by placing them onto a *Sequencer*. The sound of compositions can be controlled by various control sliders (modifying parameters which determine the shape of the sound, see 3.2.5), individual to each user.

[2] While cells don't have directly adjacent cells to their left and right, 'left' and 'right' *do* refer to the next-left and next-right cells (so *not* the upper-left, bottom-left, upper right or bottom-right cells).

[3] See http://code.google.com/p/mu3/

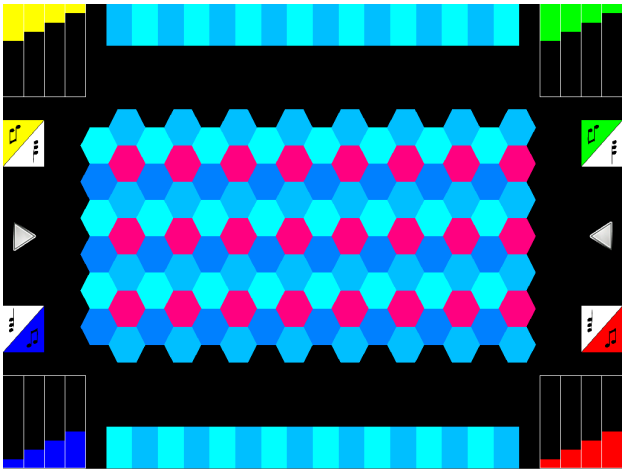


Figure 3: Overview of the TouchSound user interface

To facilitate multi-user usage, several other features have been implemented in TouchSound. The application has been designed for a maximum of four users, each of which has its own colour. All compositions made by a user have the same colour, just like the controls for that user. The two sequencers have been placed on opposite sides of the UI, such that users from all table-sides can easily access them.

3.2.2 Harmonic table

The harmonic table plays a central role in the designed system. Users are able to create *Compositions* by drawing onto the harmonic table. Each hexagon in the harmonic table is linked to a specific note value. Drawings made by users on the harmonic table are recorded and converted into compositions.

The original FeelSound application did not support the recording of polyphone compositions. That is, per composition only a single note could be played at a given moment. Because this severely limited users in their musical freedom, it was decided to include the possibility of chord recording in TouchSound. This means there two separate recording modes are available in TouchSound:

- *Melody-mode*: When the system is in melody-mode, a user can use the harmonic table to create strings of notes, commonly referenced to as a melody. A user drags his finger across the table and creates a line. The notes travelled over while drawing the line, get attached to form a string of notes: a melody. The notes in this melody will be played *sequentially* when put into the sequencer. In this mode, the timing and duration of the touch determines the timing and length of the composition.
- *Chord-mode*: In chord-mode, a user touches one or more notes sequentially[4]. These notes are grouped into a chord, when the user touches a note which has already been included in the chord. The notes of a chord will be played *together*, when put into the sequencer. Timing and duration of the touch are neglected in this mode. Instead, notes of a chord get assigned a pre-defined (and inter-equal) length. This length will be adjustable after the recording has finished (see section 3.2.3).

[4] Although theoretically a chord could also be formed by touching multiple notes at the same time, this can cause unexpected behaviour in practice, because of technical limitations of the used DiamondTouch multi-touch table.

Figure 4 shows an example of the recording of a melody and a chord. It also shows the way in which notes get recorded for a melody (notes form a sequence) and a chord (notes form a parallel group).

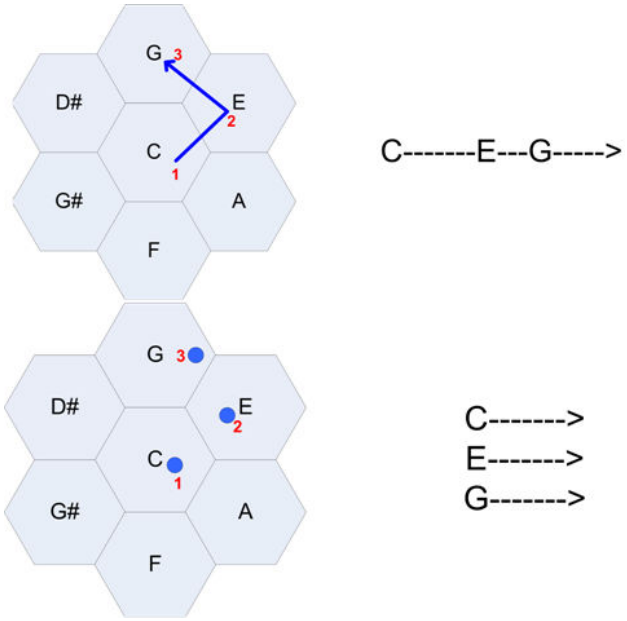


Figure 4: Examples of melody (upper image) and chord (lower image) recording

3.2.3 Compositions

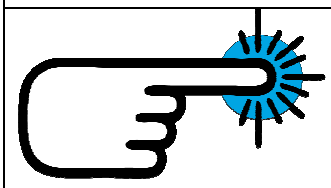
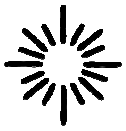
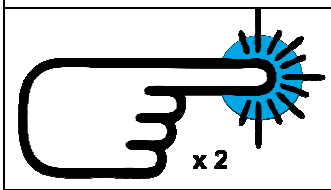
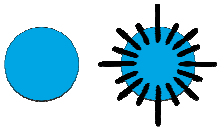
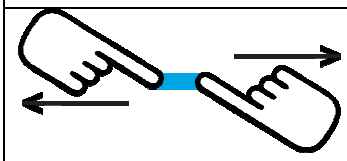
As told in the previous paragraph, compositions are the elements of a musical performance which can be created (or recorded) through the harmonic table. After a composition has been recorded, it appears as a circle (in case of a melody) or a rectangle (in case of a chord) on top of the harmonic table.

Various actions can be performed on recorded compositions; these are illustrated by Table 1:

- Tapping a composition once (briefly) will remove the composition.
- Tapping it twice will 'clone' it, such that an extra copy of the composition is added to the system.
- Additionally, chords can be stretched or compacted by touching the chord with two fingers which move apart or towards each other. Resizing the chord will adjust its duration, when being played by the sequencer. The maximum size a chord can be stretched to is the width of a sequencer.
- Finally, compositions can be dragged across the table by touching them and moving the touch across the tangible surface.

Note that once a composition has been recorded, it is not possible to change the composition afterwards. Changing a composition would be difficult in case of a melody, because timing of individual notes of the melody depends on the timing of the touch which constructed it. Editing of a melody would, besides the harmonic table, require an extra UI element in order to edit the timing of notes which make up the melody. Furthermore, users would have to listen to the result of the edit, possibly while other users are editing as well, to adjust it to their liking. Because editing a melody would then become such a difficult operation, especially in a multi user environment, it was decided not to include this possibility in TouchSound.

Table 1: Possible actions on TouchSound compositions: removal, cloning and resizing

Action	Result
	
	
	

3.2.4 *Sequencers*

While the harmonic table 'produces' compositions, a sequencer can be used to schedule these compositions on a time line. The current TouchSound application contains two sequencers, which have been located on the top and the bottom of the screen, to facilitate usage by multiple users located around different sides of the table.

A sequencer consists of a bar with a fixed number of slots on it; the current implementation features 16 slots. During playback, each of the slots will be 'activated' for a fixed amount of time. The speed with which these slots will be activated depends on the system's 'bpm'-setting, which determines how many beats-per-minute will be played. The current implementation is fixed at 130bpm and each of the 16 slots represents one beat. Each slot will therefore be activated for 60/130 ≈ 0.46 seconds. One run over the complete bar will thus take about 0.46*16 = 7.36 seconds. After the last slot has been activated, the sequencer will start again with the first slot, thus creating a loop.

At first, it might seem a severe artistic restriction to have a loop which lasts only for 7.36 seconds. After all, it would be nice to be able to have a musical performance which lasts for more than just this short period of time. Indeed, it is very well possible to have a longer musical performance. By changing the contents of the loop over time (dragging compositions in and out of the sequencers), variation in the performance can be created in having multiple loops with different content played sequentially.

To have a composition scheduled for repeated playback, it can be dragged onto a sequencer. A composition residing on a sequencer will be played at the moment the slot at the left-most point of the composition gets activated. Dragging a composition away from a sequencer removes it from the playback loop.

Internally, each of the slots of a sequencer is subdivided into a number of ticks, which define the maximum accuracy level of the sequencer. The current implementation features 4 ticks per slot, so the best resolution for playback of compositions is 0.46/4 = 0.11 seconds. Because the timing of recorded melodies will most certainly not exactly fit within the resolution of the sequencer, the timing of notes is 'clamped' towards the nearest tick. For example, a melody contains three note-events: one at t=0, one at t=0.20 and one at 0.55. In this case, the first event will be scheduled on a slot's tick 1, the second event is clamped to tick 3 (with t=0.22) and the final event is clamped onto tick 1 of the next slot (with t=0.46).

To give users insight into the mapping of compositions' notes onto the sequencer, small blocks appear at the positions of the ticks on which notes are mapped (see Figure 5).

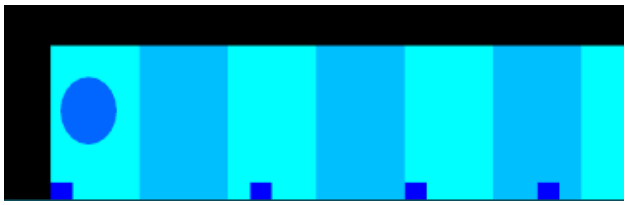


Figure 5: Detail of a sequencer with a melody placed on it

3.2.5 *Controls*

The system contains a number of controls which can be used to control recording and playback of compositions.

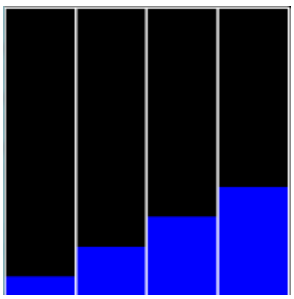
Record-mode buttons

The system includes a record-mode button for each of its four possible users. When tapped, this button toggles the record-mode for a user between melody-recording and chord-recording. Note that each user has individual control over the mode (s)he is recording in.

Playback control buttons

Two buttons on the sides of the screen control the sequencers and toggle the sequencers between either play or pause. These buttons can be tapped by any user and affect playback of all users' sequenced compositions.

Parameter controls



TouchSound has been designed for usage by multiple users at the same time. By assigning an own 'instrument' to each of the users and giving them control over the parameters of their instrument, users are able to create a multi-user, multi-instrument composition. The parameters control the 'shape' of the sound, in the case of TouchSound the parameters assigned to the controls are filter-frequency cut-off, attack, decay and sustain. For more details about the workings of these parameters, I would like to refer to an excellent book written by M. Russ [8].

3.2.6 *Output*

TouchSound has been designed to use external applications for its sound generation. The main reason for this is that sound synthesis is a very specific and complex task, for which a large number of applications have already been developed. Because the main goal of TouchSound is not to investigate sound synthesis, but the application of a novel user interface to music production, it has been decided to leave sound synthesis completely outside the application.

All musical events (notes being played, parameter control changes etc.) generated through TouchSound's user interface, are converted into MIDI[5]-events. These events are then being

[5] See http://www.midi.org

sent over a virtual MIDI-channel[6], which allows two MIDI-applications on a single computer to communicate with each other. Any external sound synthesis application which accepts MIDI signals as input, can then be used to pick up events from the virtual MIDI-channel and produce sound on the basis of these events.

Every TouchSound user has its own MIDI-channel, such that an individual instrument is available to every user.

4. EVALUATION

The TouchSound system, as it has been described in the previous sections, has been evaluated in a qualitative experiment. This chapter explains the methodology and results of the evaluation.

4.1 Methodology

To be able to evaluate the general system goal: *"Enabling a multi-user music performance on a multi-touch table"*, two types of tests have been performed. One test focuses on the aspect of music production with TouchSound in general. The other test focuses explicitly on multi-user music production. Further details about both test types will be given in section 4.1.2.

4.1.1 Setup

The evaluation has been performed in the Experience laboratory of the HMI department of the University of Twente. The test setup consisted of a table on which a DiamondTouch touch-panel had been placed. A projector had been pole-mounted to project its image onto the touch-panel. Two conductive mats for the DiamondTouch panel had been placed on floor at the long sides of the table.

4.1.2 Procedure

As mentioned before, two types of tests have been performed: one focussing on music production with TouchSound in general, the other on multi-user music production. Both tests had a similar test procedure, only differing in the number of participants for one test.

All tests started with the participant being explained the possibilities of TouchSound. Participants were given a quick-start form (see Appendix A) on which all basic functionality of TouchSound is explained. They were asked to read the quick-start form and ask the evaluator questions were necessary. After a participant had read the form, (s)he would be guided towards the multi-touch table and asked to explore the possibilities of the system for a couple of minutes.

In case of the multi-user test, another participant would be brought into the test room at this point. This second participant would already have completed the exploration phase.

After the exploration phase, an assignment was given to the participant(s). Participants were told to compose a piece of music for a scene from a science-fiction movie. To add to the inspiration of the participant(s), a picture from the earth, viewed from space, was shown to the participant(s) (see Figure 6). The participants were given five minutes to complete the task as good as possible. The limit of five minutes was chosen to avoid over-familiarization of the participants with the system.

As soon as participants felt they had completed their task, or when the time-limit of 5 minutes had been reached, participants were asked to fill out a questionnaire (see Appendix B). In addition to the questionnaire, participants were interviewed about their experiences with, and opinion on the system.

Figure 6: Fictional scene from a science-fiction movie (*image from www.wallpapers-free.org*)

4.2 Results

4.2.1 Participants

Test participants for the evaluation consisted of students and staff of the Human Media Interaction department at the University of Twente. Additionally, one test has been performed with an employee of the University of Wageningen.

The system was tested by 10 participants (3 female, 7 male), ranging from age 23 to 55. Their musical experience varied from none to somewhat, but none of the participants rated themselves as expert musicians.

Nine experiments have been conducted with a single user, while only one experiment has been conducted with two users. The main reason why only one multi-user experiment has been conducted, is that the first multi-user experiment immediately showed that results on this experiment would not differ a lot from the results of single-user experiments.

4.2.2 Questionnaire

Although the questionnaire used for this evaluation cannot provide statistically relevant results with such a low number of participants, it does provide a useful tool for hypothesis generation.

One of the questions of the questionnaire considered the amount to which users were able to produce music (as opposed to noise) with TouchSound. Remarkably, the highest scores on this question came from users which had previous experience with FeelSound (see Figure 7). This was also confirmed during the interviews with these users, all of them acknowledged that it was easier to produce *real* music with TouchSound than with FeelSound.

[6] See http://nerds.de/en/loopbe1.html

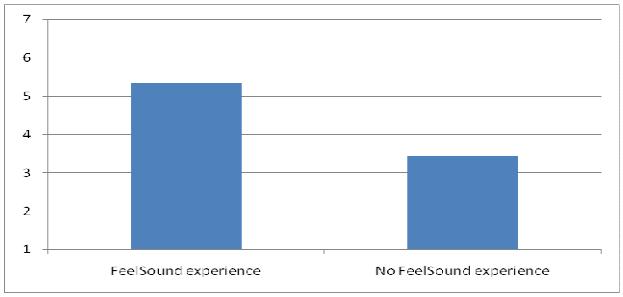


Figure 7: Results for "I was able to produce music (as opposed to noise) with TouchSound" for FeelSound experienced (μ=5.3,σ=0.8) and unexperienced (μ=3.4, σ=1.1) users

Another question considered whether users were able to produce what they had in mind. Scores on this question varied wildly, but were a little below average in general (μ=3.4,σ=1.1). Again, the results of the questionnaire were confirmed during the interview. Users remarked they found it hard to determine the exact relation between the position of a hexagon in the harmonic table, and the pitch of the note which it produced.

An interesting aspect for a system like TouchSound is its intuitiveness. It could be argued that an intuitive interface helps novice musicians in reaching the goal of music production. Most participants seemed to agree on the intuitiveness of the TouchSound interface (μ=4.8,σ=0.6). However, all of them critiqued some points of the interface during the interview.

4.2.3 Interviews

While the results of the questionnaire gave some general hints about which aspects of the system performed well, the interview was used to gain a more detailed view of TouchSound's strong and weak points.

Harmonic table

One of the results from the interviews is that users felt the harmonic table made it easy to produce music with TouchSound. Indeed, music production with TouchSound was considered easier than with traditional instruments like a guitar or piano. Not all is good however; as already mentioned before, a lot of users found it extremely difficult to determine exactly which note would be produced by a certain hexagon of the harmonic table. While it was easy to produce *some* music, it remained hard to produce exactly what a user had in mind.

Users suggested a number of solutions to this problem. First of all, the system should include some kind of tutorial. Such a tutorial should guide the user through composing a certain song, such that the user would get a better feeling for the workings of the harmonic table. Another suggestion was to highlight fields on the harmonic table which would render a nice melody or chord with existing notes in a composition. For example, when a user wants to produce a sad melody, the system could suggest adding a D# to a melody with notes C and G already included (thus forming a minor triad).

An interesting remark was made by a user which had a fair amount of musical experience (trained on multiple instruments). This user remarked that the very structure of the harmonic table made it difficult for users trained on classical instruments to produce music. Although he liked the idea behind the harmonic table, he thought it would require a mind shift to get used to the rather alternative interface of the harmonic table.

Intuitiveness

As was mentioned in the previous paragraph, users were content about the system's intuitiveness in general. There were however some minor issues which influenced the user experience. The choice to have a composition removed by touching it once, worked out to be frustrating for a lot of users. It often happened that a composition got deleted while a user was dragging it across the table, caused by detection flaws in the multi-touch device.

Another point of critique on the intuitiveness of the system is that the workings of the filters remained unclear to some users. Not only was it unclear in what way these filters controlled the shape of an instrument's sound, it was also unclear to users whether the filters apply to an individual composition or to all composition of an instrument.

Multi-user composing

During the multi-user experiment, it became clear that the current interface is suitable for at least a two-person music performance. Users felt they didn't get into each other's way and were able to compose their own creations individually.

However, when it comes to composing *real* music, there seems to be a general flaw in multi-user touch table music systems, which cannot easily be resolved. When performing a traditional piece of music, for example with a band or orchestra, each member of the group has to be able to listen to his/her own instrument carefully during a performance. Not only does this require musical skills and good ears, but also should the own instrument be audible above all other instruments of the band or orchestra. When performing with multiple users on a touch table, all sound is generally output through a single speaker system. This makes it very hard for individual performers to focus on their own instrument.

Although the above problem can partly be solved by giving individual performers better access to the sound of their own instrument (for example by providing headphones to every performer, connected to their own instrument), multi-user music performance will always require certain (advanced) musical skills which can only be mastered by training. Further research is required to determine whether experienced TouchSound users have less trouble with producing music in a multi-user setting.

Compositions

The metaphor of a circle or line for a melody or chord was well understood by all users. Still, as some users correctly mentioned, the simplistic metaphor occluded a user's view on the internals of a composition. That is, users would not be able to identify a composition after it had been made, because of the lack in distinctiveness. Fortunately, users also came up with solutions to this problem.

One solution would be to somehow highlight the notes contained by a composition on the harmonic table, when a user would touch it. Another solution would be to modify the graphical representation of the composition, depending on its contents.

A completely different, but not less interesting solution was brought forward by another user. The idea was to make compositions individually (re)playable, such that a user could identify a composition at all times by simply listening to its contents.

A different phenomenon, though related to the previous, is cluttering of the table. Users felt that they quickly lost track of their compositions, because the table would get cluttered with

the many compositions that were willingly or unwillingly produced. Some users suggested a remove-all function for the harmonic table, which could be triggered by for example a user waving his arm over the harmonic table.

Sequencer

The system parts that received relatively few comments are the sequencers. Nonetheless, the evaluator observed that it took most users quite a while before they completely understood it, if at all.

The sequencer property which provided most confusion, also mentioned by some users during the interviews, was the way on which compositions were attached to the sequencer. It was unclear to users whether compositions would be 'snapped' to discrete positions on the sequencer, or whether their placement on the sequencers was on a continuous scale. When being asked, users generally preferred a 'snapping' sequencer.

Another source of confusion were the small blocks which indicate the position of individual notes on the sequencer. Users generally didn't understand the meaning of these blocks, until being explained. Even then some users critiqued the feature, as it only shows where a note starts, but not how long its duration is.

A suggestion expressed by a user, is to make the playback position of the sequencer controllable to the user. Currently, a user can only start or pause the sequencer, but not influence its position in a more direct manner. Also, it was suggested to make the sequencer longer, such that lengthier compositions could be composed.

Additional instruments

Some users felt they were limited in their musical expressiveness by the instrument(s) provided by TouchSound. Most importantly, users would like the possibility of adding of some kind of rhythm to their compositions.

4.2.4 Discussion

One of the main motives behind this research project, was to create an application which supports *music* performance as opposed to just *sound* performance. To determine music performance is possible with TouchSound, first the term 'music' itself has to be defined. Unfortunately, this poses a problem, as the definition of music has been a constant matter of debate in history, which lasts until today. The only thing which most debaters consider a fact, is that the term 'music' is very subjective: a modern violin piece might sound as beautiful music to one person, while it sounds like the nightly crying of a neighbour's cat to another person.

This subjectivity makes it hard to conclude whether users were able to produce *music* with TouchSound. Participants to the experiments were also quite unsure how to answer the questions concerning the quality of their work. Therefore, they were told to measure the quality of their work by their own musical standards. While this might have induced an unintended bias (due to (non-)modesty), it should give at least a clue about the musical quality of the sound which can be produced with TouchSound.

4.3 Conclusions

Goal of the presented TouchSound system was *"to create an application which enables a multi-user music performance on a touch table"*. This research has shown that, at least to some extent, TouchSound was able to fulfil its goal.

This conclusion is detailed by the answer on the three sub-questions, as they have been formulated in the introduction of this paper.

Are musically inexperienced users able to produce music with this system?

To a certain extent, yes, they are. Considering the short amount of time they were allowed to interact with the system, it is surprising what some users could achieve when it comes to musical performance. Especially users who had used FeelSound before, noted that the music they could produce with TouchSound sounded better than that of FeelSound.

Besides TouchSound's advantage over FeelSound, users also remarked that learning to perform music with TouchSound is easier than with traditional instruments. Hence the system could be a good way to get first-time musicians acquainted with the phenomenon of music performance.

Are musically experienced users able to produce music with this system?

Unfortunately, none of the tested users rated themselves as being an experienced musician. Therefore, the answer to this question remains unknown. It must however be mentioned that 'musical experience' is of course a relative matter. One participant ranked his musical experience as 3 on a 7 point scale. Later, during the interview, he told that he plaid several different instruments in a band, which makes a rating of 3 seem a little modest. When considering the results of the interviews, it seems that moderately experience users certainly *are* capable of producing music with TouchSound. However, musical experience from a traditional instrument might also be frustrating the music production process in TouchSound, as its interface requires a mind-shift from users who are used to traditional instruments. Experienced TouchSound users however, are likely to be advantaged in music production with the application. However, further research is required to confirm this.

Is the system able to support a multi-user performance?

Although only one multi-user experiment has been performed, it is to be expected that TouchSound's interface is suitable for at least two simultaneous performers. As far as the interface is concerned, no substantial problems preventing multi-user performance were detected during the experiment. Although the interface did not hinder multi-user usage, users found it hard to find a suitable way of cooperation and coordination in their multi-user music performance. Further research might investigate whether these problems lessen once users get more experienced with TouchSound.

Overall conclusion

When taking everything into account, it can be concluded that TouchSound indeed succeeded in fulfilling its main goal of providing the possibility for a multi-user, multi-touch music performance. Although the quality of the music produced might not suffice for professional application, TouchSound invoked positive reactions from users, especially amongst them without musical experience. As such, future usage of TouchSound could be envisioned within an experimental, explorative setting. Furthermore, because of the quite unorthodox note layout and intuitive interface, it could also be used by more experienced or professional musicians to get inspiration for performances on more conventional instruments.

While improvements to TouchSound are certainly possible, the application has shown to be an interesting and valuable addition to the range of existing multi-touch music performance systems.

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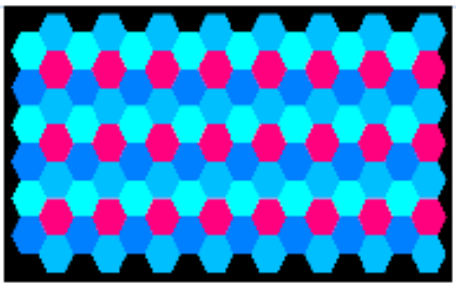
APPENDIX A: TOUCHSOUND QUICKSTART FORM

TouchSound instructions (1)

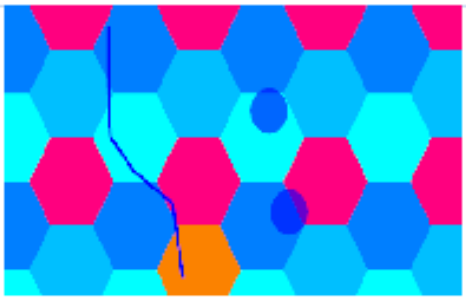


1. To create **musical compositions** with TouchSound, simply **move your finger over the hexagonal grid** in the middle of the table.

2. Musical compositions can be placed in one of the **sequencers**, the horizontal bars with rectangles, on the upper and lower side of the surface.

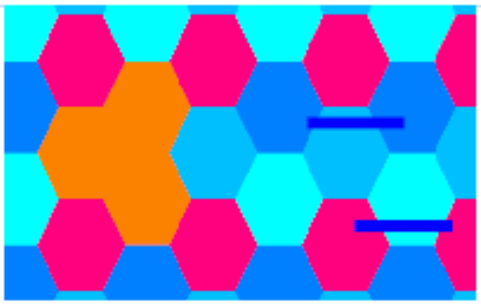
3. When the sequencers are activated (by pressing one of the **play-buttons**), all compositions placed on the sequencer will be played continuously.

4. Use your **record-mode button** to switch between Melody-mode and Chord-mode. The colour shows you which mode is currently active.



5. In Melody-mode, you can **draw lines on the grid** to create a melody. When you're finished drawing, your melody will appear as a circle.

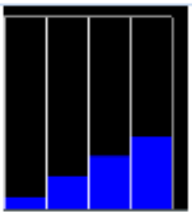
The notes of a melody are played **sequentially** when you drag it onto a sequencer.



6. In Chord-mode, you can **tip on the hexagons** to create a chord. When your chord is finished, click again on one of the notes of the chord. Your chord will appear as a bar.

All notes of a chord are played **together** when its placed on a sequencer.

TouchSound instructions (2)



7. You can use various **control-sliders** to **adjust the sound** of your instrument in real-time.

8. Besides dragging them around, a number of actions can be performed on Melodies and Chords:

- **Removal**: remove a composition by tipping it once
- **Cloning**: duplicate a composition by tipping it twice
- **Resizing** (only for Chords): adjust the duration of a Chord by stretching or compacting it

All actions have been summarized in the below quick-chart:

Action	Result
	
	
	

9. **Last but not least some tips to create nice music:**

- Drawing triangles sounds nice!
- Subtle touches give better results!
- Too many sounds at the same time may harm your musical creation
- *The thing I like most about music, is silence (Mozart)*

APPENDIX B: QUESTIONNAIRE

TOUCHSOUND QUESTIONNAIRE

Please leave blank
Participant Number

Thank you for participating in my research! Please fill out this questionnaire to complete this test.

PERSONAL INFORMATION

Age: _____

Gender: O Male O Female

Please mark the right answer in the following questions:

I have used a touch-table like this one before

O Yes O No

(Skip this question if your previous answer was 'no')
I have used the FeelSound system before

O Yes O No

OTHER QUESTIONS

Please circle the number which represents the degree to which you agree with the following statements:

I am an experienced musician

Not at all						Completely
1	2	3	4	5	6	7

I was able to produce music (as opposed to noise) with TouchSound

Not at all						Completely
1	2	3	4	5	6	7

I was able to produce what I had in mind

Not at all						Completely
1	2	3	4	5	6	7

I like the sound TouchSound's produces

Not at all						Completely
1	2	3	4	5	6	7

The interface of TouchSound felt intuitive

Not at all						Completely
1	2	3	4	5	6	7