Notes on Bimodal Muscle Sensing for the Sonification of Indeterminate Motion

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ABSTRACT

This article offers an overview of a musical performance instrument that leverages bimodal muscle sensing for the sonification of motion. Namely, the instrument a) captures the sound produced by a performer's muscles and makes it available for real-time audio processing, and b) enables a performer to drive the processing parameters using high-level features extracted from muscle activity. This enables the performer to produce and finely shape sound with gestures that do not need to be specified beforehand as a vocabulary of a finite number of movements. This allows the performer and the software to create an open-ended range of sonified movements which arise from the interplay of bodily mechanisms and software processes.

Categories and Subject Descriptors

H.5.2 [**User Interface**]: Input devices and strategies; H.5.5 [**Sound and Music Computing**]: Modeling—*Signal analysis, synthesis, and processing*

General Terms

Human Factors, Design, Measurement

1. INTRODUCTION

The instrument that will be described here manipulates sounds coming from the performer's body. Namely, the instrument uses live sampling to process an acoustic oscillation produced by the muscle at the onset of a contraction. Also known as muscle sound or MMG, this is an acoustic biosignal sitting between 1-50Hz that can be amplified and heard [6] through headphones and loudspeakers. The muscle sound is a valuable sound source for its acoustic dynamics reflects closely the physical dynamics of movement. For instance, a strong, sudden and fast arm contraction produces a loud muscle sound with a sharp attack and a very short release. The live sampling of the muscle sound is driven by a model of the performer's muscle activity, which is computed by extracting features from the same muscle sound and a distinct muscle biosignal, the electromyogram or EMG. Thus, the sonified motion arises from the interplay between corporeal mechanisms and software processes. This work builds upon previous research where single-channel and bimodal biosignals were used for digital music performance, more relevantly [7] [3], and [8] [4]. Specifically, the present work extends those studies by looking at the computational modeling of muscle activity using the MMG and EMG muscle biosignals in a bimodal configuration.

2. MODELING MUSCLE ACTIVITY

The MMG and EMG are signals produced at different moments of muscle contraction and thus provide complementary information on the movement articulation [4]. The MMG is a low frequency vibration emitted by a muscle at the onset of a contraction. It is captured in the form of sound using a contact-less microphone sensor worn on the skin[1]. The EMG is an electrical biosignal that arises from neurons firing to trigger muscle contraction. It is captured in the form of electrical voltage using electrodes touching the skin[2]. By extracting and quantifying selected frequency- and time-domain features from both the MMG and EMG the instrument obtains a model of a performer's muscular activity. The features were selected from the related biomedical literature in virtue of their capability to provide information on dynamic, whole-body gestures.

Spectral Variance is the standard deviation of the energy contained in the frequency spectra. It is an indicator of the strength of the contraction.

Activation is the averaged amount of 1-bin-wide peaks detected in the frequency spectra[3]. It conveys information on the complexity of the contraction.

Change Rate is the second order derivative of the spectral variance. It provides information on how the muscular articulation shifts from low to high force over time[4].

Mobility is the standard deviation of the first derivative of the signal over the standard deviation of the signal. It conveys information on the change in complexity of the signals.

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[1] The Xth Sense. See http://res.marcodonnarumma.com

[2] The BioFlex. http://infusioninstruments.com

[3] Distance between noise floor and peak level is user-defined.

[4] A constantly decreasing change rate also indicates fatigue.

The set of high-level features described above is mapped into a user-defined number of parameters that drive the processing of the muscle sound (Figure 1). The muscle sound is used as the exclusive sound source for the musical composition. The resulting sound output is a mix of the natural muscle sound and its digital counterpart that finely reflect the dynamics of the performer's physical movement, without the need for a pre-determined gesture vocabulary.

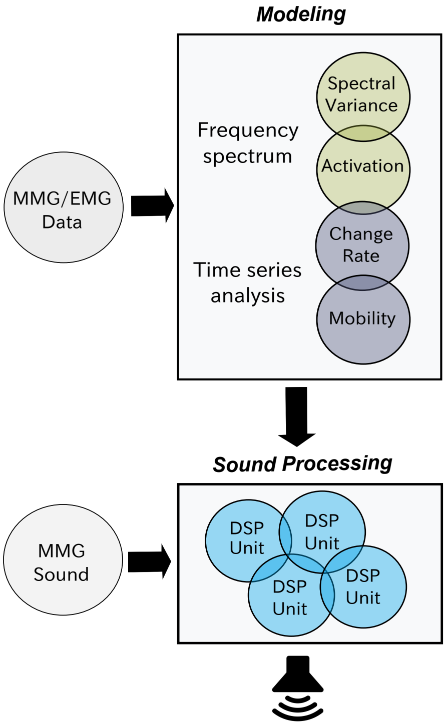

Figure 1: The instrument engine. A model of muscle activity is computed from high-level features of both MMG and EMG biosignals. The model is then mapped into parameters that drive the processing of the muscle sound.

3. PLAYING WITH BIOSIGNALS

For a player, being able to create a specific sonority by skilfully articulating physical gestures is gratifying. On a traditional instrument limb coordination is critical to both the qualities of the music and the pleasure of performing. This can be a difficult capability to achieve with digital musical instruments. This is especially true for multimodal biosignal-based musical instruments like the one described here, as i) they do not offer haptic feedback and ii) rely on corporeal processes that are conditioned by the autonomic system. In this sense, there are some aspects of muscular activity that increase the playfulness of the instrument.

Strength to loudness. A basic characteristic of the muscle sound is that its loudness increases with the strength of the contraction [1]. A simple and useful mapping technique is to extend the relationship between strength and loudness by adding multiple dimensions to it.

Sympathetic muscle actvity. A limb flexion enacts sympathetic vibrations of the adjacent limbs. The biosignal analysed at the capture point is the sum of interrelated limb vibrations. Skilful coordination of multiple limbs results in fine modulation of biosignal dynamics.

Modulation of the biosignal sound spectrum. As muscular force increases, the biosignal frequency spectrum becomes broader [5]. Whole-body coordination allows a player to grade muscular force so to produce specific and consistent spectral changes in the biosignal.

4. ONGOING WORK

A fascinating perspective that is being investigated is to make the instrument adapt to different players. Ongoing work is looking at the application of machine learning methods. Specifically, one case that is being investigated is the design of a method whereby the gesture-to-sound mapping is not pre-programmed, but rather generated by the instrument according to the specific traits of a player's performance style. An adaptive algorithm based on bayesian inference [2] is being used to follow given variations in the parameters of the current muscle activity model. That information is then used by the instrument to create personalised gesture-to-sound mapping that the player can explore, evolve, manipulate, and even 'break', simply through physical engagement.

5. REFERENCES

[1] C. F. Bolton, A. Parkes, T. R. Thompson, M. R. Clark, and C. J. Sterne. Recording sound from human skeletal muscle: Technical and physiological aspects. *Muscle & Nerve*, 12(2):126–134, 1989.

[2] B. Caramiaux. Motion Modeling for Expressive Interaction: A Design Proposal using Bayesian Adaptive Systems. *Proceedings of the International Workshop on Movement and Computing*, 2014.

[3] M. Donnarumma. Incarnated sound in Music for Flesh II. Defining gesture in biologically informed musical performance. *Leonardo Electronic Almanac (Touch and Go)*, 18(3):164–175, 2012.

[4] M. Donnarumma, B. Caramiaux, and A. Tanaka. Muscular Interactions Combining EMG and MMG sensing for musical practice. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, Seoul, South Korea, 2013. KAIST.

[5] C. Orizio, R. Perini, B. Diemont, M. Maranzana Figini, and A. Veicsteinas. Spectral analysis of muscular sound during isometric contraction of biceps brachii. *Journal of applied physiology (Bethesda, Md.: 1985)*, 68(2):508–512, Feb. 1990.

[6] G. Oster and J. S. Jaffe. LOW FREQUENCY SOUNDS FROM SUSTAINED CONTRACTION OF HUMAN SKELETAL MUSCLE. *Biophysical Journal*, 30(1):119–127, 1980.

[7] A. Tanaka. BioMuse to Bondage: Corporeal Interaction in Performance and Exhibition BioMuse. In M. Chatzichristodoulou and R. Zerihan, editors, *Intimacy Across Visceral and Digital Performance*, pages 1–9. Palgrave Macmillan, 2012.

[8] A. Tanaka and R. B. Knapp. Multimodal Interaction in Music Using the Electromyogram and Relative Position Sensing. *Proceedings of the 2002 conference on New interfaces for musical expression*, pages 1–6, 2002.