The Andantephone: A musical instrument that you play by simply walking

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ABSTRACT

I present a new way of teaching musical tempo and rhythm by writing out the music on a timeline along the ground, with, for example, chalk, in a form in which each beat of the music corresponds to one footstep. In some setups I use computer vision to track participants so that the music is actually generated by their footsteps moving through the space. In other embodiments I installed patio stones, leading to a musical garden, and outfitted each stone with a pressure sensor. I connected the pressure sensors to a central computer, which I programmed to step through a song, as people walk to the garden. Each footstep activates the next note in the song, so that there is perfect synchronization between the music and the speed of your walking (i.e. if you walk faster the song plays faster, if you stop walking the song stops, etc.). In one embodiment the computer controls an outdoor pipe-organ sculpture that I made from PVC pipes. Another provides a MIDI output to control a piano or other sound-producing device. Some versions of the sculpture are human-powered, either electrically, or wholly acoustically without the use of a computer.

I also arranged various musical compositions suitable to this new form of art.

This teaching method, together with various sculptural embodiments of it were found to break down social barriers and create cross-cultural and cross-generational ties. For example, children and their grand parents enjoyed walking through the gardens at Pine Hill Estates where a version of my sculpture is permanently installed.

Other variations of the sculpture include arrays of hydraulophonic fountain jets that play a song in a water park when a person walks on the water. Each note or beat is triggered by a water pressure increase when one of the water jets is blocked by the foot of a user stepping on it.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]; H.5.5 [**Sound and Music Computing**]; J.5 [**Computer Applications**]: ARTS AND HUMANITIES—*Fine arts*

General Terms

Design, Experimentation, Performance, Theory, Verification

Keywords

Musical sculptures, interactive sculptures

1. RELATED WORK

Tangible media [1][2] have been demonstrated in various forms. The proposed "andantephone" consists of pressure sensors arranged along a garden path, as a multimedia interactive sculptural element. This could be considered an example of tangible media.

2. INTRO: STEPPING THROUGH MUSIC

When I teach music to my children, I write the lyrics in sidewalk chalk, spaced out so that there is one beat of music for each footstep. Thus walking at a constant pace, singing the words as they are stepped on, moves through the song with the correct musical timing. I refer to this approach as "the andantephonic method" of teaching music.

2.1 The andantephone: A new musical instrument that is played simply by walking

Based on this simple principle, I invented a new musical instrument that I call the "andantephone". Andante is the Italian musical term for tempo that is "at a walking pace". Combining the Italian "andante" with the Greek word "phone" (meaning "sound", a commonly used suffix for musical instruments), results in "andantaphone".

Various embodiments of the andantephone include, but are not limited to, the following:

- A system comprising sensor-equipped shoes connected to a wearable computer programmed to play music where the rate at which the music is played is linearly related to the rate of walking. Typically the system is programmed to advance through a song andantephonically (i.e. at a rate of one beat for each footstep taken);
- A computer vision system that monitors people walking through a space and plays music at a footstep synchronized rate;
- Sensor pads that each receive one footstep, each pad connected to a one or more devices that play a beat of music for each pad that's pressed; and
- An aquatic play environment in which a row of water jets, each equipped with a hydraulophone, cause music to play when the water jets are successively blocked by the feet of participants.

I experimented with different public spaces that had geometric patterns of patio stones, slabs, or other similar periodic design elements. See for example Fig 1.

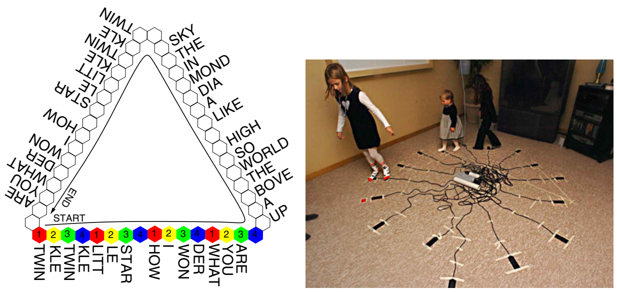

Figure 1: (leftmost) **Many songs like Twinkle Twinkle Little Star are mostly andantephonic, i.e. all or most notes have exactly the same one-beat duration:** Lyrics of "Twinkle Twinkle Little Star" are painted, on color coded slabs. People walk on the slabs to "step out" the song based on tracking by way of an overhead camera with a computer vision system. The unique color of each slab helps to make the background subtraction tasks very easy. (rightmost) Alternative embodiment of the andantephone based on sixteen pressure sensors, arranged for being walked on in sequence.

Figure 2: **Garden stone slabs each define one beat in the song:** As people walk on the slabs they "step out" the song by way of a computer-controlled pipe organ sculpture made from grey PVC electrical conduit pipes hanging from a tree adjacent to the garden.

3. ANDANTEPHONE EMBODIMENTS USING PRESSURE SENSING PATIO STONES

Rather than rely on computer vision, I wanted to make a more expressive garden for a permanent installation at Pine Hill Estates in Toronto, where I used pressure transducers that I attached to each patio stone.

On the path to the gardens there is a curved path of patio stones in the grass. Because the grass is damp, owing to the in-grass automated irrigation system, people usually step on the stones to walk to the gardens, so that they don't get their feet wet in the damp grass. Since people generally walk on the patio stones, one stone at a time, this is an ideal setting for a musical sculpture in which notes are triggered in a pre-determined sequence, by footsteps.

Now, when people walk along the path defined by the stones, their footsteps step them through a song. If more than one person is on the path, a nice musical "round" results. See for example Fig 2. Sounds are produced by a computer controlled pipe organ sculpture I made from grey PVC electrical conduit pipes hanging from a tree adjacent to the garden.

4. ARRANGING OR COMPOSING MUSIC SPECIFICALLY FOR STEPPING-STONE SCULPTURES

One of the interesting observations made on the sculptures, is that when two successive notes of the song are the same, there needs to be some way to define a break in the notes. In particular, the problem arises when a person steps on one stone, and then the next, without stepping off the first stone before stepping on the next one.

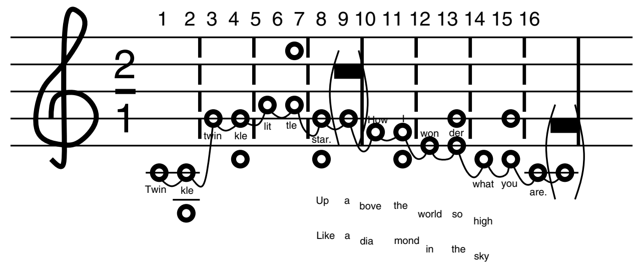

Figure 3: **Grace harmony used to break-up sequential occurrences of the same note:** Here an unusual harmony provides a whimsical reverse-emphasis, by coming in during the second beat of each bar, i.e. "twinKLE twinKLE litTLE star...". Since the harmony comes in late (i.e. in a repeated melody note), additional creative opportunity exists to have it ride above the melody at times, without the risk of having it start the bar off on the wrong note. In this simple song, each foot step corresponds to one whole note, hence the time signature of 2/1, in which each bar of music contains both a left footstep and a right footstep. Note that I've used non-standard harmony at time-index 4, 6, and 7, rather than making the grace harmony from C, F (or C), and C, that would more expectedly form part of the chords for C-major, F-major, and C-major. The unusual harmony is in keeping with the spirit of a garden sculpture, suggestive of the playful harmony one hears from wind chimes.

This problem can be solved by putting the stones further apart, or by computer with beat-tracking. However, a more creative yet natural way of attaining a break in one long note, is to insert what I call "grace harmony". Grace harmony works like the grace notes in bagpipe music, and serves to break up a long note into smaller pieces. My arrangement of the simple children's song, Twinkle Twinkle Little Star, for the garden sculpture, is shown in Fig. 3

5. MULTI-SONG ANDANTEPHONE SCULPTURE

The andantephones described so far, are sculptures designed to play only one specific song.

I now describe a more general form of andantephone that can be programmed for a wide variety of songs.

When my wife and I renovated our house, we included a permanently installed andantephone to teach our children music. We did not want this sculpture to be limited to only one song, so we constructed it in a way that it could be programmed with a variety of songs. I designed for 64 textured non-slip but durable tiles, running down the center of corridors that ran around the house in a square shape. We designed around the stairwell and bathroom that already formed a central "island" in the dwelling, making use of the island to define an endless path that one could walk around and around.

We designed the instrument to play, starting from the kitchen, because we would typically play just before or after dinner. We designed for 16 tiles running down the center of the corridor that runs from the kitchen to the bedroom, then another sixteen tiles running through the corridor into the living room, sixteen more tiles that run through the living room to the entrance hall, and finally another sixteen tiles that run from the entrance hall back to the kitchen. This arrangement results in a perfect square with sixteen tiles on each side of the square, as shown in Fig. 4.

Many children's songs have four beats to every measure (four beats to every bar of music), so each side of the square represents four measures, which is typically one phrase, i.e. there are:

- four beats (four tiles) per bar;
- four bars per side of the square;

- four sides of the square per revolution (once around the house).

Thus, for many songs, each verse of the song represents a distance once around the square, so that each time we reach the kitchen we move to the next verse of the song.

The tiles are made of solid porcelain, set in concrete. The surface of each tile is textured to create a nonslip surface, as well as to allow it to function like the slate on a chalk board. When the andantephone is programmed with a particular song, the lyrics may either be projected onto the tiles, using data projectors, or, alternatively sidewalk chalk is used to write lyrics of the song, spread out along the tiles. The cement floor makes it easy to erase these 64 miniature chalkboards with a standard mop.

Other re-configurable andantephones use translucent tiles with rear-projection.

5.1 Programming an andantephone

The easiest songs to program are those that are *strictly andantephonic* or at least those that are *almost andantephonic*, i.e. those that have entirely (or at least mostly) one note per beat. Songs that are (at least approximately) andantephonic serve as the best teaching examples. Programming begins with an arrangement of the song. Consider, for example, a simple nursery rhyme like "Mary had a little lamb". I first lay this out in a table, as shown below, where note-rests are denoted "o" and chord rests as "0".

Tile #	lyric	chord	note	foot	2/ time	4/ time	8/ time
1	**MAR**	**loud C**	e	L	**1**	**1**	**1**
2	y		d	R	2	2	2
3	HAD	quiet C	c	L	**1**	3	3
4	a		d	R	2	4	4
5	LIT	medium C	e	L	**1**	**1**	5
6	tle		e	R	2	2	6
7	LAMB	quiet C	e	L	**1**	3	7
8	o		o	R	2	4	8
9	**LIT**	**loud G**	d	L	**1**	**1**	**1**
10	tle		d	R	2	2	2
11	LAMB	quiet G	d	L	**1**	3	3
12	o		o	R	2	4	4
13	LIT	medium C	e	L	**1**	**1**	5
14	tle		g	R	2	2	6
15	LAMB	quiet C	g	L	**1**	3	7
16	o		o	R	2	4	8
17	**MAR**	**loud C**	e	L	**1**	**1**	**1**
18	y		d	R	2	2	2
19	HAD	quiet C	c	L	**1**	3	3
20	a		d	R	2	4	4
21	LIT	medium C	e	L	**1**	**1**	5
22	tle		e	R	2	2	6
23	LAMB	quiet C	e	L	**1**	3	7
24	its		e	R	2	4	8
25	**FLEECE**	**loud G**	d	L	**1**	**1**	**1**
26	was		d	R	2	2	2
27	WHITE	quiet C*	e	L	**1**	3	3
28	as		d	R	2	4	4
29	SNOW	medium C	c	L	**1**	**1**	5
30	o		o	R	2	2	6
31	0	drum 0	0	L	**1**	3	7
32	o		o	R	2	4	8

*This chord may seem "wrong" to persons more familiar with the usual chord progression of the "1234" tempo, but serves to create the "12" tempo, in which the finer granularity of the chord progression more closely follows the melody (i.e. the note "e" is a member of the chord "C" but not "G"). Removing all of the quiet chords would make the melody match what most people are familiar with, i.e. to emphasize only every 4th beat, so the volume of the quiet chords is set low enough that the "1-2-1-2-..." effect is as subtle as desired. This song uses 32 tiles.

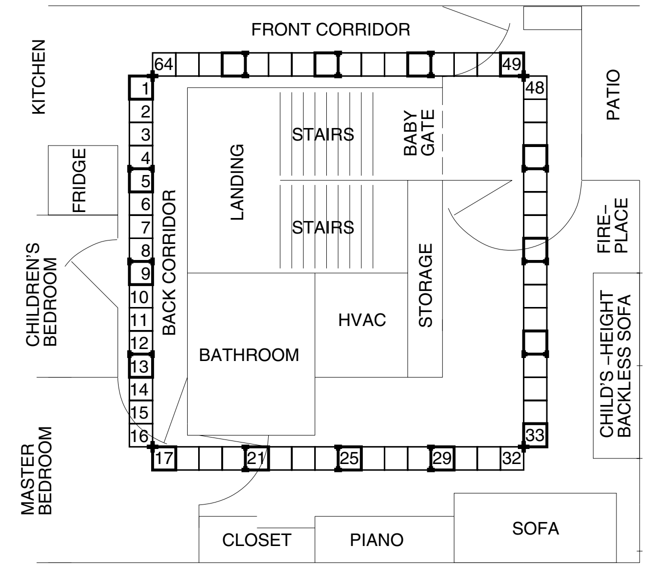

Figure 4: **General-purpose 64-tile andantephone designed as part of a home renovation project:** There are 64 tiles arranged in a square pattern in which every fourth tile is emphasized to construct one bar (measure) of music. Four bars The tiles are made of solid porcelain, with a non-slip textured surface. Each tile is a chalk board so that a word from the song's lyrics can be written on a tile, to begin the day's music lesson once the song is programmed. When it is time for a new music lesson, a new song is programmed, the "chalkboards" are erased with a standard floor mop, and new text is drawn in fresh chalk.

Let us suppose that, for this arrangement, we wish to have a strong walking beat. We an achieve this by alternating chord, note, chord, note, and so on. Thus if you begin with your left foot, then, for this particular arrangement, each time your left foot hits a tile, a chord (or rest) will play. Each time your right foot hits a tile, only an individual note (or rest) will play. This creates a sense of 1-2-1-2-1-2... timing.

Moreover, each four steps has medium accentuation, so the sculpture also expresses an element of 1-2-3-4-1-2-3-4-... timing.

Additionally, each eight steps has a strong accentuation, so the sculpture also expresses some degree of 1-2-3-4-5-6-7-8-1-2-3-4-5-6-7-8-... timing.

Chords are implemented by having a three or four port jumper (electrical actuation), broadcast (software actuation), or fluid manifold (hydraulic actuation) for each chord, as shown in Fig. 5.

Some of the sculptures use electric actuation of acoustic organ pipes in a similar way, to maintain the same full range of expression. In this case an analog electric current takes the place of the fluid. In some versions of the sculpture, the entire process is modeled in a computer program, and sensor pads in the tiles are each connected to an individual analog input on the computer. A typical computer with a sixteen channel analog to digital converter allows for 16 tiles.

6. PROGRAMMING ARBITRARY SONGS

There are two main issues that need to be addressed to fully generalize the andantephone: (1) songs of arbitrary

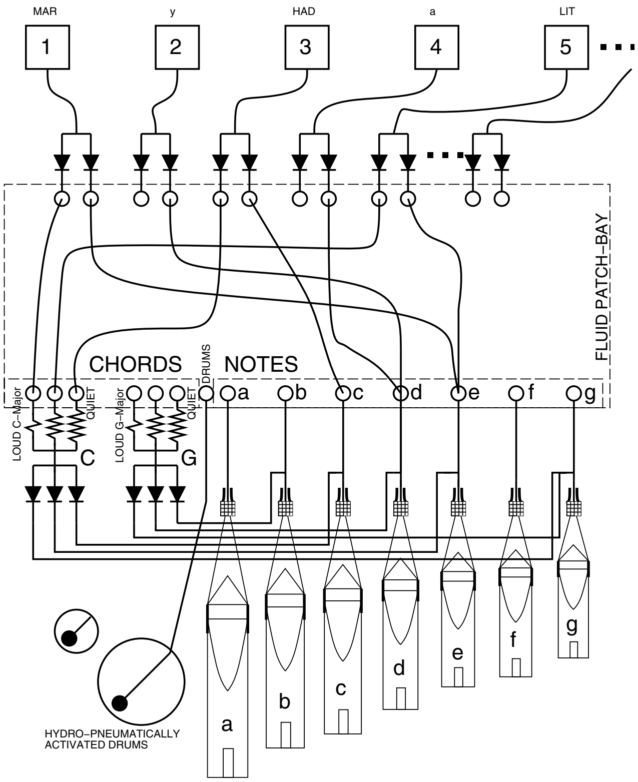

Figure 5: **Hydraulic patch bay:** A song is programmed into the sculpture by connecting hoses in the patch bay as illustrated. The one-way valves (fluidic diodes) keep fluid flowing in the proper direction. Flow control valves (denoted as resistors) reduce the volume levels so that the chords do not overpower the melody, and so that loud or quiet chords can be separately programmed, as desired. Rather than patch the chords as individual notes, for simplicity, they are grouped as separate sub-patch panels, made from one-touch tee fittings. For simplicity, only the first five slabs are shown patched in.

length (not necessarily matching the length defined by the number of tiles); and (2) less-andantephonic songs, especially when the capability for sub-tile not duration is desired.

To address the first of these issues, a rolling window is defined, as illustrated in Fig. 6. Beat tracking, by way of a phase-locked-loop apprach, also uses a rolling window to estimate not just the position, but also the speed, acceleration, jerk, jounce, etc., of the participant, and the estimate the position of the participant to sub-tile (sub-pixel) accuracy. Accordingly, songs that have note durations less than that defined by the tile/beat spacing, can be used.

7. CONCLUSIONS AND FUTURE WORK

A new method of teaching music was presented. The method involves writing the song out with temporally/distance linearity, on the ground, at a physical scale in which each footstep represents a beat of music.

This gave rise to the invention of a new musical instrument that is played by walking on or in it. This new and fun input device was successful in teaching children musical timing concepts like rhythm and tempo.

Presently we are building other multimedia parks in public spaces, including waterparks, that use rows of water jets in place of the patio stones and sensors. Songs are played by walking on water, sequentially blocking water from coming out of the water jets. Blocking the water jets

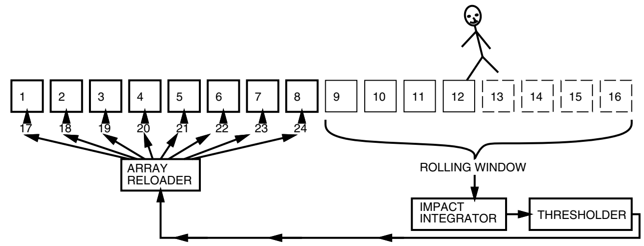

Figure 6: **Rolling window:** In this example, a 16-beat song is played on a 16-tile andantephone. After a participant has walked on the first 12 tiles, the first eight tiles are loaded with a new musical phrase that represents beats 17 to 24 of the song. This is done by way of a rolling window that robustly determines the position of the participant on the instrument. The rolling window is centered on the participant's estimated position along the instrument. At the point in time depicted in the illustration, the window now spans tiles 9-16. Even if the participant misses some of the tiles, or another person runs across only one or two tiles in the sculpture, the system is robust to such perturbations because it uses robust statistical inferences to determine user position. For example, it doesn't reload the first part of the sculpture (the tiles depicted in bold lines) with the next part of the song until a certain minimum number of tiles in the second phrase have been stepped on. When more than half of the tiles in the second phrase have been stepped on, the impact integrator accumulates enough "points" that the thresholder considers the user to have passed into the second phrase of the song, and thus the array reloader is activated to swap new notes (17-24) into tiles 1-8. When the tiles are multi-level (analog or having various discrete pressure levels, not just binary on/off) the impact integrator considers the total amount of impact from the user's feet, integrated over time, and summed over all tiles within the window.

generates sound by hydraulophonic and/or restrictometric mechanisms[3] (See also, "Hydraulophone design considerations...", published in this ACM MM 2006 conference proceedings). A long winding path through the waterpark allows participants to walk from one water jet to the next. Each jet produces a different part of a musical composition when it is blocked. The full range of expressive capability is increased, because of the infinitely many different ways in which the water jet is blocked. The sculpture, for example, responds to differences in the pressure, displacement, velocity, and acceleration with which the foot comes down on the water stream. Additionally, the sound depends on whether the jet is blocked straight across or obliquely. Finally, there are differences in whether the user's foot goes down on the jet from above or "slices" into the side of the jet. As a result, people with no musical training can play music in a very soulful and expressive way that captures their emotional engagement in their specific performance of the song that is programmed into the andantephone.

8. REFERENCES

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