Seen Music: Ambient Music Data Visualization for Children with Hearing Impairments

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ABSTRACT
In this paper, we propose a prototype of music visualization system that captures and records the music component into digital data form, and then displays the data in visual form for children with hearing impairments. The analog sound data of music played physically is scaled into a binary matrix and scalar values that is then used as data structures for transcribing the output. We designed a system that detects tune and speed from a physical violin, and demonstrated three tangible music visualizations that children see in their daily lives, employing a flowerpot, plants and a picture of frame. We describe how the data captured from physical musical instruments can be seen through these objects, and suggest future possibilities for interactive sound visualization in music education for children with hearing impairments.

Categories and Subject Descriptors
D.2.2. [**Software Engineering**]: Design Tools and Techniques-Evolutionary Prototyping, Modules and Interfaces, User Interfaces; H.5.2. [**Information Interfaces and Representation**]: User interfaces-Interaction styles, User-centered design, J.5. [**Computer Applications]:** Arts and Humanities-Performing Arts.

General Terms
Human Factors, Design

Keywords
Music Visualization, Music Education, Assistive Technology

1. INTRODUCTION
Since music has been shown to play a significant role in relieving stress, understanding beauty, and developing empathy skills, it has been taught in classroom settings from early childhood [7]. Understanding components of music such as, melody, harmony, and rhythm, is the main theme of music education in classrooms. Although many researchers and interaction designers have thought of a computer aided tool for early childhood music education (in part because of the unique property of music itself), teaching music is not an easy task for teachers of children with hearing impairments. Only limited parts of music was felt by kids having hearing defects, such as feeling beats throughout vibrations. We suggest a system that integrates the process of recording physical music, interpreting music data, and translating it into visible form. Our design goal includes four main considerations:

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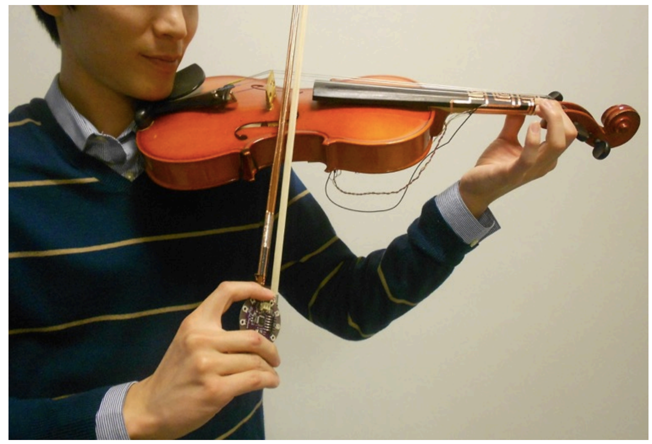

Figure 1. Playing violin with Seen Music system to capture tune, and rhythm, components of music.

- **Capturing physical music sound in digital format:** There are several ways available to record analog music data, and interpreting it into digital form using signal processing. To simplify the process, we designed a system to directly capture digitized sound, and save it in an efficient data structure for digitized visualization.
- **Cost effective rapid prototyping:** Integrating many delicate sensors enables the preciseness of captured music data. However, keeping the system as simple and cheap as possible allows the general public to use the proposed design widely in classrooms for the hearing impaired, with little amount of resources.
- **Visualization of music with tangibles:** Feeling music with all the senses is highly recommended for music education, especially for children. Although the main goal of the system is visualizing sound for children with hearing impairments, we designed the visualizations to be tangible and tactile, thus enriching the music experience for non-impaired children as well.
- **Time effective differentiation of visualization:** With the least amount of time required, our system provides fluent differentiation of visualization patterns with various combinations of output, encouraging users to free transform and customize the visualization.

2. BACKGROUND

2.1 Music Education for Children Who Need Special Help

Music was traditionally used in education for building emotional sympathy skills in early childhood. However, for children with hearing impairments, it is challenging to teach the concepts of melody and rhythm in music since it is primarily based on sound.

We conducted casual semi-structured interviews with teachers of deaf school, to understand how music has been traditionally taught for children with hearing impairments. There are a few ways to enable children feel the music teachers use, the easiest way is signing lyrics of songs in *ASL*[1], and teachers also used large drums or speakers so children can feel the vibrations through their hands on them. They also used videos to “show” the scene music is played, and recently, teachers tried to integrate a sound reactive light column to express components of music in visualized forms. One of the schools for deaf students is building a vibrating floor with speakers underneath to help children feel the music through floor vibrations. A similar solution was invented by Hyundai, which is called *Touchable Music Seat* [5]. The solution uses vibrating seats to help people with hearing impairments to feel the beats while driving. Several samples of these seats have also been installed in classrooms. For those who cannot listen to the sound, the seat provides precise vibrations based on music beats to those sitting in the car. However, our questions were left unanswered, how *melody* and *timbre* could be delivered with *rhythm* that interpreted by these method at the same time?

2.2 Sound Visualization

Information Visualization, especially music has become a rising interest among practitioners, educators, artists, and researchers. The equalizer (Figure 2, left) is the most common form to show how tune and rhythm of music progresses over time, with various colors of lines representing pitch, and height and gaps between bars representing amplitude and frequencies, respectively. Installation artists have used a combined series of LEDs, motors, and sensors to visualize various components of music. A good example is the *Dancing Music Water Fountain* as also shown in Figure 2 (right). With appropriate mapping from music notes to the combinations of colors and movements, melody of music can be efficiently delivered to children with hearing problems, while the frequency of color, and rhythms of movements change.

Figure 2. Equalizers visualize music in vivid colors and geometry (left), and music fountain presents music with direction or height of water released, colors reflected (right).

2.3 Tangibles for Information Display

Last year, *Muzlog* presented how the sound of physical instruments can be taken in digital format directly, by seizing pitch and stroke during guitar play into digital music notes [6]. Likewise, *Coolmag* also tried to think how tune could be generated by interface of random musical instruments [12]. Those two works are good starting points for catching analog melodies to readable digital form. Early *Noteput Project* explored graspable representations of notes, to compose and play music with tangibles on the screen interactively [3]. Putting physical notes on an empty digital manuscript, which is projected on a tabletop interface, enabled recognizing tune by the controller automatically.

Meanwhile, *Laughter Blossom* presented the artificial flower that interacts as an ambient form of information display with people [11]. It proposed a tangible way of symbolizing the sound of laughter in visual form, through a blossoming flower. In this way, they opened a possibility for natural phenomenon to represent music. *Laughter lossom* was originally inspired by *LaughingLily*, which used digital flowers as a mean of information visualization [1]. The number of flowers, the shape of the petals, colors, and the level of blooming all affected how the flower expresses data. Another example of information display with ambient objects was *Infortropism* [4], that manipulate plant’s leafs to correspond to the density of light being projected, through degree of bend and lean.

As the *Muzlog* system and *Noteput* were limited to input of music and were not designated for children with hearing impairments, in our design we employ, (1) information visualization is realized through objects that children see in their daily lives, and (2) interactive tangibles for capturing and expressing music will empower children to learn and feel music in classroom.

3. IMPLEMENTATION

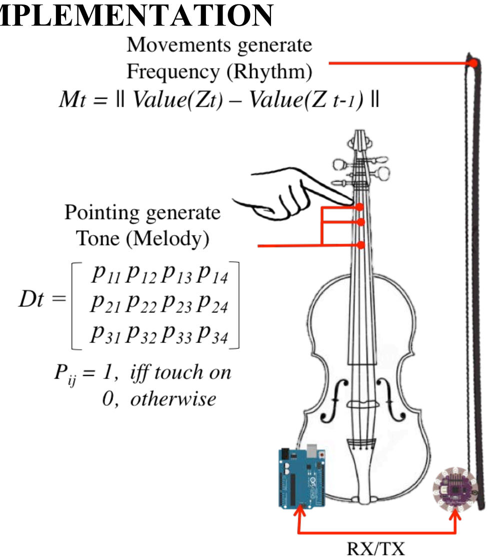

Figure 3. Music data (Rhythms and Melody) generation and data schema to transfer into music visualization system

Our system consists of two modules, one for capturing physical music data and the other for interpreting this data into an ambient display. In our system we combine violin performance with three applications of information display. The software application was programmed in Sketch [2] so it can translate violin sound to three different output modes, (1) analog ranged (0 ~ 180°) output into one servo for flower, (2) binary ranged (High/Low) output into one vibration motor for plant pot, and (3) six binary ranged output into LEDs for picture of frame. A LilyPad Arduino, which is coupled with an accelerometer on the bow of the violin, transmits data to a main Arduino Uno board via a serial communication bus (Figure 3). The main Arduino also receives data from the fingerboard of the violin, and transmit output signals into display.

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[1] American Sign Language

3.1 Collecting Physically Played Music Data

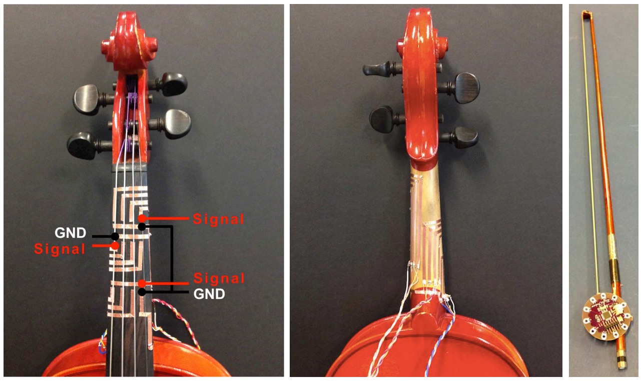

Figure 4. Initial settings for detecting tune of violin play. Each of three positions on the fingerboard has four digital input by four strings, closed the circuits grounded by finger touch.

Transcribing physically played music into digital form is neither easy nor simple, needing a special system to interpret the data. For example, to avoid noise, a musician should play instruments in a soundproof room. It also requires signal processing to interpret components of music, because recorded music is still in analog form. Not only that, the analog frequency and amplitude should be quantized to integer, in order to be digitized. To ease this process without a complex computer system, we designed a sticker circuit for capturing touch signals, which is attachable to almost any kind of musical instruments. With the violin example, we built the proper data structure to record data as shown in Figure 3. As a violinist touches the fingerboard to generate chords while playing, s/he closes copper tape based circuits. Finger touches on the violin neck trigger resistance changes because of human skin's conductivity, which can be used to code finger position. The input value changed from 1023 to 0 when finger perfectly closes, however, we set the threshold of detecting input as less than 50. Otherwise, subtle resistance changes along with fast play would not be caught. The main Arduino board is attached to the back of violin body. Since the fingerboard only generates the level of tune, we also employed an accelerometer (connected to a Lilypad) at the tip of the bow to capture the dramatic z-axis movement while playing. Two controllers are connected each other by wires for serial communication, since the bow would be otherwise too heavy for wireless communication modules such as Xbee.

3.2 Musical Data Visualization

Our goal in projecting music data into ambient visualizations [10] is to help children appreciate the aesthetic quality of music. As people listen to music anywhere, anytime, with anything (CD player, smartphone, Radio, etc.), we hope children with limited hearing ability can enjoy music through any everyday-objects. Now we propose three different types of ambient visualizations.

3.2.1. Blooming Flower

Based on the kind of objects, different forms of mapping can be realized. *Laughter Flower* and *Laughing Lily* inspired us to design a flower blossoming by a servo, synchronized with the violin playing. The degree of blooming flower's petal is mapped to the servo's rotational degree from 0 to 180°, which is transcribed from tune as data by the string input. We planted three flowers with one servo with every 60° assigned to one position on the fingerboard position, and 15° to four strings at one position, so that it could present 3 by 4 matrix. Each of the petal was attached to the rotating axis of the servo pivot, enabling movements in both directions. The speed was normalized to scale, and sent to direct speed. The degree of the motor rotation was calculated by passing the position of the data schema in the *Dt* matrix over time as a parameter to the data mapping function.

```
for (rows = 1:3, cols = 1:4) in Dt
   Servo.write( rows*60 + cols*15);
   LED(rows, HIGH);
   delay(Mt);
```

If we embed three motors, assigning each to one flower, we can individually map each to three positions, allowing larger degree of blooms. LEDs embedded into the flower stamen can also show data, by being turned on/off.

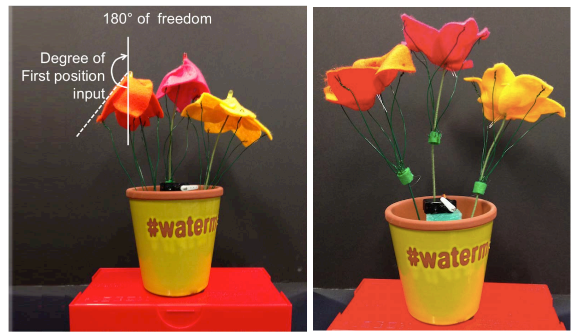

Figure 5. Blossom's petals move up and downs by servo in horizontal direction, stating from blooming or closing.

3.2.2. Waving plants

In the second example of waving plants, the direction of lean in plant can also be used to demonstrate data. We attached pairs of leaves to the several horizontal volvelle axes to plug movements along with spinning motor. Owing to the axes are attached to leaves by Velcro tapes, users can choose the number of leaves to attach, differentiating movement pattern. Since the servo can rotate up to 180°, the leaves lean in the left and right directions, and with enough high speed, mimic vibration.

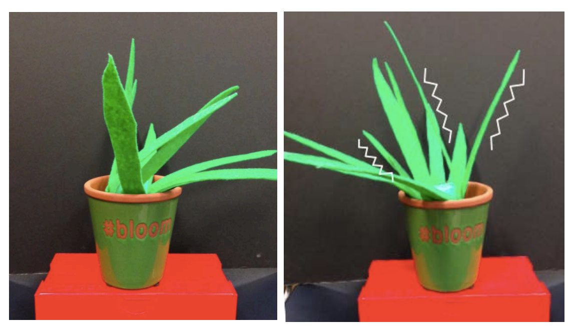

Figure 6. Waving plants that indicated melodies and rhythm. If user turns the state of plant off to binary, it simply vibrates over time while music plays.

3.2.3. Colored Frame

The window reflecting sunlight is one of the most common objects found around children. Inspired by colorized stained glasses, we similarly designed two types of transparent standing frames, one that was laser engraved (Figure 7, left), and another that was a cut pattern (Figure 8, right). We assigned five different colored digital LEDs to represent 12 inputs, as the music proceeds slowly, the LEDs incrementally turn on and allow for a variation of colors to represent music.

LED	Red	Yellow	Green	Blue	Violet
Trigger	p_{11}, p_{22}, p_{33}	p_{12}, p_{23}, p_{34}	p_{13}, p_{24}	p_{14}, p_{31}	p_{21}, p_{32}

Table 1. LEDs assigned to 12 inputs

The output board simply projects colors through a serialized array of LEDs and dimming is used to represent how long the sound sustains. We used a transparent acrylic sheet, so that the LEDs light up to the front. The engraved pattern refracts light creating a more salient image. At the same time, it is also tangible since the patterns are concave. For sure, if we incorporate 4 by 3 grids of LEDs, it will directly map the music data in Matrix *Mt* 1 by 1.

Figure 7. Laser engraved pattern of "*Starry Starry Night*" with five LEDs installed into standing slot (left), and two overlayed laser cut frames of skyline with blue/yellow enabled (right)

4. DISCUSSION

Our prototype could also be applied to other musical instruments that trigger sound through push or touch, such as the flute or the piano by attaching sticker circuit on them. Visualizations can be used for early stage childhood music education. While the physical visualizations are not as precise as screen output, these objects make *natural* movements that maybe embody natural athletics of music. This could be beneficial to children for developing emotional empathy, but at the same time, this also could be a limitation of data visualization in terms of preciseness. This rapid prototype of music capturing and visualization is simple, not wholly representative of actual music. However, this is a trade-off between cost and delicacy. The chords of open strings are not captured, because our system needs at least one grounded position on the fingerboard as an input signal. This could be replaced by the 4th position of the previous string, but it does not guarantee freedom to the performer. This could be remedied by applying *CordUIs* [9], recognizing the stretch level of strings through a stretch sensor. Including more sensors will enrich the detail of data visualization, however, it costs more and increases complexity. It would probably increase the stress level of the user because of increased information overflow.

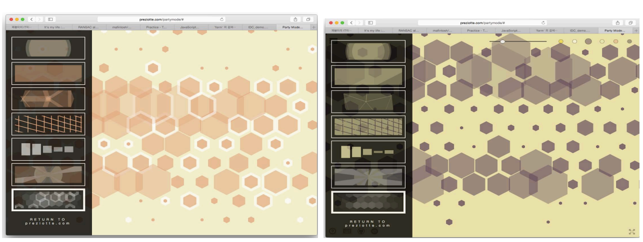

Figure 8. Hexagon geometries pattern mode in *PartyMode* CSS visualization library

In the future, we need to conduct a user study to examine if the different visualizations actually help music comprehension in hearing impaired children, and what needs to be added to guarantee music perception. We plan to expand the instruments range that our prototype can be applied, not only to the violin, but also to piano, etc. We are also considering building a C3/D3 visualization library, can be connected with any screen display in the classroom. Figure 8 shows a *Partymode* library that reads music data and streams it to users in different colors, size, and geometry patterns [8]. To empower children's deep engagements in music, we could also design a virtual game character that reacts to the music played by the instruments, by facial expression, or motion, etc.

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