SORISU: Sound with Numbers

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Abstract

It is surely not difficult for anyone with experience in the subject known as Music Theory to realize that there is a very definite and precise relationship between music and mathematics. This paper describes the SoriSu, a new electronic musical instrument based on Sudoku puzzles, which probe the expressive possibilities of mathematical concepts in music. The concept proposes a new way of mapping numbers to sound. This interface was designed to provide easy and pleasing access to music for users who are unfamiliar or uncomfortable with current musical devices. The motivation behind the project is presented, as well as hardware and software design.

Keywords: Numbers, Game Interfaces, Mathematics and Sound, Mathematics in Music, Puzzles, Tangible User Interfaces.

1. Introduction

"Music is a secret arithmetical exercise and the person who indulges in it does not realize that he is manipulating numbers."

- G. Wilhelm Leibniz (1646-1716)

At first sight, music and mathematics are two completely different disciplines. However, there are many co-relational [1] and historical accounts [2] of relationships and similarities between mathematics and music. [3 4]

Figure 1. SoriSu

SoriSu (Figure1) is a project that explores the relationship between numbers and sound through play that is simultaneously mathematical and musical. The interface allows users to manipulate sound by placing blocks onto a Sudoku puzzle board while playing a game. One or more players can play with SoriSu using blocks. Every performance is unique because the sequence, timing, and combination possibilities are completely in the hands of the players.

2. Motivation

2.1 Previous Work

SoriSu builds upon my earlier investigations into interactive devices that map music and mathematics. In 2007, I developed Abacus, a calculable music controller incorporating a real 1:4 bead Korean abacus. Abacus is designed to function in two capacities at once: as a calculator to solve arithmetic problems and as a musical controller. This novel interface was my first investigation into ways of relating music and mathematics. (Figure 2)

Figure 2. Abacus

2.2 Performance Experience

In December of 2007, I used an Abacus in a live performance at Exit Art, a gallery in New York City. Simple arithmetic questions appeared on a screen behind me, and I moved Abacus beads to find their solutions. During the performance, the audience shouted answers even before I finished my calculations with Abacus. After the show, I was also able to observe a variety of users and receive feedback. This experience with audience interaction prompted me to consider developing a project that is more fun and easy to play. SoriSu is conceptually connected to the goals of a musical game piece. In a game piece, players follow simple rules to win a game and to invent their own music together. The purpose of the rules is often to restrict the degree to which users can interact with the interface.

Similarly, the Sudoku puzzle has simple rules that create diverse scenarios. My challenge for SoriSu was to design a game with music that would allow people to be creative and spontaneous within reasonable boundaries. With SoriSu, users do not need musical talent. No matter what users try, or how they work with its options, the ultimate result will be something that sounds beautiful.

3. Related Work

3.1 Chance Music – Mozart Dice Game

Musical Dice Game is one of the earliest examples of chance music. The idea is to cut and paste pre-written measures of music together to create a minuet. The basic of the musical dice game consists of 272 musical measures and a table of rules used to select specific measure given a certain dice roll. The result is a randomly selected 16 bar minuet and 16-bar trio. All possible choices were given by Mozart in such a way that by any selection results in a pretty minuet fulfilling the harmonic and compositional requirements of minuets at that time. In a related investigation, serial composers of the 20th century often openly employed algorithmic techniques, and many composers, such as John Cage and Xenakis, used random number generators to compose chance music. [5]

3.2 Algorithmic Generative Music – The Sound of Mathematics

Algorithmic composition is the technique of using generative patterns to create music. Algorithms have been used to compose music for centuries. One of the simplest uses of an algorithm to generate music is a mathematical model that maps mathematical formulae and constants to produce sequences of notes. In Swedish composer Daniel Cummerow's[1] musical works, each compositional fragment is determined by a mathematical recipe through the use of a formula that links numerical digits with musical notes.

3.3 Game as Instruments – ElectroPlankton

ElectroPlankton[2] is an interactive music video game developed by Toshio Iwai, an artist who won accolades for his innovative work that blends images with aural experiences. At the start of the game, each user possesses 10 different Electroplankton species. Each species offers its own style of musical creation.

4. Conceptual Framework

4.1 System Overview

SoriSu is based on Sudoku, a grid-based number game. Each Sudoku puzzle is made up of 81 squares, which form 9 columns, 9 rows, and 9 boxes. Each box is a 3x3 square distinguished by a bold line. The aim of Sudoku is to enter the digits 1 through 9 in the squares without repeating any digit in each column, row or 3x3 square. The level of difficulty depends on how many numbers are initially revealed, which also affects the technique users should employ as they approach each puzzle. To solve the game, users rely on logic derived from narrowing possibilities.

The SoriSu interfaces have three basic layers: a Sudoku puzzle game, the sound system, tangible interface using board and blocks. The tangible interface communicates to a computer running the SoriSu software using Processing[3] and SuperCollider[4]. The Sudoku puzzle program in Processing starts initially with a pre-programmed puzzle, but any puzzle can be generated when the user starts a new game. Once the puzzle is revealed, the user can activate the sound system by placing initial numbers onto a board.

4.2 Sound Synthesis Algorithm

4.2.1 Sound System

A SuperCollider patch was created to map numbers to musical parameters. SuperCollider is an environment and programming language for real time audio synthesis and algorithmic composition. The sound system begins with a basic note and simple pattern. As users play the interface, placing the right number in the right place, the sound system evolves into a richer sound and more delicate pattern.

- Each number corresponds to a basic melodic phrase.
- As the user approaches the solution for the puzzle, the melody becomes more pleasing and sophisticated.

SoriSu consists of a 9x9 array of squares and blocks of nine different numbers that rest in those squares, matching the rules of Sudoku. Each of the nine columns in the grid represents nine notes. Each row is designed to play nine patterns based on the assigned note. One of the nine patterns can be selected, depending on which column is placed by the block right before. Therefore current sound system in SoriSu could be represented as nine synchronized melodic patterns running in parallel.

4.2.2 Pattern Development in Sound System

Music, simply defined, is an ordered pattern of sounds. [6] The strategy of the sound pattern development for SoriSu is based on a Generative Theory of Tonal Music. [7 8] The so-called *root* is the base note of a pattern. [9] A pattern can be constructed from any pitch by building intervals above a given *root*. This *root* can be changed all the time because the way that the user solves the puzzle by narrowing possibilities are various even though the user plays the same Sudoku puzzle with others. In this way, each performance can be a unique musical composition.

- One or more initial notes are given as being the root members of the pattern.

[1] http://www.geocities.com/Vienna/9349
[2] http://electroplankton.nintendods.com
[3] http://processing.org/
[4] http://www.audiosynth.com/

• And one or more modes of combination are specified by which new members of the pattern can be constructed from the root ones or from previously constructed members.

4.2.3 Sound Structure

The following schematic describes the structure of each song produced by the SoriSu interface.

• The lifespan of the SoriSu puzzle is same as the lifespan of the song it produces.

Underlying the sound synthesis system is a sound structure that governs the structure of each song. The song begins when the user starts playing the Sudoku game. As the user proceeds to complete the puzzle, the sound structure changes, depending on how much of the puzzle has been completed. Currently SoriSu follows an ABA'B' type format. A and B correspond to different musical phrases. If people who play SoriSu complete 25% of a puzzle, they can generate sound from the end of the A part and take different turn to another direction of the song. (Figure. 3) In this way, users have the sense that they are really composing a song.

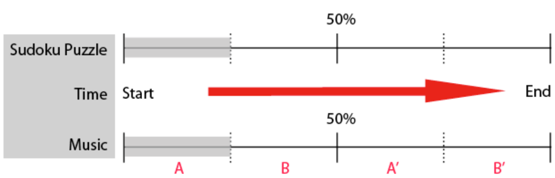

Figure 3. Song Structure

In other words, the song structure inside SoriSu progresses according to a "completion system", where the degree of puzzle completion dictates the song structure. Currently SoriSu follows a Nine Rows and Nine Column Completion format.

• Nine Rows and Nine Columns Completion

A row is a horizontal collection of cells in a Sudoku puzzle. A column is a vertical collection of cells. By scanning the 18 lines of the puzzle (9 rows + 9 columns), users can evaluate how much of the puzzle has been completed. (Figure. 4)

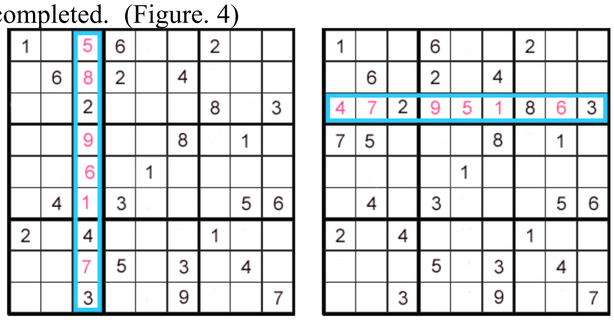

Figure 4. Nine Rows and Nine columns completion.

• Nine Blocks Completion

A block is a 3x3 group of cells in a Sudoku puzzle. Each block contains all of the digits from 1 to 9, with no repetition of digits. A block can be distinguished from normal cells by its thicker border. (Figure 5. Diagram on the right) By scanning the number of completed blocks, the user can evaluate how much of the song has been completed.

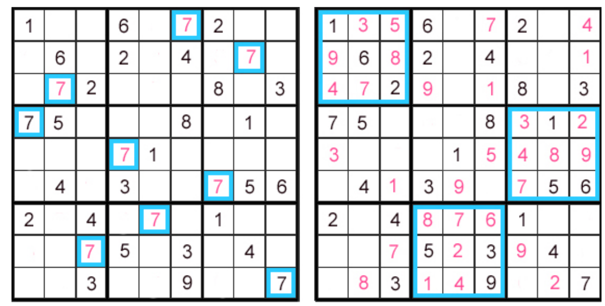

Figure 5. Numbers Completion / Nine Blocks Completion

• Numbers Completion

In Sudoku, each number from 1 to 9 is used 9 times to complete a puzzle. (Figure 5. Diagram on the left)

4.2.4 Features

• If a user makes an incorrect choice, placing the wrong number in a block, the system produces a sound that is clearly outside the melodic pattern, alerting the user.
• The system volume responds to the amount of time it takes to solve the puzzle. If one minute passes without the user moving any block for one minute, the system volume begins to decrease.

5. Technical Framework

5.1 Pen-based Musical Control

The first implementation for SoriSu was a paper-pen based interface similar to a traditional Sudoku puzzle. For prototyping, I used a piece of paper and conductive ink. Conductive ink is applied on the back of the paper in a way that causes the resistance of the ink to change when the paper is marked by a pencil. The carbon in pencil graphite completes a circuit but creates a resistance. This can give analog values. On the front side of paper, there are nine dots inside each square. By connecting each dot, users can write any number from 1 to 9. Figure 6 demonstrates how numbers 2 and 9 are written according to this scheme. Writing the number on the paper connects resistors made of conductive ink on the back of the paper, allowing different analog values can be detected.

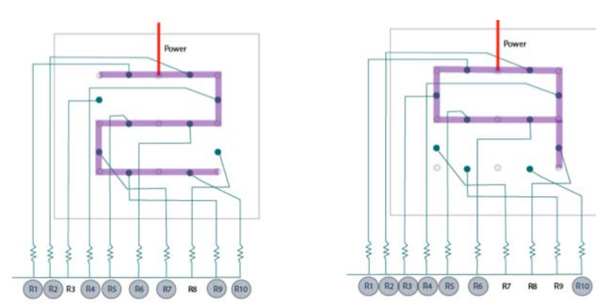

Figure 6. Detect number 2 and 9 using conductive ink.

• Problems encountered
The general expressiveness of the paper interface was initially satisfactory. Over time, however, the resistance from conductive ink would drift and change. These values from the paper circuit were not enough to detect and distinguish numbers 1 to 9. Another problem was the circuit design itself. The user needed to connect nine dots in order to draw numbers, preventing the natural handwriting experience that I wanted to achieve from paper-pen based interface.

5.2 Board and Block System
An alternative, improved, puzzle interface solution uses a board and block system. By using blocks to solve a Sudoku puzzle, users get tactile as well as musical feedback. (Figure. 7)

Figure 7. Board and Blocks.

5.2.1 Overview
The final hardware system for SoriSu consists of a board that is composed of nine rows by nine columns like a normal Sudoku puzzle. The user is able to create and manipulate sound by physically re-arranging the 81 wooden blocks to solve the puzzle. As users place blocks in the grid, the sound samples mapped to each number are played at the appropriate time. All processing is done in real time, providing users with immediate feedback on their interactions with the blocks.

Figure 8. Child playing the SoriSu

5.2.2 Implementation
The numbers in the grid are detected using resistors mounted inside each block. Each block contains resistors that designate its specific identity. Each field within the matrix has two magnetic contact points that read the presence of a block and its resistor value. A separate thread in the processor reads the values from the 9x9 array to control program output. For each default value, the appropriate message is sent to the SuperCollider, which uses the message to generate sound.

6. Conclusion
The starting point of this project was my interest in the correlation between numbers and sound. With SoriSu, I have designed and implemented a music controller that uses Sudoku puzzles to relate music and sound. The SoriSu was demonstrated at the ITP 2008 Spring Show and the Guthman Musical Instrument Competition in 2009. Users quickly understood the SoriSu interface with little or no instruction. After having observed the visitors at an exhibition, I became particularly interested in examining how the game interface can encourage people to play using musical contents. In short, successful game playing adds pleasing layers of melody, while a misplayed block triggers jarring dissonance. With these simple rules, it was enough to entertain people and gave a rewarding experience to their answer to the puzzle. In the future, I would like to explore a way to simplify the framework for musical mapping so that users can get a sense of the change he/she just made in music by placing the right block. In the current system, users can notice music keep changing more beautiful as more they put the right answer but it is hard to tell how they are changed exactly. Also I would like to try different completion systems in addition to pattern development in sound system.

7. Acknowledgements
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