SOUNDIA-A Learning Application for Musical Correlations According to "The Musical Space"

Fabian Ehrentraud [a] Monika Di Angelo [b] *

[a] *Vienna University of Technology*
[b] *Vienna University of Technology*

Abstract

"The Musical Space" provides a framework for teaching musical correlations to beginners and experts alike. It does not require any previous knowledge and uses a very unique approach to look at – or listen to – possibly familiar compositional and sound engineering techniques and phenomena.
This paper presents an app (Soundia) for this innovative music teaching concept, where the characteristics of "The Musical Space" are introduced. In this space, sound objects can be placed in a way so that they either disturb or complement each other, or coalesce. They are used to represent musical correlations. Sound objects do not necessarily represent a single instrument. Several instruments might form a single sound object, whereas a single instrument may correlate to several sound objects.
So far, "The Musical Space" was only presented by chalk and blackboard. In order to reach a larger audience outside the class room, a learning application was called for to facilitate the envisioning of "The Musical Space".

Keywords.

INTRODUCTION

Perception of music largely depends on musical listening habits. Therefore, one of the main goals in music teaching lies in the formation of adequate listening skills, to "perk up one's ears".

Gruber developed a teaching concept entitled "on the search for order in music" (Gruber, 2008) in the course of his master degree in composition (with a focus on arts and pedagogy) because he perceived classical music theory as "cluttered". His approach focuses on breaking listening habits in order to enable an abstract access to music, independent of the music genre or instruments. His concept works with analogies to sensual perceptions beyond listening. One of his ideas rests upon the imagination of "The Musical Space" (Ehrentraud, 2013) where sound objects can be placed. As an interesting aspect, these objects can either disturb or complement each other, or coalesce. Using such representations for exemplary songs, Gruber illustrates structures within musical ideas and parallels between different songs. Thereby he instills abstract and active music listening skills.

While diverse music visualizations are mainly used for teaching musical instruments or music theory (Ferguson, Moere, & Cabrera, 2005; Ng & Nesi, 2008; Percival, Wang, & Tzanetakis, 2007; Smoliar, Waterworth, & Kellok, 1995; Yin, Wang, & Hsu, 2005), none of these systems uses visualization in a way similar to Gruber's musical space. Within reacTable (Jordà, 2003a, 2003b) sound objects can be placed on a round plane. There is no visualization of a possible acoustic fit of the objects, though.

In contemporary music software, object representations are often used to illustrate sound characteristics, like in Blip Shaper by subcycle labs (BlipShaper, 2013), or to visualize sound producing correlations of single elements in non-linear sequencers, like NodeBeat (NodeBeat, 2013). Nevertheless, these visual representations were helpful in finding suitable visualizations for Soundia.

Some musicians use graphical notations, as outlined in (Cage, 1969). They equally represent sound objects in a visual manner. Most of these notations are read on a time scale left to right, and do not represent a space.

The positive effect of visualizations (among other tools) on the grasp of music theory or instruments has been widely documented (e.g. Fober, Letz, & Orlarey, 2007; Gkiokas, 2008; Knight, Boulliot, & Cooperstock, 2012; Yin et al., 2005). There are also intentions to establish educational standards for music teaching, for example with the pilot study "HarmoS Musik" (Huber, 2008) where Huber defines seven categories for pedagogical goals for music teaching.

Currently, the visualization of "The Musical Space" is done via drawings on the blackboard or scribbling on paper. It rather concentrates on representing relationships between the sound object graphically, and describing

E-mail address: werteplus@gmail.com

its qualities verbally with visual analogies. Since so many analogies within “The Musical Space” are borrowed from the visual domain, the teaching could be supported by an interactive learning app. Note that a visual representation of sound objects themselves wasn’t part of the original teaching concept, and represents a major contribution of this work. Its goal is to facilitate a playful and interactive way to comprehend music within “The Musical Space”.

This leads to the research questions: “To what extent is an interactive visualization of “The Musical Space” and its ideas helpful for the comprehension of musical correlations as laid out in the original teaching concept?” and “To what extent does it facilitate the recognition of these correlations in similar contexts?”
To reach the set objectives, the following methods were used:

- Gruber was interviewed to provide his teaching concept in written form.
- Educational goals and scenarios were derived using Bloom’s Taxonomy (Bloom, Engelhart, Furst, W.H., & Krathwohl, 1956).
- A concept for the visualization and user interaction was created to account for the defined educational goals.
- For selected parts of the visualization concept a prototype was implemented.
- To test for a successful achievement of the set goals, an evaluation was conducted.

APP CONCEPT

This section introduces the learning application’s concept by defining general parameters, aspired teaching goals, a suitable example scenario, essential and optional requirements, and appropriate learning steps. These lay out the basics for the prototype implementation and the subsequent evaluation.

General Parameters

The intended audience has been set to teenagers from 16 years of age and adults who hold an interest in music and have some spatial sense. Concerning language understanding, they should be familiar with the notion of “dimension” and “3D space”. Furthermore, a certain amount of self-reliance and autonomy with respect to learning activities is expected, since the app represents an informal learning tool.

Teaching goals

From Gruber’s teaching concept (Ehrentraud, 2013) the following teaching goals could be derived that deal with the comprehension and application of the concepts of “The Musical Space”:
The student is able to

L1. classify a sound into the four presented categories of sound generation.
(Understand/Classifying)
L2. classify a sound into the categories “undefined“ and “defined“.
(Understand/Classifying)
L3. recall the basic categories of extra-musical terms for sound description.
(Remember/Recalling)
L4. use suitable non-musical vocabulary for sound description.
(Understand/Inferring)
L5. distinguish a sound within a piece of music according to a given sound description.
(Analyze/Differentiating)
L6. define a given sound by means of a sound description.
(Apply/Implementing)
L7. partition a perceived piece of music into sound objects and arrange them within “The Musical Space” graphically or in his/her mind.
(Analyze/Organizing)
L8. assign one or more of the roles rhythm, harmony, and melody to a sound within a piece of music.
(Analyze/Attributing)
L9. discover correlations between sound objects within a piece of music.
(Analyze/Organizing)
L10. compare several pieces of music with respect to sound descriptions, sound generation category, roles of sound objects, and overall sound impression.
(Evaluate/Critiquing)

L11. make qualitative statements about balance, limits (within the panorama, the pitch, and the offset in depth), colorfulness and overall sound impression of a piece of music using the analogy of “The Musical Space”. (Evaluate/Critiquing)
L12. recognize colliding sound objects in a piece of music. (Evaluate/Checking)
L13. use predefined methods for resolving collisions. (Apply/Execute)
L14. achieve improvements in the sound impression of a piece of music by applying insights gained by inspection in the domain of “The Musical Space”. (Create/Generating)

Table 1 shows the arrangement of these teaching goals within the revised scheme of Bloom’s taxonomy of the cognitive domain (Krathwohl, 2002).

Cognitive Process / Knowledge	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	L3	L1, L2	L6	L5, L7, L9	L10, L11	
Conceptual	L3	L1, L2, L4	L6, L13	L7, L8, L9	L10, L11	L14
Procedural			L6, L13	L5, L7, L9	L10, L11, L12	L14
Metacognitive				L7, L9		

Table 1: Teaching goals in Soundia according to the revised Bloom’s taxonomy (Krathwohl, 2002).

Example Scenario for L7

In order to achieve the stated teaching goals, a collection of 28 interactive learning scenarios was designed. One of these was selected for realization as a prototype app. The scenario intends to satisfy teaching goal L7:

Multiple sounds are played back and are displayed in “The Musical Space”. Details correlating to the basic dimensions are explained. Additional characteristics like ranges where pitch becomes indiscernible or locatability of low pitches are shown. To place emphasis on interactivity, several sounds are played back simultaneously, with the option to mute single sounds. A more sophisticated way of interaction could be achieved by making sound objects moveable within the dimensions of “The Musical Space”. This influences pitch, panorama, offset in depth, and possibly also their sound description.

Requirements

In order to develop a useful learning application, the selected example scenario was analyzed for basic and advanced requirements. Basic requirements cover the teaching goals with a minimal amount of interactivity:

- 2D visualization of “The Musical Space”.
- Non-interactive visualization of single sound objects by simple rectangles representing position and expansion.
- Non-interactive audio output for sound examples. At least one contrasting sound example for each explanation step.
- Explanation of the dimensions of “The Musical Space”.
- Explanation of ranges where pitch becomes indiscernible.
- Explanation of the dependence between locatability and the pitch of a sound.
- Explanations are given in written form next to the visualization of “The Musical Space”.
- “Next” and “Previous” buttons to jump between explanation steps.
- Additional requirements cover advanced ways of interaction:
- Controls to interactively adjust position and expansion of sound objects.
- Manipulating sound objects influences sound output. For example, if the height of a sound object in the pitch dimension is being increased, then the notes are distributed in the chosen pitch range.
- Explanation steps are shown in the manner of the “steps-left” pattern, and it is possible to jump freely between explanation steps.

Explanation Steps

The subject area was split up into 6 main topics and several small explanation steps to facilitate comprehension:

- Introduction – 7 steps
- Panorama – 3 steps
- Pitch – 3 steps
- Offset in depth – 2 steps
- Ranges of indiscernible pitch – 2 steps
- Locatability – 2 steps

PROTOTYPE APP

In order to reduce the complexity of the overall system, it has been subdivided into functional components and their respective interplay. Then suitable technologies for the implementation of these abstract functions were selected, and the interfaces were defined. An important aspect was the representation of the sound parameters and the visual elements.

Functional Concept

The functional concept comprises three components, as shown in Figure 2. The component “Musical Brain” is a master controller which supervises the scenarios (e.g. help texts, size and positioning of sound objects), and controls the communication between the scenarios. The component “Visualization & Interaction” is responsible for the UI and the communication with the user. The component “Audio Generation” takes abstract parameters from the “Musical Brain” and transforms them to acoustically useful ones.

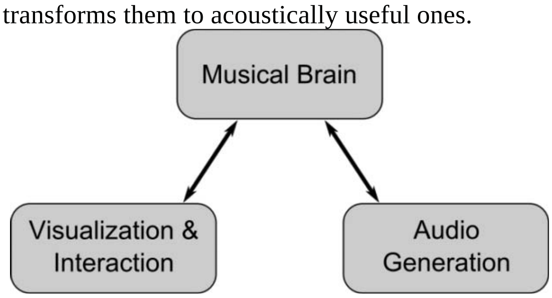

Figure 2: Main components of the prototype

Implementation

After some initial test, Java in combination with Processing, as well as FL Studio and Flowstone for a real-time sound generation were chosen for the implementation.
Figure 3 depicts the interplay of the applied technologies. While the functional components “Musical Brain” and “Visualization & Interaction” are implemented entirely in Java, the component “Audio Generation” had to be split up into a Java part, a Flowstone part, and an FL Studio part. In general, Java provides abstract audio parameters via TCP to Flowstone which itself is embedded into FL Studio as a plug-in. Flowstone decodes the TCP messages and converts them into commands for FL Studio.

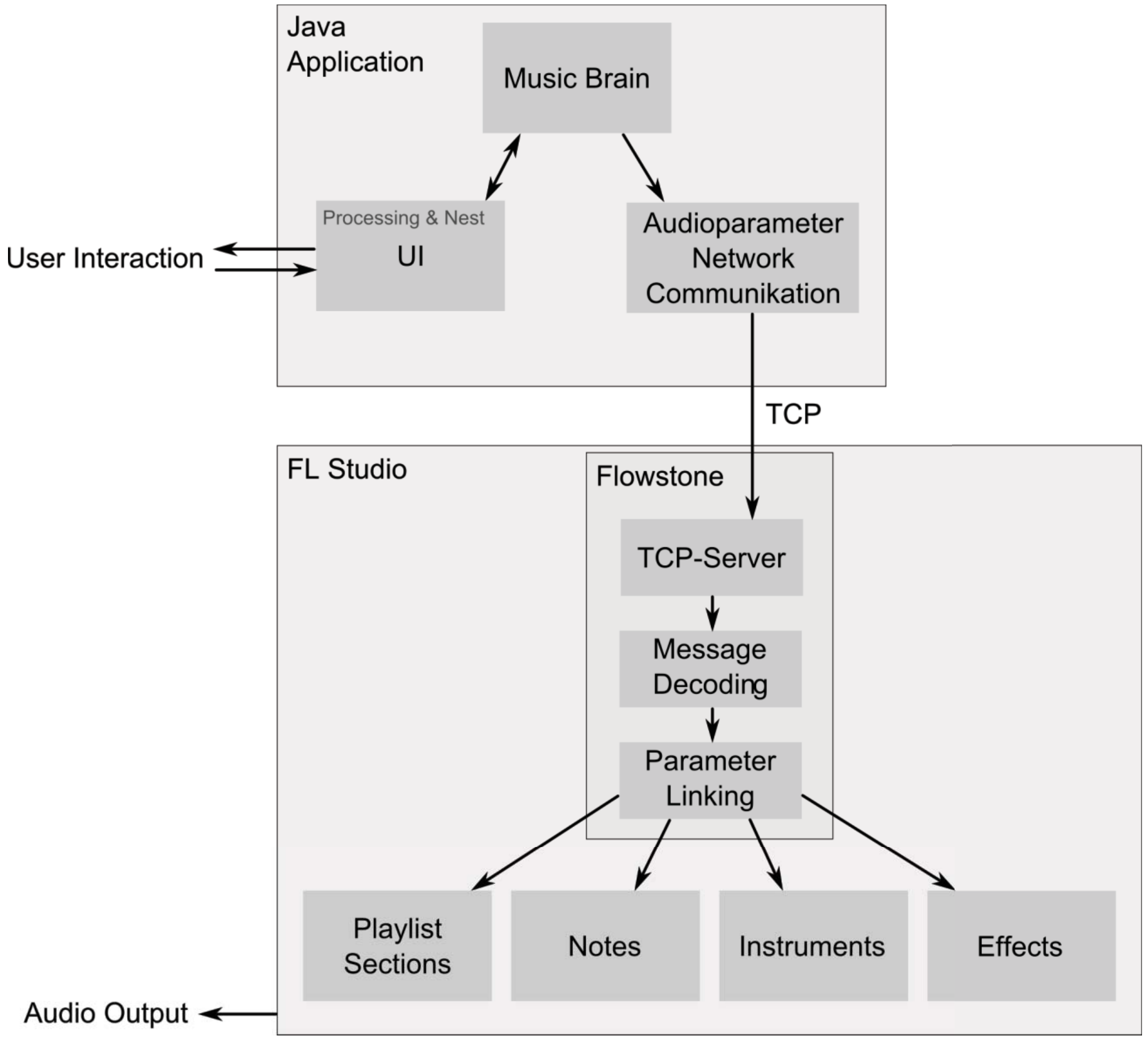

Figure 3: Implementation architecture

The usage of the network protocol TCP generally enables the distribution of the app onto two separate computers. This has been successfully tested and resulted in a marginally higher latency caused by the network communication.

Processing

With Processing one can either use the included IDE for developing an app, or its core library only is used in a regular Java project. Soundia was developed as a Java project since it allowed the inclusion of regular Java libraries and the use of the IDE Eclipse. Apart from the Java standard libraries the Processing library Nest was used in order to implement the UI with components as a scene graph.

FL Studio

With the digital workstation FL Studio it is possible to record music, generate music with synthesizers or add audio effects. This software tool was selected because of its large freedom in generating and manipulating synthetic sounds. Furthermore, it allows the change of notes in real-time that have been imported via Flowstone. Additionally, pieces of music can be partitioned with song markers which are used as jump targets. These markers are used in Soundia to delimit sound examples.

Flowstone

Flowstone is a visual programming environment that runs as a plug-in in FL Studio. It facilitates the generation and processing of audio, MIDI, and control data. A screenshot of the Flowstone interface can be seen in Figure 4 where the first layer of the audio generation is depicted.

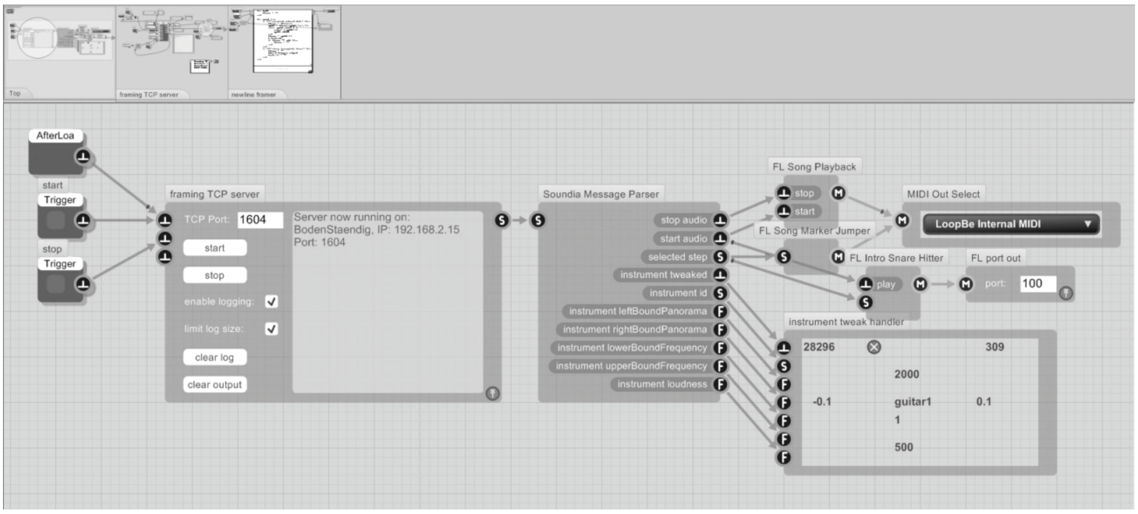

Figure 4: Screenshot of Flowstone showing the first layer of the audio generation

The plug-in for Flowstone offers a module for TCP communication and one for controlling FL Studio. With this it represents an interface between the abstract Java sound objects and the audible examples in FL Studio. Hence it provides means to jump between audio examples, to manipulate effects like echo, or to play and change MIDI notes.

Interfaces

Music Brain → UI

- show the start screen
- show the learning scenario
- jump to an explanation step within the scenario
- show the end screen

UI → Music Brain

- click the start button to start the learning scenario
- click the back button
- select an explanation step
- indicate the completion of a step
- transfer the position and range of each sound object after manipulation by the user

Music Brain → Audio parameter-network communication

- forward position and range of each sound object
- stop audio rendition
- select an explanation step to load the respective music example

Audio parameter-network communication → Flowstone

This interface transfers data via TCP with the Java application as client and Flowstone as server. TCP was chosen because it represents a standard communication between software components. Its advantage over UDP lies in the guaranteed correct transmission of data.

Soundia uses four types of messages. These are shown below with typical values:

- stopAudio
- startAudio
- selectStep=stepX
- instrumentParameters={instrumentId=instrumentX;leftBoundPanorama=-1.0;rightBoundPanorama=1.0;lowerBoundFrequency=20;upperBoundFrequency=200 00;loudness=1.0}

Flowstone → FL Studio

Flowstone translates the received messages into commands for FL Studio. The first three messages (start and stop of audio renditions, as well as jumps to song markers) are translated into MIDI messages. The changes of parameters of sound objects (fourth message type) are translated into FL Studio parameters.

Sound Parameters

For the prototype it was necessary to find acoustic representations of visually changeable parameters. According to Gruber's teaching concept arbitrary pieces of music are representable in "The Musical Space". This doesn't necessarily include that a certain visual representation results in a single acoustic representation. Therefore certain acoustic representations have been chosen for each interaction in the prototype. These affect the three dimension of "The Musical Space".

Dimension: Stereo Panorama

The pan parameter of the mixer has been associated with the movement of a sound object in the stereo panorama. This proved as simple and effective. The change of the width in the stereo panorama eventually was associated with a stereo separation effect which made the sound effectively seem wider or less wide.

Dimension: Pitch

It took a lot of research to make this dimension interactively changeable. In the prototype it has been solved by means of a real-time manipulation of MIDI notes.

Dimension: Offset in depth

Initially this parameter has been associated with the volume of the mixer only. The acoustic rendition could be improved by adding reverb. When the sound object is moved to the back, its volume is decreased and its reverb is increased simultaneously. This seemingly moves the sound object further away, even if there is only one object.

Visual Elements

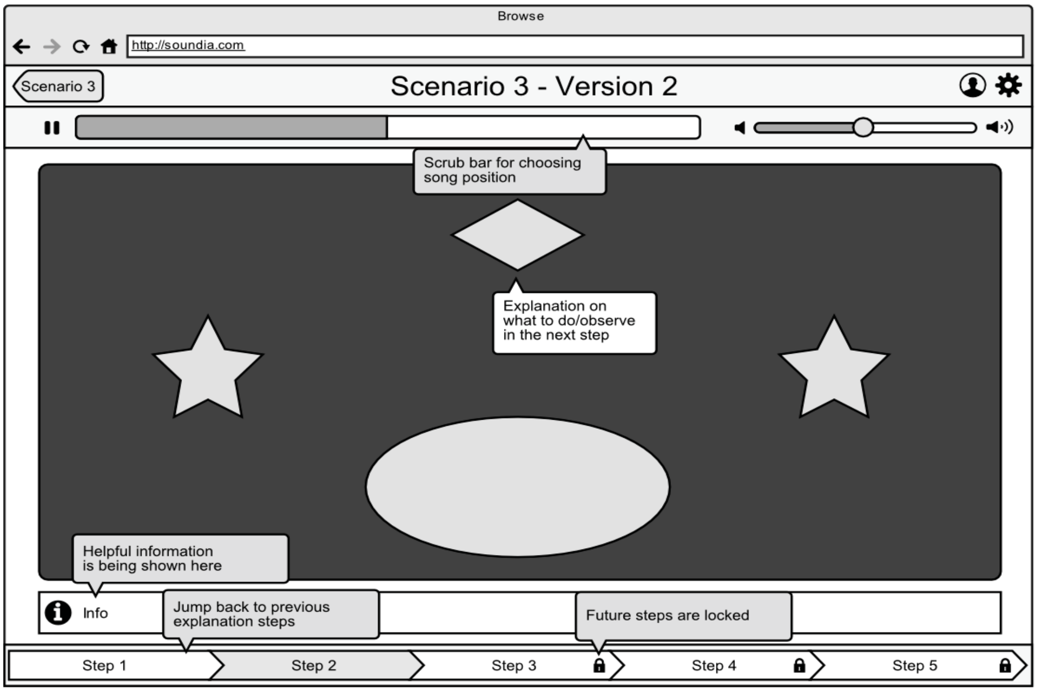

Figure 5: General UI concept, mock-up

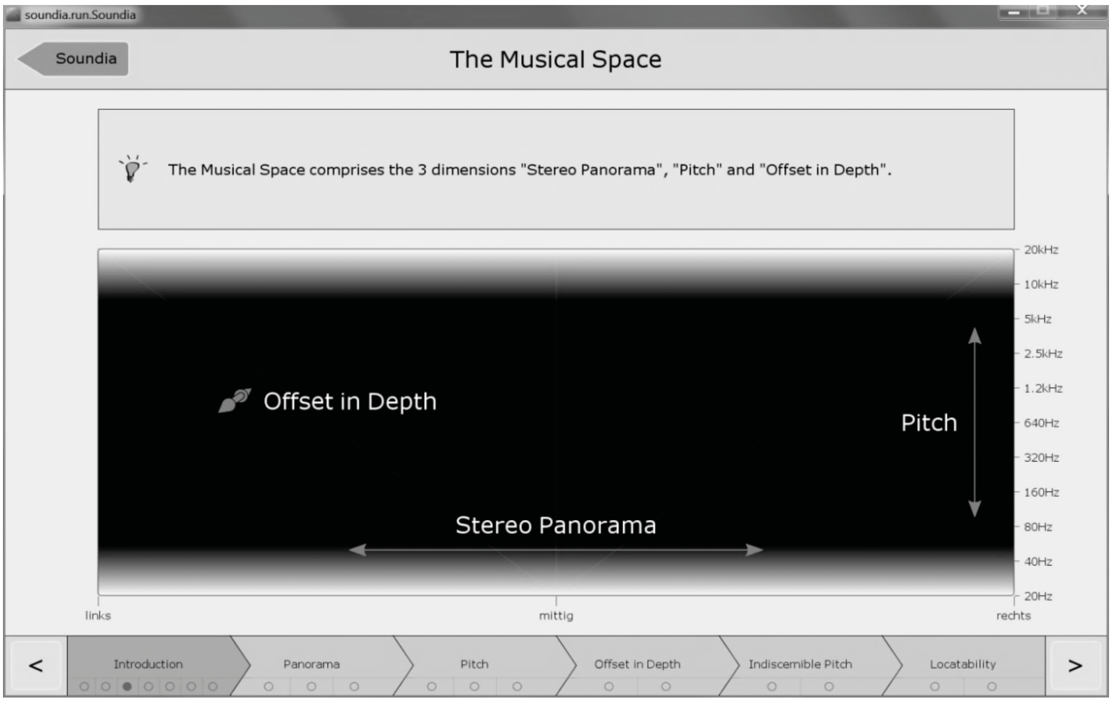

Figure 6: Visual representation of “The Musical Space” within SOUNDIA. Introduction of the three dimensions: pitch measured in Hertz, stereo panorama as in left/right, and offset in depth as in overlapping objects.

The interaction area is detailed in Figure 7. Special ranges at the top and the bottom are represented by a black-to-white gradient to mark it as an area of indiscernible pitch. Sound locatability in dependence of pitch is denoted via diagonal lines.

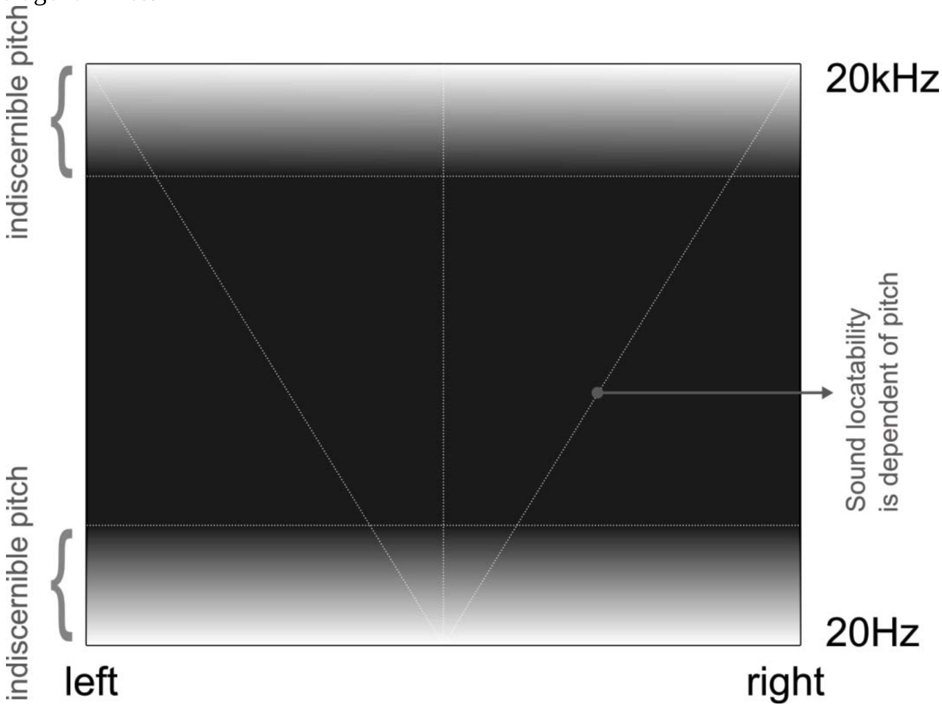

Figure 7: Special ranges in stereo panorama and pitch

In Figure 8 a top-down view on the 3D-space is shown. This visual concept was designed for a learning scenario other than the realized one, but it denotes how louder sounds can mask more quiet ones.

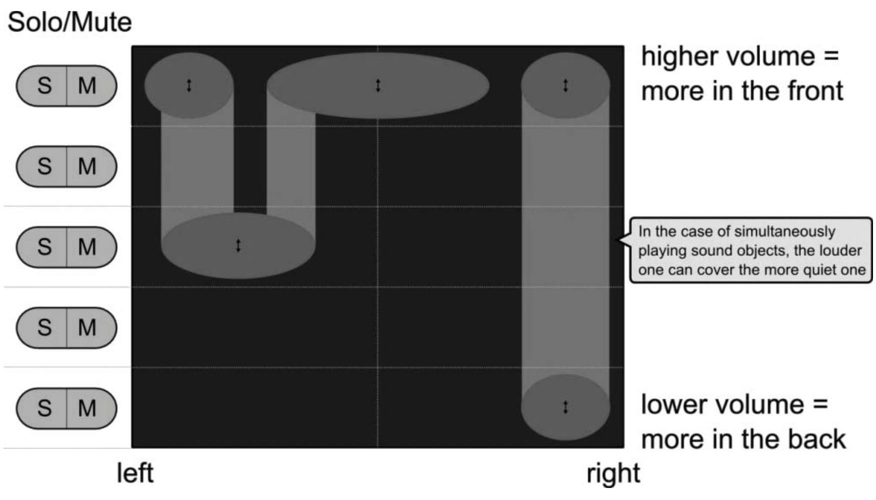

Figure 8: Offset in depth

Figure 9 shows the concept for a visual representation of sound object descriptions. For the prototype this was not employed, but it will be necessary for the realization of further scenarios.

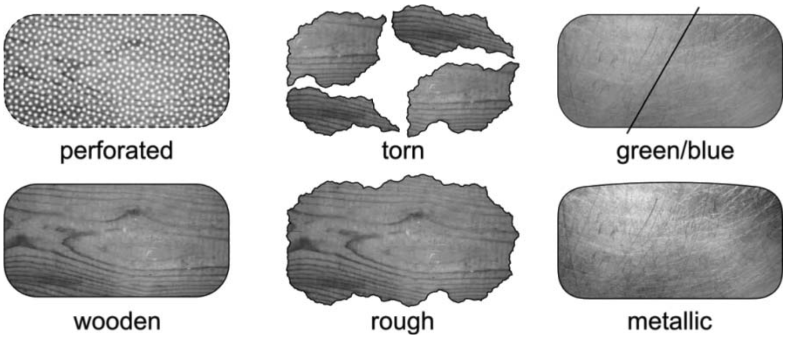

Figure 9: Representation of sound objects

EVALUATION

The evaluation was done with a group of eight test subjects with diverse educational background. After using the app the test persons were asked questions about the presented music theory and had to solve practical exercises. Their responses were all well-considered. It could be shown that the app is suited even for people without previous musical knowledge, and that it increased the interest in musical concepts. The test persons appreciated the possibility to interactively visualize music. They found the app instructive.

The feedback also showed that for some parts visual representations should be improved. The representation for the offset in depth caused problems for some test persons. There is also a discrepancy between the musical impressions of a test person and the teaching concept, as could be seen with the locatability of low pitches. Furthermore, there is no visual representation for time in the prototype.

It could be concluded that the interactive visualization proved to foster the understanding of musical correlations as intended. Another finding was that test subjects were pleased with the playful way to learn with this software, and were motivated to engage further in the learning contents.

CONCLUSION

The focus of this work was an interactive visualization of “The Musical Space” by means of a learning app. It could be shown that this app supports the comprehension of musical correlations as intended.

Firstly, Gruber was interviewed to lay down his ideas of “The Musical Space”. Based on this interview, 14 learning goals could be derived. In order to devise a learning app, these goals were embedded into 28 scenarios. Additionally, an appropriate visualization and interaction concept was developed. In order to evaluate the approach, one of the scenarios was chosen to be implemented as a prototype. The evaluation was done with eight test persons. While it generally proved the usefulness of the app for the comprehension of “The Musical Space” and its teaching goals, it pointed out some problems and suggestions for improvement.

Inevitably, there is a limitation for any possible implementation: auditory impressions and imaginations happen on an individual basis. Therefore visualization can only be offered by way of choice. This could be seen in the variety of solutions to the practical exercises of the evaluation. Nevertheless, the app in general proved useful, especially since it offers new ways of looking at and listening to music.

In summary, it can be concluded that an interactive implementation of Gruber’s music teaching concept is possible in a way that enhances the comprehension of the teaching goals.

REFERENCES

Bloom, B. S., Engelhart, M. D., Furst, E. J., W.H., H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: Handbook I, The cognitive domain*. (B. S. Bloom, Ed.). David McKay.

Cage, J. (1969). *Notations*. Chelsea, Manhattan: Something Else Press.

Ehrentraud, F. (2013). *Soundia - Eine Applikation zum Erlernen musikalischer Zusammenhänge mittels Ideen des Musikalischen Raums*. Master Thesis at Vienna University of Technology.

Ferguson, S., Moere, A. V., & Cabrera, D. (2005). Seeing Sound: Real-Time Sound Visualisation in Visual Feedback Loops Used for Training Musicians. In *Proc. IEEE International Conference on Information Visualisation (IV’05)*. IEEE.

Fober, D., Letz, S., & Orlarey, Y. (2007). VEMUS - Feedback and groupware technologies for music instrument learning. In *Proc. 4th International Music Conference*. Lefkada, Greece.

Gkiokas, A. (2008). Real-time detection and visualization of clarinet bad sounds. In *Proc. Digital Audio Effects*

Conference (DAFX08) (pp. 59–62). Espoo, Finland.
Gruber, C. (2008). Blog "Die Suche nach Ordnung in der Musik." Retrieved from http://ordnung-in-der-musik.blogspot.co.at/
Huber, J. (2008). *Standards im Musikunterricht, Pilotstudie. Forschungsbericht Nr. 9*. Luzern, Switzerland.
Jordà, S. (2003a). Sonigraphical instruments: from FMOL to the reacTable*. In *Proc. New Interfaces for Musical Expression (NIME-03)*. Montreal, Canada.
Jordà, S. (2003b). Interactive music systems for everyone: exploring visual feedback as a way for creating more intuitive, efficient and learnable instruments. In *Proc. Stockholm Music Acoustics Conference*. Stockholm, Sweden.
Knight, T., Boulliot, N., & Cooperstock, J. R. (2012). Visualization feedback for musical ensemble practice: a case study on phrase articulation and dynamics. *IS&T/SPIE Electronic Imaging*.
Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory Into Practice*, *41*(4), 212–218.
Ng, K., & Nesi, P. (2008). i-Maestro Framework and Interactive Multimedia Tools for Technology-Enhanced Learning and Teaching for Music. In *Proc. IEEE International Conference on Automated Solutions for Cross Media Content and Multi-Channel Distribution*. IEEE.
Percival, G., Wang, Y., & Tzanetakis, G. (2007). Effective use of multimedia for computer-assisted musical instrument tutoring. In *Proc. ACM international workshop on Educational multimedia and multimedia education (Emme'07)*. ACM Press.
Smoliar, S. W., Waterworth, J. A., & Kellok, P. R. (1995). pianoFORTE. In *Proc. ACM international conference on Multimedia (MULTIMEDIA'95)*. ACM Press.
Yin, J., Wang, Y., & Hsu, D. (2005). Digital violin tutor. In *Proc. ACM international conference on Multimedia (MULTIMEDIA'05)*. ACM Press.

BlipShaper (2013), http://www.subcycle.org/
NodeBeat (2013). http://nodebeat.com/