Sonification of Real-Time Physiological Data for Meditation Practice

Assignment Two

Sound Design for New Media – DESC9117

Architecture Design and Planning, University of Sydney

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• Description of scenario

Translating biophysical data to meaningful audible pieces has been under investigation in plants, animals and humans [2]. For example, the electrical signal resulting from changing the galvanic response of human skin (GSR) [3] by a physical or emotional stimulus can be used for mapping the parameters of a musical piece [6]. In a similar manner, the temperature change created by the human breath can be translated to audible signals.

On this basis a scenario has been developed for a real-time sonification of breathing patterns and GSR data to create an audible reflection of the unconscious mind. This instrument can be a practical device to enhance the power of self-control in meditation practice as mapping the user's psychophysical signals to musical notes can be a powerful way to control stress by enhancing mindfulness about internal layers of psychological patterns [1].

• Design intent brief

The design intent is to create a real time sonification of the either positive or negative physiological data that can result due to a change in skin conductance, palm muscles contracting, expanding and vibrating as well as the temperature gradient of exhaled breaths. Psychological activities in the human brain which manifest themselves through the mentioned physiological responses can be sonified into a combination of random polyphonic and monotonic semi melodic and effective tones to reflect various characteristics of the responses. It also has been assumed that any deviation in the mental balance can be reflected as a brighter or darker note in the live sonification.

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The goal of this sonification is to enable individuals to gain an in depth understanding of their own unconscious mind when engaged in meditation and can thereby guide meditators through their practice. GSR has been shown to be indicative of emotional responses to biological and psychological stimuli and can be used as a means of determining an individual's level of engagement in meditation, with the response decreasing as concentration decreases [7]. Thus, sonification of GSR data allows the listeners to assess their focus and make the necessary adjustments to improve their involvement in meditation. Moreover, paying attention to one's breath and reaching a state of calm with deep, even breathing is at the core of many meditative practices [4]. Therefore, the sonification of breathing patterns through the detection of the gradient temperature of exhales can be highly useful in informing the meditators of their progress in practices and overall stress levels.

• Technical discussion

The main hardware used to control the sonification parameters is Arduino UNO (programmable microcontroller) which has been connected to Max for Live (Software) through the USB serial port by *Standard-Firmata* firmware. Another Arduino has been programmed (Appx 1) for scaling and converting GSR signals to the corresponding pulse width modulation (PWM-pin9) signal. The PWM signal has then been filtered (Pic 2) to follow up the subtle variations of the GSR and connected to the pin-A1 of the interface Arduino. The analogue inputs (A0-A2) of the interface Arduino have been used for connecting the sensors to the Max Connection kit and Max Step Sequencer has been chosen as the main synthesizer in connection with the dual signal generator (*All Alone Pad)* and Arduino. The different parameters and notes in the Step Sequencer have then been designed to play a series of slow meditative rhythms (Timing, 1/1) of the main musical beats with a moderate tempo (120 bpm). The sequence has been looped and can be played indefinitely either by clicking the play button on the MIDI stripe (Live) or space bar button on the keyboard. The musical notes are designed for four sequences that can be played in different orders according to the designed sequential direction (Forward, Random, Rotate, Random). Other parameters such as Probability, Velocity and Durations in the Step Sequence patch were adjusted properly for reflecting the musical and artistic aspects of the meditative tones.

The oscillators (*All Alone Pad)* have been adjusted for generating and synthesizing tones which can be played in accordance with the sequences in Step Sequencer 1. The changes of GSR and palm muscle contractions and pressures detected by the striped sensor have been mapped to Bright Pad (All Alone Pad generator). A sensitive thermistor sensor has been installed in a conical nozzle and then used for detecting the breath flow and converting it to the correspondent analogue voltage and then connected to the pin-A0 of the interface Arduino (Schematic-part 2) which controls Noise Pad (All Alone Pad oscillator).

The principle of the magnetic sensor (A2) is based on the Hall Effect located in the middle of the Striped sensor which controls the Volume Pad (All Alone Pad). The sensor detects the movement and proximity of the user's hand to the electrodes which can modulate the sound amplitude and change the perceived loudness. In this case, taking the hand off the striped sensor can fade out the sound and putting the hand on the sensor can fade in the sound. It can create a sense of liveliness in the real-time sonification and serve as a user-friendly switch for shutting down the sound without stopping the sequence. All sensors have then been calibrated properly through Arduino auto calibration system while they were used for one to two minutes to detect the maximum and minimum values by Arduino. Since the range of GSR values and breath temperatures can vary for different positions and individuals, calibration should be done in any session of meditative sonification. The dual oscillators (All Alone Pad) have been set to the Membrane and Beam synthesizers for creating the proper timber of meditative tones. Breathing has been sonified through variations in the low pass filter (LP) parameters by shifting its cutoff frequency and increasing the noise effect at the same time. The proper Min and Max points are adjusted in Arduino to prevent the excessive sharpness by controlling the filter's bandwidth.

Picture 1. *GSR sonification hardware and associated sensors. The south pole of the magnet on the right hand is directed downwards to close the linear magnetic switch.*

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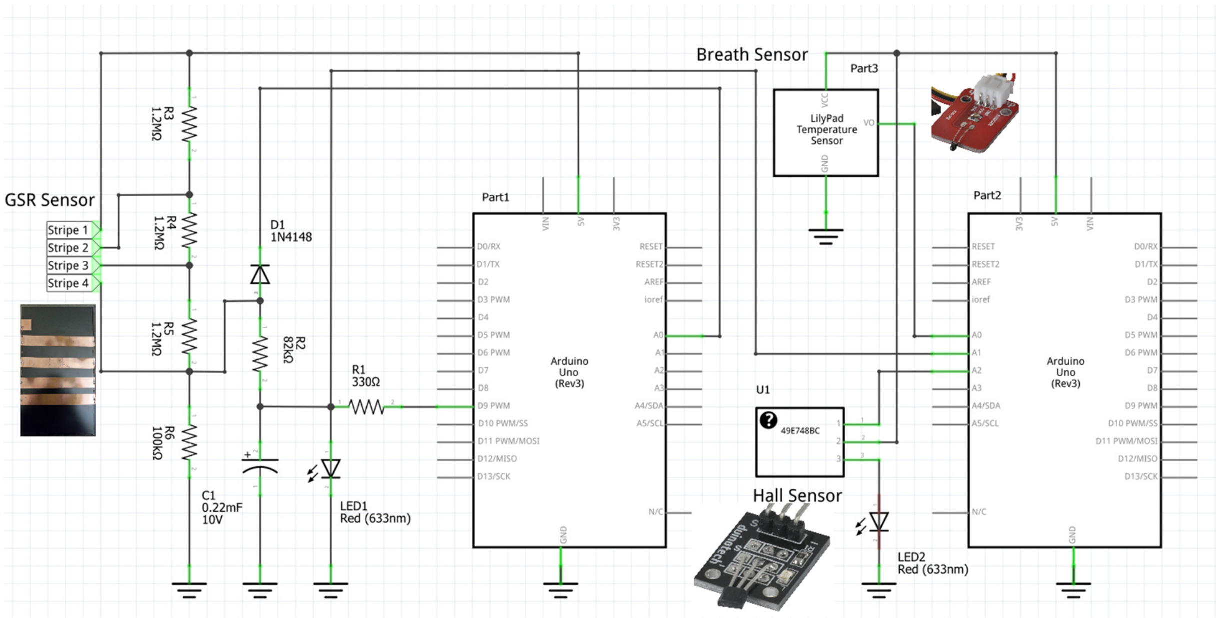

Picture 2. *the left Arduino (Rart1) has been use for scaling the GSR signal and converting it to the correspondent PWM(D9) output. The filtered PWM (GSR) analogue voltage then has been used to control the Bright pad in the Live session through the pin A0 of the interface Arduino (Part2). The linear Hall sensor has been activated by the magnetic flux of a strong magnet attached over the hand (downward south pole) and controls the overall volume of the sonification. The Breath sensor is a small and sensitive thermistor that detect the gradient temperature in the breathing air flow and control the level of Noise pad in the Live session.*

• Conclusion

It has been shown that using Galvani Skin Response (GSR) signals as well as the temperature gradient of exhaled breaths as data sources for sonification can be practical and useful. The subjective test has also shown that users with some experience are able to influence the real-time sonification through medication and mindfulness. The reason for success can be the use of some simple but effective real-time data sources and converting them to simple musical tones compatible with the rhythm and amplitude of the psychological fluctuations and reflections in the physical body. As the user's unconscious mind can be heard [8], this device can be great for practicing meditation as well as research.

Moreover, the tone and tempo and the sounds used have been chosen in accordance with the purpose of the design project to maximize the user's experience. Calming tones have been chosen which are reflective of settings in which meditation and mindfulness can be effectively practiced (such as Buddhist temples). Overall, the tool has succeeded in enabling meditators to gain real-time insight into their subconscious functions through the sonification of GSR, subtle hand movements and breathing patterns. To improve the effectiveness of this tool, more sensitive sensors can be used, and a greater number of physiological factors taken into consideration.

References

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[5] Martens, M. (2018). Sound design for new media. Intro to Sonification and auditory display, part 1&2. DESC9117 Week 6, power point slides

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Appendix 1

Arduino (Part 1) sketch

```
/*
  Analog input, analog output, serial output

  Reads an analog input pin, maps the result to a range from 0 to 255 and uses
  the result to set the pulse width modulation (PWM) of an output pin.
  Also prints the results to the Serial Monitor.

  The circuit:
  - potentiometer connected to analog pin 0.
    Center pin of the potentiometer goes to the analog pin.
    side pins of the potentiometer go to +5V and ground
  - LED connected from digital pin 9 to ground

  created 29 Dec. 2008
  modified 9 Apr 2012
  by Tom Igoe

  This example code is in the public domain.

  http://www.arduino.cc/en/Tutorial/AnalogInOutSerial
*/

// These constants won't change. They're used to give names to the pins used:
const int analogInPin = A0;  // Analog input pin that the potentiometer is attached to
const int analogOutPin = 9; // Analog output pin that the LED is attached to

int sensorValue = 0;        // value read from the pot
int outputValue = 0;        // value output to the PWM (analog out)

void setup() {
  // initialize serial communications at 9600 bps:
  Serial.begin(9600);
}

void loop() {
  // read the analog in value:
  sensorValue = analogRead(analogInPin);
  // map it to the range of the analog out:
  outputValue = map(sensorValue, 0, 1024, 0, 550);
  // change the analog out value:
  analogWrite(analogOutPin, outputValue);

  // print the results to the Serial Monitor:
  Serial.print("sensor = ");
  Serial.print(sensorValue);
  Serial.print("\t output = ");
  Serial.println(outputValue);

  // wait 2 milliseconds before the next loop for the analog-to-digital
  // converter to settle after the last reading:
  delay(2);
}
```