

Sonic Echoes of Ink, for sEMG Mediated Piano and Live Electronics

Pingting Xiao

Department of Music

University of Manchester

pingting.xiao@postgrad.manchester.ac.uk

Abstract

Sonic Echoes of Ink is a live electroacoustic composition for acoustic piano, two-channel surface electromyography (sEMG), and live electronics. The piece explores embodied music cognition through the relationship between forearm movement, piano performance, and real-time sound manipulation. All sound materials originate from the piano (including keyboard playing and inside-piano string plucking), shaping resonant traces reminiscent of Chinese ink painting, from clear outlines to blurred, layered textures. The work studies how forearm muscle activation can shape musical form through a transparent computational mapping rather than functioning only as an effect trigger. Sensors on the performer's left and right forearms send data, and the signals control real-time processing of sounds produced by the piano.

1 Introduction

Building on Marc Leman's embodied cognition framework, the study investigates the dynamic interplay between sound energy, mental representation, and the human body as a biologically designed mediator in musical activities. The construction of composition will seek to address how embodied cognition can bridge the gap between the physical encoding of music and its experiential interpretation, with a particular focus on Electroacoustic Music, and will study how artificial systems can extend natural bodily mediation in both creative and live interactive media contexts.

Sonic Echoes of Ink takes its title and formal imagery from Chinese ink painting. Outlining refers to clear contours, isolated marks, and the articulation of space around a gesture. Ink Splashing refers to accumulated layers, diffusion, and a less stable boundary between figure and ground. These ideas guide audible contrasts in note density, dynamic weight, harmonic saturation, resonance, and the depth of electronic transformation. Silence and decay are active materials: a pause leaves the piano's resonance and the body's previous effort perceptually present. This piece explores the intersection of embodied music cognition and Electroacoustic Music composition, aiming to advance our understanding of how humans engage with music through bodily mediation and technology.

2 Development method

This work interconnects theoretical framework, system construction, data processing, and mapping design, aiming to establish an interpretable path from Surface Electromyography (sEMG) signals to musical context.

2.1 System construction

The system consists of a piano (acoustic piano / MIDI keyboard), dual-channel forearm sEMG, and Max/MSP.

- Hardware: Arduino Uno R3; two sEMG sensors (dual channel)
- Software: Arduino performs dual-channel acquisition and outputs data; Max/MSP receives data in real-time, performs mapping and sound processing

- Data pathway: sEMG □ Arduino □ Serial □ Max/MSP

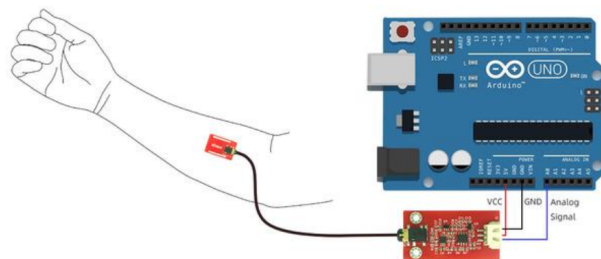


Figure 1. Wiring diagram

The piano functions both as the primary acoustic sound source and as the physical site of the performer's gestures. These gestures include conventional keyboard playing and direct interaction with the strings. Rather than attempting to identify complete gestures from the sensor data, the system measures changes in forearm muscle activation and uses them to influence the electronic processing of the piano sound.

2.2 Signal processing and mapping design

Surface Electromyography (sEMG) signals are not viewed as a transparent or direct representation of physical movement. However, they are regarded as a data source that is inherently unstable and even somewhat "dirty". Due to their low amplitude, sEMG signals are susceptible to factors such as mains interference, power supply and ground noise, fluctuations in skin impedance, electrode placement and contact quality, baseline drift, and the analog-to-digital conversion process. Consequently, prior to transmitting data to Max/msp, the technical development focused on deriving a representation of muscle activation that is stable, clear, and musically interpretable.

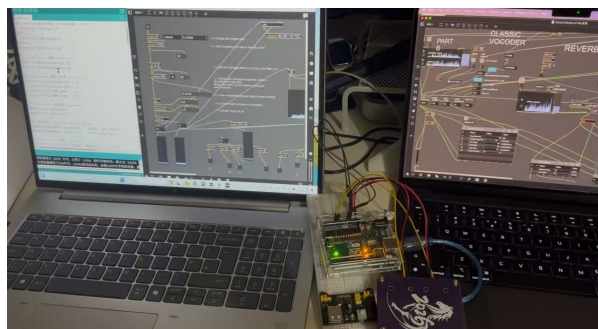


Figure 2. Workflow

The process involved four stages: establishing a functional data acquisition system, improving signal reliability, giving musical meaning to the processed data, and developing performance strategies through repeated experimentation.

The first step involves examining baseline noise and artifacts caused by electrode contact across various environments and placement configurations. The second step entails calibrating and evaluating the system by recording and comparing sEMG data generated by different forearm movements. This process helps identify which changes in the sEMG signal can be interpreted consistently, while avoiding the pitfall of equating sensor data directly with the physical movement itself or the performer's intentions. In the third step, the Mean Absolute Value (MAV) is calculated over a fixed time window for the sampled input data. This feature extraction method mitigates rapid

amplitude fluctuations and outputs control signals at a relatively stable and consistent update rate. The processed data can be utilized for mapping within Max/msp without the need to preserve every irregularity present in the raw signal.

Finally, the mapping process is approached as a composition structure rather than merely a technical conversion of sensor values into effect parameters. Variations in muscle activation levels influence timbral transformations and the intensity of sound processing, while also contributing to the development of the work's overall structure and the accumulation and release of musical tension. Through this way, the performer's body movements become a form of embodied decision-making within the structural organisation of the piece.

3 Composition structure

This piece is divided into two sections, Outlining and Ink Splashing. The first section highlights single notes, discrete attack transients, inside-the-piano string plucking, and decays. The electronic component as a complementary layer in this section, with its evolution tracking the performer's finger touch and the muscular intensity. The second section introduces the dynamics. In this section, more sustained and continuous physical movements exert a more pronounced influence on the evolution of timbre and structure. The transition between the two sections entails not only a shift in musical material but also a change in the degree to which physiological data controls the electronic component.

4 Conclusion and reflection

This work employs surface electromyography (sEMG) signals to connect physical exertion and piano resonance with the morphology of real-time acoustics. Variations in these signals not only influence timbre transformation and the intensity of processing but also drive the evolution of musical form and the accumulation and release of musical tension. This evolutionary process suggests that the primary value of sEMG lies not in the direct recognition of specific physical gestures, but rather in its nature as a contextual and dynamic signal whose musical significance emerges from the interplay between sound processing and the performance context.

The current system utilises an intuitive mapping strategy rather than machine learning. Future research will investigate whether adaptive or learning-based mapping methods can further enhance system responsiveness without compromising the relationship between physical exertion and the electroacoustic context.

Acknowledgments

This work was developed within the PhD project “Embodied music cognition in Electroacoustic Music” at the University of Manchester (NOVARS Research Centre). The author would like to thank the supervisory team who provided feedback during the Year 1 process and related dissemination events.

References

- Bertissolo, G. (2019) Composing understandings: Music, motion, gesture and embodied cognition. *Proceedings of the International Conference on New Interfaces for Musical Expression*.
- De Stefani, E. & De Marco, D. (2019) Language, gesture, and emotional communication: An embodied view of social interaction. *Frontiers in Psychology* **10**:2063.
- Di Donato, B., Bullock, J. & Tanaka, A. (2018) Myo Mapper: A Myo armband to OSC mapper. *Proceedings of the International Conference on New Interfaces for Musical Expression*.
- Donnarumma, M., Caramiaux, B. & Tanaka, A. (2013) Muscular interactions: Combining EMG and MMG sensing for musical practice. *Proceedings of the International Conference on New Interfaces for Musical Expression*.
- Fiebrink, R., Trueman, D. & Cook, P.R. (2009) A meta-instrument for interactive, on-the-fly machine

- learning. *Proceedings of the International Conference on New Interfaces for Musical Expression*.
- Ghelli Visi, F. & Tanaka, A. (2021) Interactive machine learning of musical gesture. In E.R. Miranda (ed.), *Handbook of Artificial Intelligence for Music*. Cham: Springer.
- Jia, R. & Liu, X. Appropriating technology for interactive media in theatre: Design strategies and aesthetic insights.
- Kursell, J. (2011) Visualizing piano playing. *Grey Room*.
- Maes, P.-J., Van Dyck, E. & Leman, M. (2014) The coupling of action and perception in musical meaning formation. *Music Perception* **32**(1).
- Rhodes, C., Allmendinger, R. & Climent, R. (2019) New interfaces for classifying performance gestures in music. In *Intelligent Data Engineering and Automated Learning – IDEAL: 20th International Conference, Proceedings*.
- Rhodes, C., Allmendinger, R. & Climent, R. (2020) New interfaces and approaches to machine learning when classifying gestures within music. *Entropy*.
- Rhodes, C., Allmendinger, R., Jay, C. & Climent, R. (2023) Towards developing a virtual guitar instructor through biometrics informed human-computer interaction. *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*.
- Tanaka, A. (2011) Sensor-based musical instruments and interactive music. In *The Oxford Handbook of Computer Music*. Oxford: Oxford University Press.
- Tanaka, A., Fierro, D., Di Maggio, F., Klang, M. & Whitmarsh, S. (2013) The EAVI ExG muscle/brain hybrid physiological sensing. *Proceedings of the International Conference on New Interfaces for Musical Expression*.
- Tanaka, A., Di Donato, B., Zbyszynski, M. & Roks, G. (2019) Designing gestures for continuous sonic interaction. *Proceedings of the International Conference on New Interfaces for Musical Expression*.
- Tepe, C. & Demir, M.C. (2022) Real-time classification of EMG Myo Armband data using support vector machine. *Ingénierie et Recherche Biomédicale*.
- Van Zandt-Escobar, A., Caramiaux, B. & Tanaka, A. (2014) PiaF: A tool for augmented piano performance using gesture variation following. *Proceedings of the International Conference on New Interfaces for Musical Expression*.
- Yang, Q. & Essl, G. (2014) Evaluating gesture-augmented keyboard performance. *Computer Music Journal*.