SONIFICATION SYNTHESIZER FOR SURFACE ELECTROMYOGRAPHY

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ABSTRACT

Surface electromyography (sEMG) is a means for measuring muscle activity. sEMG data are typically displayed graphically on a computer screen and while this can be a useful way to display the data, it is not always ideal. This extended abstract details the development of a sonification tool that allows users to sonify sEMG data in real-time. The tool will allow the user to independently control the sound of each channel, similar to a software synthesizer. Independent real-time control of each channel will allow the user to create sonification models, which are mappings of certain sounds to specific muscle groups. A prototype of the tool is currently being developed using SuperCollider in parallel with a Delsys Trigno Wireless sEMG system. This tool will allow users to easily explore various kinds of sEMG sonification models and test them for intuitiveness and effectiveness.

1. INTRODUCTION

Surface electromyography (sEMG) is used for measuring initiation of muscle activation, its relationship to the force produced by a muscle, and is used as an index of fatigue processes occurring within a muscle [1]. Researchers use sEMG as a biofeedback tool [2] and to evaluate the biomechanics of human movement. Understanding the biomechanical data that sEMG provides could lead to a better understanding of inefficient or dangerous movement patterns.

Currently, the standard for displaying sEMG data is plotting the data graphically on a computer screen [3]. Though informative, graphical displays of sEMG data are not ideal for a variety of reasons. First, a typical sEMG test measures multiple muscle groups simultaneously resulting in a sEMG visual display containing multiple graphs. Each of these graphs must be monitored simultaneously, forcing the researcher to focus all of his or her attention on the screen, rather than on the test subject. Second, graphical displays can only be analyzed by inspection and statistical analysis. However, statistical comparisons of sEMG data for different tasks and physical positions are shallow with regard to understanding the full impact of different actions and environments on the muscle systems that work together to perform various tasks. Thus, the benefits of using sEMG are often diminished because the data are difficult to analyze. Last, during a sEMG test, data streams from different muscle groups can become corrupted due to motion artifacts, high frequency noise from electronic systems, and 50-60 Hz noise from power lines [4]. If this is not immediately recognized (as is often the case since the researcher is attempting to monitor multiple graphs at once) and the noise cannot be adequately filtered out, the data from those sEMG leads must be discarded and usually the entire test as well, wasting time and money.

Previously, artists and scientists have used sonification of sEMG as a method for displaying human muscle activity [5, 6]. sEMG sonification could also be used for biofeedback and data analysis. Some of the benefits of doing this include allowing the visually impaired access to sEMG data, allowing scientists to analyze the data in a more holistic manner, and providing a means for exploring potential emergent properties of the data. Although these efforts of sonifying sEMG have met with some success, there has been little science investigating the effect of different auditory display designs on the comprehension of sonified sEMG. Given that previous work in auditory graphs and other auditory displays has found that display design can remarkably impact comprehension and performance [7], it is important for researchers to conduct this type of work for sEMG sonification. However, for those who are not engineers, it is currently very difficult to manipulate the dimensions of sounds when building sonifications of sEMG. The work proposed in this abstract will lead to the development of a unique sonification tool that will allow researchers and practitioners a method for easily manipulating various dimensions of sound in sEMG sonifications. This will allow for further discovery regarding the applications of sonified sEMG and the appropriate display design for these applications.

2. SONIFICATION SYNTHESIZER

The sonification tool that is being developed as part of this project consists of two parts: a graphical user interface (GUI) on the front end and sonification code on the back end, similar to a software synthesizer. The GUI will ultimately allow the user real-time, independent control of multiple parameters of sound, though initially the focus is on allowing the user to control the pitch, spatial location (panning), and tempo of the sonification. The GUI allows these parameters to be customized for each incoming channel of sEMG data, thus allowing each channel to produce a different sound. This allows sonification profiles to be developed. A sonification profile is simply a mapping of specific sounds to specific muscle groups. Once a profile is created, the user can save the profile through the GUI and access it again for later use. This will allow researchers to develop their own sonification profiles and test them for intuitiveness and effectiveness for different tasks.

3. SONIFICATION SYNTHESIZER DEVELOPMENT

Originally a proof-of-concept prototype was attempted using NI LabVIEW in conjunction with a Delsys Trigno Wireless sEMG system. LabVIEW was chosen as the proof-of-concept platform because the development team had more experience with LabVIEW than other programming languages and because the Delsys software developer's kit (SDK) included several LabVIEW virtual instruments (VI's) that can be used to monitor the incoming sEMG data.

However, three main issues arose with the use of LabVIEW. First, mapping each sEMG data point to the frequency of a tone generator yielded uninformative 'buzzing' sounds when the data were played back in real time. Second was a large lag (latency in the system) that prohibited any effective use of real-time auditory feedback. Lastly, National Instruments' VI which should allow for independent control of sound channels (used to control panning) did not work due to a bug in LabVIEW's sound card driver which prevents proper channel selection.

Due to these issues, the development team decided to switch to the SuperCollider programming environment. SuperCollider is a powerful audio synthesis tool and can generate a wide variety of sounds, import data, create custom GUIs, and has been used for sonification in the past [8].

This abstract presents the results of the first phase of the project, which is limited to the tool controlling three parameters of sound (pitch and loudness, tempo, and spatial location). To create the sEMG sonifications, we used the SynthDef and Task functions in SuperCollider and had the oscillators set to generate triangle waves as the output waveform during sonification playback. Further, the sound is not continuous, but is a discrete stream of beeps.

The parameters are controlled using sliders on the GUI and each slider controls one parameter independently of the other two, meaning that one parameter (e.g., tempo) can be altered without affecting another parameter (e.g., spatial location).

- The Tempo slider on the GUI controls the rate of the beeping. This is accomplished by applying a square wave duty cycle (controlled by the slider) to the amplitude of the oscillator within SuperCollider.
- The Spatial Location slider controls whether the sounds are heard on the right or left channel.
- The Pitch slider controls the pitch range over which the sEMG data are sonified. Regardless of the pitch range, the polarity of the mapping is positive with low sEMG data point values (indicative of little to no muscle contraction) corresponding to lower pitch and loudness, and likewise higher sEMG data points (which indicate muscle contraction) correspond to higher pitch and loudness. We choose to map these dimensions redundantly because previous research has found that for some tasks, using pitch alone for mapping results in reduced performance and redundant mapping with loudness can compensate for this [9].

During the second phase of the project, the tool will be expanded to allow for more parameters of sound to be controlled (e.g. timbre), and will be configured to allow for live sEMG data sonification.

4. MOTIVATION

The motivation behind developing a tool that can create sonification profiles lies in the need for biofeedback systems and data analysis tools. As a result of humans' finely tuned hearing systems, it is likely that developing sonification profiles could provide users a highly informative data analysis experience. It is anticipated that different sonification profiles will be better suited to different tasks. For example, a profile that is complex and requires a trained ear could be more suited for analyzing data while a less complex profile could be more intuitive for biofeedback. With this tool, both types of sonification profiles could be developed, providing avenues for biofeedback as well as data exploration and analysis.

5. REFERENCES

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