Software Design Document v1.0a: Capstone Project in the Music Department

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I. OVERVIEW

This is a proposal for a capstone project in the music major at Stanford University. I intend to implement a biosignal sonification exhibit where one can view their vital signs artfully sonified. Vital sign sensors will read data into a C++ program running on a Raspberry Pi/Arduino, and communicate with a ChucK sonification algorithm to output a live musical representation of an individual's biodata.

II. CONTEXT

The goal of this software design document is to outline a capstone project proposal in the Music Major at Stanford University, with a concentration in Human Computer Interaction. I have always found myself stretched between a desire to practice medicine, and a passion for playing music. It seemed that neither interest would allow the other to dominate.

A requirement for graduation with a Bachelor's of Arts in Music at Stanford University is the **capstone project**. This is defined as the *"culmination of the 16 units of coursework in your focus area."* Though the core of the department focuses on a traditional music education with classes in music history, ear training, and music theory, the concentration allows for interdisciplinary exploration. I have chosen to design my own concentration: **Human Computer Interaction**. The culmination of my concentration has focused an interdisciplinary application of music to the domain of neuroscience, audiovisual design, and computer generated sound processing and synthesis. Therefore, my **proposal for a capstone project is the development of artful biosignal sonification software**.

i. GOALS The goals for this project are as follows:

- Artful biosignal sonification software
- Implementation of playback and livestream mode:
  - Playback mode would allow a complete dataset to be played through the sonification algorithm to generate an output file.
  - Livestream implements a direct pipeline from hardware sensors to biosignal aquisition, digital signal processing (DSP) algorithms, to sound synthesis in an instantaneous format.
  - Ultimately, a audiovisual exhibit to **artfully** represent human vitals in the domain of music.

III. PROPOSED SOLUTION

The proposed implementation of software for my capstone project is as follows.

In `sonifyBiosignals_Ex/` There is a prototype of my proposed capstone. A Python script using a music framework running on a Java VM takes in a biosignal dataset stored in `biosignals.txt`. The format of the data is saved in the following format:

```
[time(hour:minute:second:milisecond)] [skin conductance (microsiemens)]
[blood pressure (ratio of systolic to diastolic)]
```

Over time, the Python script maps skin conductance to a pitch (C3-C6), and blood pressure to both a scale step in a two octave scale [0, 24] and a dynamic magnitude [0, 127]. As skin conductance doesn't varry greatly, the pitch at a certain time point is the sum of a base pitch computed from skin conductance and pitch variation between 0 and 24 scale steps computed from blood pressure, played at a dynamic computed from blood pressure where each value is calculated relative to the minimum and maximum blood pressure in the dataset.

The output is a MIDI value which can be used in any musical context.

Though this example covers a specific and narrow scope, it is a foundation which I will build upon. I will design an algorithm in ChucK to represent raw signal data in a musical format. To do this, I will experiment with various parameters so that heart rate, blood presure, temperature, and pulse oximetry (and perhaps skin conductance as well) work in a system to accurately, yet artfully represent the emotional and physiological state of the user.

i. SYSTEM ARCHITECTURE This software will use C++ to gather and process biodata, and send that data to ChucK for sonification. I am still uncertain if ChucK will be used natively with C++ so as to compile a single program which can run on a specified platform, of if a C++ program will communicate with ChucK over an Open Sound Control (OSC) protocol. Additionally, I am still uncertain how biodata will be collected live, and what the target platform will be (laptop, Raspberry Pi, etc.). Though, in the past I have implemented an electrocardiogram (ECG) machine using electrodes and various capacitive filters running on an Arduino.

The system architecture I propose is a basic vitals machine using electrodes and sensors to create an isolated exhibit where individuals may hook themselves up to an ECG, temperature probe, blood pressure cuff, galvanic skin response sensor, and pulse oximetry sensor to view their vitals sonified live. The vital sign sensors would run through a Raspberry Pi/Arduino running the proposed C++/ChucK software.

ii. SYSTEM DESIGN

```
[ECG pads, temperature probe, blood pressure cuff, galvanic skin response, and pulse oximetr
```

```
|
|
|
----> [Microcontroller]
|
|
|
----> [Data collection and processing]
|
|
|
----> [Data Sonification]
|
|
|
----> [DAC Output]
```

IV. TIMELINE

Fall Quarter 2021: 1 Unit Music 199

- write documentation (DONE)
- prototype using Jython (DONE)
- compile build of C++ and ChucK (DONE – see `src/`)

Winter Quarter 2022: 1 Unit Music 199

- gather datasets which will be used to test software
- build out `host` to read datasets and process data
- seamless communication between processed data in C++ and ChucK
- build data aquisition hardware to read 5 vital signs into `host`
- END GOAL: MVP

Spring Quarter 2022: 2 Unit Music 199

- build out ChucK sonification algorithm
- futher build out software to transition from an MVP to a polished product
- refactor (if needed)
- ship out final audiovisual exhibit software and hardware.