CubeHarmonic: A New Interface from a Magnetic 3D Motion Tracking System to Music Performance

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ABSTRACT

We developed a new musical interface, CubeHarmonic, with the magnetic 3D motion tracking system IM3D. This system precisely tracks positions of tiny, wireless, battery-less, and identifiable markers (LC coils) in real time. The CubeHarmonic is a musical application of the Rubik's cube, with notes on each little piece. Scrambling the cube, we get different chords and chord sequences. Positions of the pieces which contain LC coils are detected through IM3D, and transmitted to the computer to recognize the status of the Rubik's cube, that plays sounds. The central position of the cube is also measured by the LC coils located into the corners of Rubik's cube, and, depending on the position, we can manipulate overall loudness and pitch changes, as in theremin playing. This new instrument, whose first idea comes from mathematical theory of music, can be used as a teaching tool both for math (group theory) and music (music theory, mathematical music theory), as well as a composition device, a new instrument for avant-garde performances, and a recreational tool.

Author Keywords

Rubik's cube, Group Theory, Magnetic 3D Motion Tracking, Music Theory, Performance

CCS Concepts

•**Applied computing** → **Sound and music computing;** Performing arts; •**Human-centered computing** → **Sound-based input / output;**

1. INTRODUCTION

Music and combinatorics have a long tradition of intersections, research, and music composition [2, 5]. We can think of musical dice game (Musikalische Würfelspiele), used to compose from random combinations of pre-composed musical material, with examples by Llull, Haydn, and Mozart [13, 10]. Combinatorics deals with *group theory*. A combination of two elements of a group gives an element of the same group. Groups verify closure, associativity, identity, and invertibility properties [11]. In a *permutation group*, the permutations of a given set (elements) can be composed (operation) giving other permutations of the same set. First developed as a pedagogical tool by Ernö Rubik, the homonymous cube is a toy based on group permutations in three dimensions. In our work[1] (Figure 1), we start from a musical Rubik's cube, the *CubeHarmonic*, to propose a new musical instrument, using a magnetic 3D motion tracking system developed at the Tohoku University [4, 3]. The *CubeHarmonic* was first thought by Maria Mannone in 2013 and then described in a textbook about mathematical music theory [7]. A cube-like device for musical chords connects the concept of *tonnetz* (a 2- or 3-dimensional scheme with points as notes or chords, and paths as connections between them) with the permutations [6], see Section 3.1. Other musical applications of the Rubik's cube were independently proposed in a NIME article [9] and in a TED tutorial[2] [12]. In [12], only a theoretical idea is discussed. In [9], a new device is proposed, where "the precise combination itself is not so compositionally important," "not directly under the performer's control." However, in our case, the precise combinations are compositionally relevant, as well as the performer's control. Moreover, instead of a simple controller, we are considering both precise theoretical reasons, as well as many other musical features (overall loudness and pitch change) creating crossmodal effects.

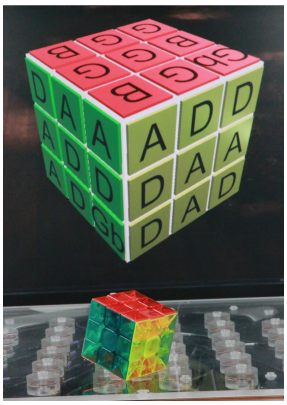

Figure 1: The CubeHarmonic

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[1] See our video: `https://youtu.be/r_wNpQnsWhg`

[2] This tutorial dates back to November 2015, while the book [7] was submitted to Springer in September 2015.

2. MAGNETIC 3D MOTION TRACKING

The system generates a magnetic field to tiny and wireless LC coils. It detects the resonant magnetic flux from the LC coils to compute their 3D location and orientation, see Figure 2 [4, 3]. If the LC coils are attached to a Rubik's cube, we can track in real-time the facets' movements. We can visualize the cube in a virtual environment and convert the facet combination into sounds.

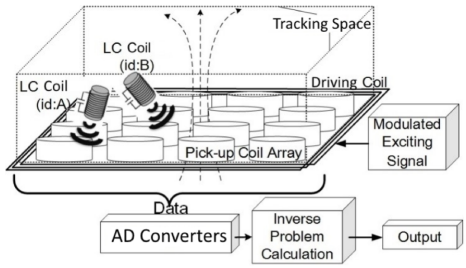

Figure 2: Magnetic 3D motion tracking system

3. MUSICAL PERSPECTIVES

3.1 A tool for music theorists

In [7], a 4x4x4 cube is used for a 4-part harmony. The current prototype is a 3x3x3 cube. With a 3-part harmony, the performer can still enjoy a considerable amount of combinations, with the advantages of easiness in cube's scrambling, and only a few markers (LC coils) for motion tracking. The CubeHarmonic allows a tangible application of *slot-machine transformations*.[3]

3.2 A tool for composers and improvisers

Figure 3 shows a perspective from above of the cube and the magnets. The user can scramble the cube (blue arrow), getting new chords and chord sequences. The overall displacement of the cube (red arrow) changes the overall loudness and pitch; e.g., we can play a diminuendo to silence, or a crescendo with glissando. We can play quarter-tones, and adapt to other instruments' tuning. The pitch-change option can be enabled or disabled. The notes can be customized, determining the degree of harmonic variability. In a performance setup, the combinations given by the cube may constitute an harmonic basis for the other instruments. There is no fixed-tempo sequencer. In our video, we show cube playing featured in a composed cube-piano duo (Mannone's *Hello Cube!*) and in a free improvised trio (with percussion).

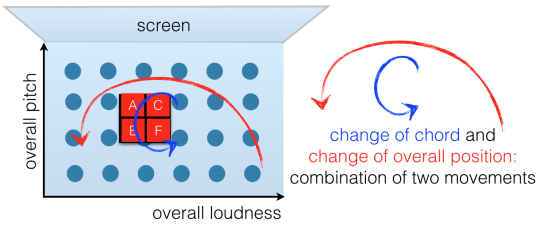

Figure 3: Movements and their musical output

[3]In Music Theory, the slot-machine metaphor refers to a permutation, more than a rotation. Let us imagine to have three discs with three notes each one. The notes of a disc played after the other give a sequence of three 3-note chords. If we rotate one of the discs, the vertical sequence $0-1-2$ will become $1-2-0$: the harmonic content is the same, while the melodic content is not [1].

4. CONCLUSIONS AND FUTURE WORK

The advantages of our device are the easiness to use, the possibility to customize the harmonic material, and the easiness to 'reset.' In fact, to go back to the initial "unscrambled" configuration, we do not need to solve the cube: even if the physical cube is still unsolved, the program can be restarted to an initial unscrambled configuration. The advantage over instruments such as theremin is that we can have chords, and an easier interface to play. Vibrato might be made possible. Next applications will include collaborative and more complex music with theremin and haptic devices [8] and the improvement of the mobile app to simulate our instrument without IM3D. Tracking speed and precision, as well as timbral variety, will be improved in future prototypes. A more user-friendly interface is under development, to enable the performer in changing the initial note-material without any coding. A new visual cue with multiple views would allow the performer to more easily predict the upcoming combinations. We will also include a MIDI output, enhancing the cube's compatibility with synthesizers and other electronic instruments. We can investigate the cube in classroom scenarios, to make tangible and enjoyable some *abstract* concepts.

5. ACKNOWLEDGMENTS

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