QuakeScope: a Prototype Toolkit for Interactive Sonification of Earthquake Data

Robin Morabito – Intelligent Instruments Lab

Iceland Student Innovation Fund – Summer 2022

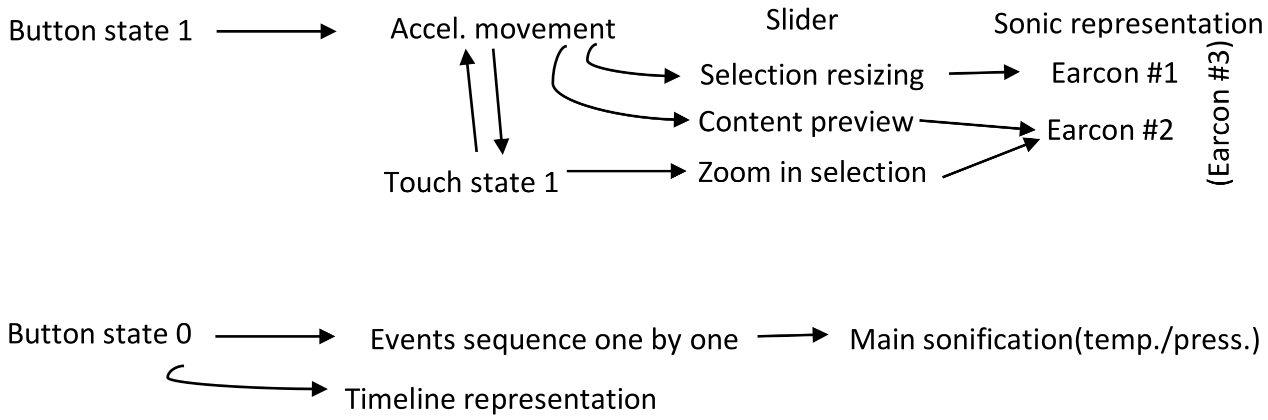
ENVIRONMENTS

- (*stage 1*), where the data is sketched sonically in relation to the timeline; a selection on the entire dataset can be made;
- (*stage 0*), where the content of the selection is represented in higher resolution to the player.

FUNCTIONS

- Button (index finger on thumb): holding it pressed gates stage 0, and displays “Scanning” on the GUI; releasing it keeps the sonification in stage 1 displaying “Listening”.
- Accelerometer: while in stage 0, tilting along Y axis increases and decreases slider range (affecting selection size), tilting along X axis moves the slider boundaries to the left or to the right (so does the current selection on the timeline); while in stage 1, moves the pointer/head across the 2D map.
- Flex: while in stage 0, bending it moves the point deeper into the crust; GUI map turns whiter. While in stage 1, does nothing.
- Touch (middle finger on thumb): pressing it while in stage 1 briefly displays “Zooming..” before returning to “Scanning”. This operation implements essentially a zoom, or enlarging, of the current selection in the timeline, that overwrites the current boundaries of the timeline itself. In other words, a smaller selection in the timeline allows for fine selection of specific segments in time. Pressing it while in stage 0 scans Backwards/Forward/Pauses depending on the tilt angle.

Button state	**GUI display**	**Accelerometer funct.**	**Flex sensor funct.**	**Touch sensor funct.**	**Timeline representation**
Released (state 0)	*Listening* Listening point and seismic events on map Brightness on map depending on depth	*along x axis:* move listening point west (tilt counter-clockwise) or east (tilt clockwise). Determines playback position while touch sensor is pressed. *along y axis*: moves listening position north (tilt front) or south(tilt back). Determines audio spatialization (with flex sensor).	Sets depth of listening point close to the surface (no flexion) or at the deepest registered event (max flexion). Determines audio spatialization (with accelerometer).	*Backwards <<* *Forwards >>* *Pause* Determines playback direction according to accelerometer X axis position: *backwards*, if accel. tilt to left *forward,* if accel. tilt to right *pause*, if pressed with accelerometer horizontal.	By timestamp of single events *Year:* none. *Month*: root note. *Week*: # 1 (day 1-7) – Lydian chord; # 2 (day 8-14) – Mixolydian chord; # 3 (day 15-21) – Aeolian chord; # 4 (day 21-end) – Locrian chord. *Day:* limited resolution through *week*. *Hour:* limited resolution by shifting higher octave (midnight-noon) and lower octave (noon-midnight).
Pressed (state 1)	*Scanning* Slider state adjusts to accelerometer.	*along x axis:* move selection left (tilt counter-clockwise) or right (tilt clockwise). *along y axis*: squeezes selection (tilt front) or stretches selection (tilt back). Controls Interval of earcon #1.	none	*Zooming.. -> Scanning* Updates selection extension.	By a 1 second-long sequence of 3 earcons # 1 – two blips of 250 ms each at interval determined by accelerometer. # 2 – a pitch envelope of 500 ms. # 3 – two simultaneous pad synth C notes at 1 octave distance, repeated, 1 second long.



month	1	2	3	4	5	6	7	8	9	10	11	12
root	C	F#	F	B	A#	E	D#	A	G#	D	C#	G

week	1	2	3	4
mode	Lydian	Mixolydian	Aeolian	Locrian

brighter → darker

daytime	hours 1-12	hours 13-24
octave	high	low

reference drone chord

GUI functionalities

The main element of this graphic interface is the map, which displays a blank map of Iceland with a pointer (black) representing the head facing the land, and temporary dots (red) for seismic event in the dataset. The map can be opened separately in a bigger window using the “open map” button. Right below the map, a thin timeline points at the current index in the data series; underneath, current cursor coordinates are displayed. Right to the map, three knobs (head size, speed of sound, coeff. amp slope) respectively tune *h, a* and *k* parameters shown before. This is meant to give the player some control over the personalization of the 3D soundscape, to adapt to their own preference.

Underneath these three-knobs panel, another display signals parameter values of the current seismic event sonified. Right to this panel, there’s a knob to shift the frequency range of the sonified events upwards.

A line of colored buttons provides global control over the sonification:

- Force stop interrupts the sonification and resets it to default;
- A longer button is actually a display, showing “Scanning”, “Listening”, “Forward”, “Backwards”, “Pause”, “Zooming” as introduced in tab2
- Loop on/off (on by default) restarts or stops the sonification reaching the last data point
- Reset restarts the sonification without pausing
- Open map (mentioned above)

Right to these buttons, two vertical sliders allow control over

- Volume context: amplitude of *all sounds but event sounds*. While in state 1, it controls the volume of earcon #1 and #3; while in state 0, controls the volume of the background drone chords
- Time scale: accelerates the duration of 1 day in the sonification time from 43 seconds (default) to 7.2 seconds. This control is independent from the increased playback speed triggered by going Forward and Backwards.

At the bottom of the GUI, a panel signals current date range and status of the selection, and below a horizontal range slider is controlled by the accelerometer in state 1.

BINAURAL AUDIO

When the timeline reaches each data point, event's depth, longitude and latitude are used to give a red point (x_e, y_e, z_e) corresponding coordinates on the map. On the other hand the position of the pointer is computed every 30ms, triangulated on the accelerometer X, accelerometer Y and flexion values, updating pointer coordinates (x_p, y_p, z_p). Each event's amplitude in channel left and channel right is calculated independently at 30ms rate based on the current distance of pointer(x_p, y_p, z_p) from event(x_e, y_e, z_e), assuming head size *h*, speed of sound *a*, and amplitude decay coefficient *k*.

> *h* ("head size") • represents the distance between each ear, and is set between 0 (left and right ear in the same spot = mono audio) and 1 (maximum ears distance, entire map width).
> *a* ("speed of sound")• is a value of speed of sound relative to the (imaginary) medium. It's used to set the amount of delay at which each ear (or each headphones channel) receives the sound coming from the event; it's adjusted between 1 and 500 m/s, normalized to 0.01-0.5.
> *k* ("coeff. amp. slope") • is adjusted between 0.01 (fast decay in both channels) to 10 (great delay between left and right channel).

Ears coordinates are calculated as two distinct points of x_L, y_L, z_L and x_R, y_R, z_R coordinates. Both ears are imagined to be at fixed angle along y and z axis:

$$x_L = accel_x - (h/2);$$
$$x_R = accel_x + (h/2);$$
$$y_L = y_R = accel_y;$$
$$z_L = z_R = flex;$$

Distance source – channel (left and right independently) is calculated as the distance between two points in a 3D space:

$$ds_L = \sqrt{(x_L - x_e)^2 + (y_L - y_e)^2 + (z_L - z_e)^2}$$
$$ds_R = \sqrt{(x_R - x_e)^2 + (y_R - y_e)^2 + (z_R - z_e)^2}$$

Then amplitude for each channel is calculated as:

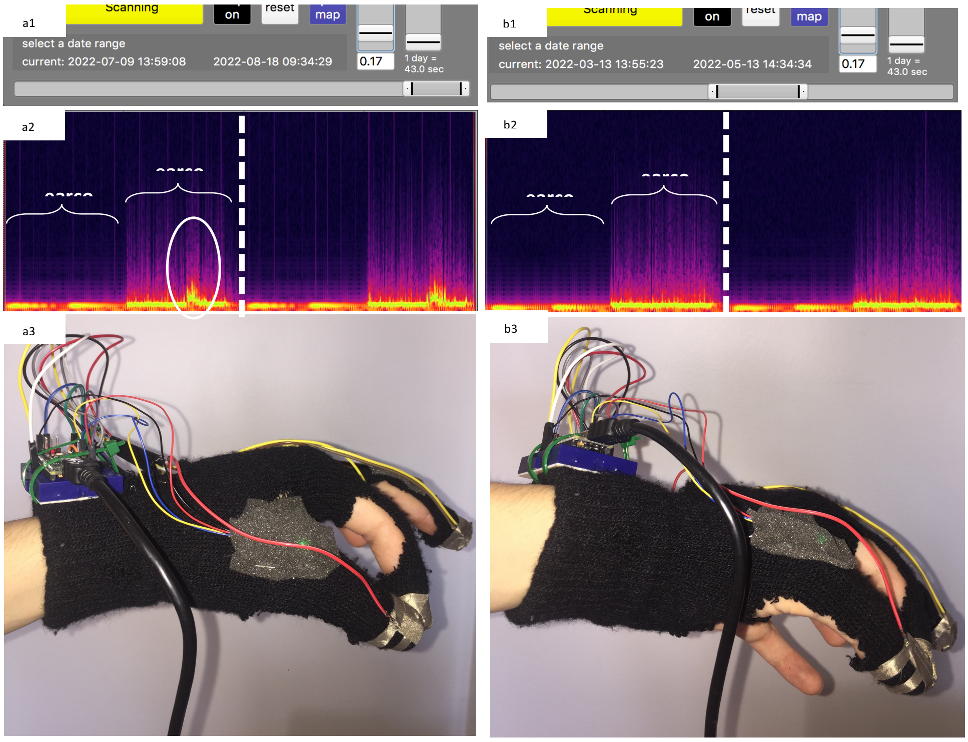
$$ampL = 2^{-k*ds_L}$$
$$ampR = 2^{-k*ds_R}$$

Haas effect is used to produce a realistic delay of the sound source as it reaches one of the ears before the other. This amount of delay is added to each channel in the Supercollider synth:

$$haasL = a * ds_L$$
$$haasR = a * ds_R$$

moving further in depth from the source, or quite clear and sharp sounds when approximating the sound source. The remaining column of the dataset that does not directly affect the sound spatialization is magnitude; however, this parameter is used to compute absolute volume of the sound event and to determine harshness (high magnitude) or softness (low magnitude) of the synthesized sound. In other words, magnitude parameter characterizes the synthesized sound's timbre and articulation much more than all other parameters (mapped to spatial sound properties instead).

USE EXAMPLE: data mining



Task: try to trace the earthquakes felt in south-west Iceland from the end of July to the first days of August 2022, and compare it with a “mute” timespan where no major earthquakes happened. This experimental setup is replicable any time:

- Series a and series b both take place during stage 1. To confirm this, in a3 and b3 index and thumb fingers are touching, meaning that Button is pressed. In a1 and b1, the GUI section displayed shows the yellow display button says “Scanning”. Stage 1 it is;
- In a1, the range slider at the bottom is oriented to the right-end of the dataset; such position is reflected in the hand position in a3;
- In b1, the range slider is oriented to the middle section of the dataset; such position is reflected in the hand rotation in b3, as compared to a3;
- In a1 and b1, current date selection reads respectively as “(from) 2022-07-09 13:59:08 (to) 2022-08-18 09:34:19” in a1, and “(from) 2022-03-13 13:55:23 (to) 2022-05-13 14:34:34” in b1. Practically, in a1 the range selected spanned from the 9th of July ’22 to the 18th of August ’22; in a2, it spanned from the 13th of March ’22 to the 13th of May ’22. Both selections include approximately 2 months of earthquake data;
- In b1 and b2, a spectrogram (obtained by recording and analyzing the interaction in the software Reaper) displays two seconds of earcon #1 and earcon #2 playing over earcon #3. The sequence is shown repeated twice for clarity, but keeping the hand steady can produce endless repetitions (as long as the slider doesn’t move too much!)
- In b1, we first see the half quarter second long earcon #1 on the left portion of the spectrogram. The two distinctive notes are recognizable. Immediately after it, earcon #2 is shown as a more intense half second long section. This sequence is repeated twice; all the same applies to b2;
- The difference between b1 and b2 is shown in the white circle in figure 10: that circle identifies a rise in pitch in the spectrogram reproducing earcon #2, because that area corresponds to earthquakes of much higher magnitude than the rest of the period. This doesn’t occur in b2, as no major earthquakes were recorded those dates;
- The difference between b1 and b2 can be heard, as the latter will sound mostly as uniform noise, while the former will sound as uniform noise interrupted by a quick sweep up and down in the pitch range, pointing at the presence of higher magnitude events in the selected section.