PaperTonnetz: Supporting Music Composition with Interactive Paper

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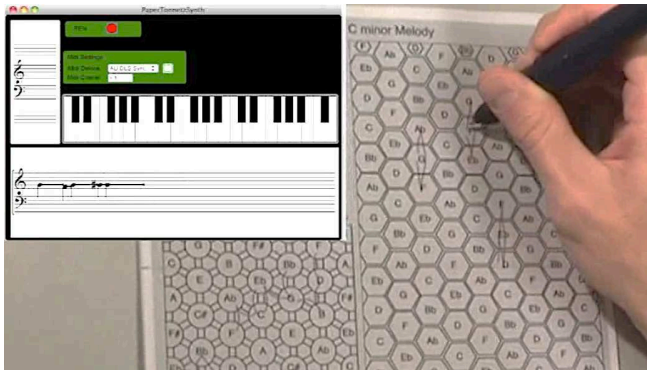

Figure 1: Using the paper interface with the digital pen to create and listen musical sequence on the computer.

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Abstract
A Tonnetz, or “tone-network“ in German, is a two-dimensional representation of the relationships among musical pitches. In this paper, we present *PaperTonnetz*, a tool that lets musicians explore and compose music with Tonnetz representations by making gestures on interactive paper. In addition to triggering musical notes with the pen as a button based-interface, the drawn gestures become interactive paths that can be used as chords or melodies to support composition.

Author Keywords
Music, Composition, Interactive Paper, Tonnetz.

ACM Classification Keywords
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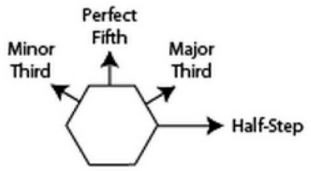
Available Pitch Layouts

PaperTonnetz lets users compose with several hexagonal tonnetz layouts.

Tonnetz layouts are organized along three main directions (diagonal-right, diagonal-left, vertical), each associated with a constant interval. In the neo-riemannian Tonnetz, these intervals are the major third, the minor third and the fifth. This Tonnetz is suitable for creating and analyzing chord progressions.



Heptatonic layouts are built from a seven-pitch (heptatonic) scale. The organization in space does not preserve chromatic intervals but rather the steps inside the scale. Any path inside this type of tonnetz produces a melody in the associated tonality.

Introduction

This paper presents *PaperTonnetz* [2]: composers can create their own Tonnetze, print them on interactive paper, and 'play' them with a pen. A Tonnetz, or "tone-network" in German, is a two-dimensional representation of the relationships among pitches. Created by Euler in 1739 to represent acoustic distances between pitches, Tonnetze are used today to support musical analysis and performance. For example, systems such as Harmony Space [4] and Isochords [1] allow composers to analyze chords, harmony and MIDI sequences using different Tonnetz representations. Tablet-based systems such as Musix [8] and IsoKey [9] offer users a customizable isomorphic layout on the screen. Users can perform music by pressing the hexagonal cells, producing individual pitches, melodies and chord patterns.

We are interested in another role for Tonnetze, *i.e.* to support music composition. We were inspired by Jean-Marc Chouvel's composition process in which he designs his own Tonnetze, prints them on paper, and then generates chords and melodies. In **Figure 2,** he draws paths through Tonnetz cells which provide the inherent order necessary to define musical elements. After exploring his ideas, he then translates them into standard musical notation on a score. We wanted to take his approach one step further by linking paths drawn on a paper Tonnetz with online composition tools, as in **Figure 1**. Here, a user interacts with the path he drew on a tonnetz printed on paper in order to listen and visualize the corresponding melody on the computer.

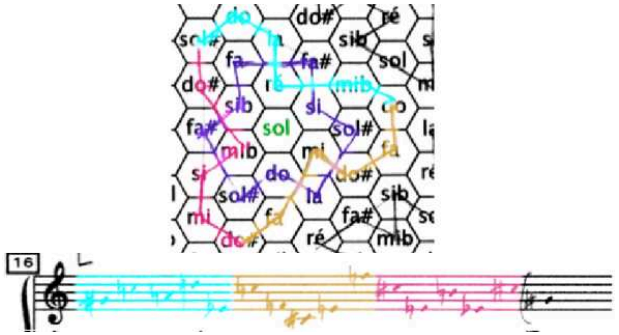


Figure 2: Chouvel's work on paper for his piece *Traversée*. The composer translates drawn shapes in a score and operates geometrical transformations to create variations.

Prior works

In previous work, we observed that even composers well-versed in computer technology still rely on pen and paper to express and explore their musical ideas [3,5]. We thus developed and explored several techniques that incorporate interactive paper into the composition process. For example, Musink [6] allows composers to define their own vocabulary of annotations on musical scores, which can then be interpreted as functions in computer-aided music composition software. Similarly, InkSplorer [3] lets composers experiment with different curves drawn on paper to control computer-based algorithms and then use them as a resource for new compositions.

PaperTonnetz: Design and implementation

PaperTonnetz supports creating, printing and interacting with Tonnetze that are printed on interactive paper. *PaperTonnetz* is designed primarily for composition, enabling the composer to capture, replay, transform and compare melodies and chords. However it can also be used as a simple performance tool,

Supporting three main musical activities

Discovery: *PaperTonnetz* makes each cell and path interactive so they can reveal their musical properties and functionalities. This allows both novices and experts to discover their properties, with real-time auditory feedback.

Improvisation: *PaperTonnetz* makes previously drawn paths accessible for future interaction. The user can create individual chords or melodies and then reuse them to explore different musical possibilities.

Assembly: *PaperTonnetz* enables expert users to capture musical sequences based on their improvisations and to export them to other music composition systems. *PaperTonnetz* supports both MIDI and OSC protocols, so any musical sequence created with it can be imported and edited in any other dedicated application.

similar to the tablet-based systems described above, but with an emphasis on drawing paths rather than pressing buttons.

Technical details

PaperTonnetz is written in Java and uses ADP-301 digital pens that use Anoto technology to associate strokes captured by a tiny camera on the pen tip with a printed pattern of dots on the paper. These pens communicate in real time via a Bluetooth connection. The application interprets the events coming from the pen and shares runtime data using the Open Sound Control Protocol [7] to a Max/MSP application, which plays pitches in real-time and displays them with common musical notion or routes them to other MIDI- or OSC-compatible applications.

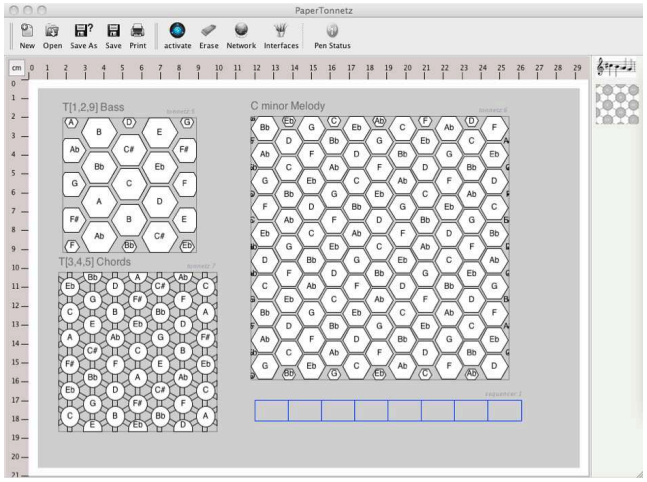


Figure 3: *PaperTonnetz:* The main interface displays the virtual page with three different Tonnetze and one sequencer for assembling chords and melodies.

Creating the paper interface

Composers can design their own paper interfaces, choosing from preconfigured Tonnetze. They next define musical and graphical properties and lay them out on a virtual page. They then print their custom Tonnetz directly onto one of 20 unique pages printed with an Anoto dot pattern and begin interacting with the pen. **Figure 3** shows the graphical user interface with three different Tonnetze and a sequencer.

Interacting with Pen and Paper

Users can explore the different auditory relationships among pitches by clicking on cells and drawing paths through them. The duration of each pitch is defined by the length of time that the pen stays within each cell. More advanced musicians can capture their own improvisations to explore musical ideas in real time.

Replaying paths

Once a path is draw on paper, it becomes an interactive element that the composer can use and reuse. The composer can either treat it as a melody, clicking on any line with the pen tip to replay the initial gesture, or as a chord, holding the pen on the line to play all the notes touched by the line. This simple mechanism lets users interact with their own explorations with live audio feedback.

Assembling paths

PaperTonnetz supports the assembly of paths into tracks. To create a new track, the user draws a stroke in the sequencer's recording area. All paths selected as a melody or as a chord are added to the track. The user can stop recording by drawing a crossing stroke on the track. The track can now be listened to and viewed in the Max/MSP application for editing or further

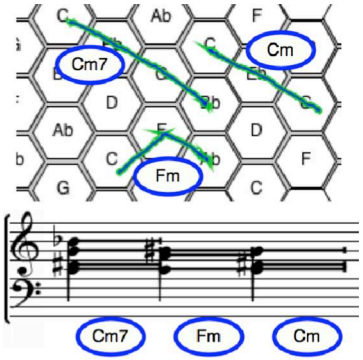


Figure 4: Top: Visualization of drawn paths in the C-minor heptatonic Tonnetz. Bottom: A sequence created with the three paths treated as chords.

processing. Figure 4 illustrates a scenario in which three paths drawn on a paper Tonnetz are assembled and displayed in a track.

Discussion and Conclusion

We demonstrated an early version of *PaperTonnetz* at the Paris *Palais de la Découverte* to discover how musicians and non-musicians respond to an interactive paper Tonnetz interface. Non-musicians began by scribbling on paper to sonify their gestures, without any idea of what it might sound like. In contrast, musicians started with musical ideas, such as scales or chords, and tried to represent them directly in the Tonnetz space. The system's latency was short enough, around 40 milliseconds, such that participants did not notice it.

PaperTonnetz integrates handwritten gestures into interaction with paper so users can create chords and musical sequences. We developed a set of interaction techniques that facilitate the discovery, improvisation and assembly of musical sequences on paper. We also created a graphical user interface that lets composers build their own interactive paper interfaces. Future work will include close collaboration with composers, so we can extend their ability to control the interface. We plan, for example, to investigate rhythm representations and multiple pen inputs. Moreover, further pitch layouts could take octaves and microtone intervals into account.

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