

Sonic Experimentalism in the Practice of Conducting

Sound Sticks and Magic Wands, or Expansion of Practice?

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ABSTRACT

The sonic baton is a novel intelligent instrument that expands the practice of conducting by sonifying conductor gestures, with or without an ensemble. This paper reviews related sonic baton technologies developed over the past two decades before it introduces the sonic baton, an intelligent instrument using neural audio synthesis with Realtime Audio Variational autoEncoder (RAVE) models, applying practice-research in a series of performance experiments. These experiments highlight the baton's potential for diverse sonic expressions. Reflections on performances reveal unique opportunities for conductors, ensembles, and composers. The paper concludes that artificial intelligence can significantly expand conducting practices and augment musical ensembles' sonic expressions, reinforcing the emergence of a new music-science paradigm.

THE EMERGING MUSIC-SCIENCE PARADIGM

The growing interdisciplinary, cross-disciplinary, and trans-disciplinary approaches to the study and practice of music are leading to new and recurring intersections with science. Some recent examples include the effect of music on brain function in neuroscience [1], computer scientists developing music algorithms to generate music [2], musical analysis applying sophisticated mathematics in understanding early music counterpoint [3], and music to improve medical outcomes and provide psychological benefits [4,5]. The growing number of intersections are driving an emerging new music-science paradigm. While the aforementioned cases apply artificial intelligence technologies in their research, AI is also changing the way that humans create and broaden their artistic and musical expressions, and recent examples include the Intelligent Instruments Lab, Iceland University of the Arts [6–8].

To understand the significance of technologies in the context of conducting, we must consider changes to the practice of composition, orchestral formulation, and musical performance, which have gone hand in hand with each Industrial

Revolution. The first Industrial Revolution (1760–1880) was defined by the scaling of production systems through mechanization [9]. Concurrently, musical instruments were mechanized [10,11] allowing for greater tonal complexity in performance and the ensemble went through an expansion; see Tresch and Dolan [12]. The second Industrial Revolution impacted music by increasing urban access to musical entertainment and music publishing. Instrumental mechanical improvement created demand for quality performances with ambitious compositions [13] that required conductors to have clear technique to lead and unify large symphony orchestras. The third Industrial Revolution commenced in the 1950s and is characterized by the shift from mechanical and analog electronic technologies to digital electronics [14]. Orchestral music was consumed on a global scale through digital recording and distribution (CDs, streaming), transferring apex power to the conductor in the mid-twentieth century [15]. New electronic instruments and synthesis created alternative mediums of expression for composers and eventually led to New Interfaces for Musical Expression (NIME) in the early twenty-first century. Compositions that blended electronic music with acoustic instruments in live performance required a conductor to unify the orchestra or ensemble with the audio recording. This required the conductor to acquire the skill of “perfect tempo” (a precise interpretation of the metronome mark) as well as familiarity with audio technologies and interpretation of spectrograms to ensure unification of the ensemble. This brings us to the fourth Industrial Revolution, which is concurrent with, and evolving from, the third Industrial Revolution. The fourth Industrial Revolution is likely to be characterized by a convergence of technologies between the physical, digital, and biological spheres [16]. AI is already playing an increasing role in broadening musical expression; what might this mean for the conductor?

In this respect, technologies continue to expand the artistic possibilities for instrument-makers, instrumentalists, symphony orchestra spaces, composers, and conductors [17]. While financial and social realities within professional

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orchestras are currently driving extensive changes, the continued convergence of music, science, and technology is certainly creating new forms of artistic expression within orchestral music productions. Conducting is no exception to the emerging new music-science paradigm—what was once innovative hundreds of years ago is now considered traditional practice [18]. New technologies such as gesture motion tracking through computer vision, and gesture-based time stretch algorithms applying machine learning, allow for increased accessibility, diversity in sonic spectrum, and new performance experiences. This article explores what new technologies can mean for the expansion of the practice of conducting and presents artistic outcomes and reflections from several experiments. It argues that the practicing of specific gestures with the new intelligent sonic baton instrument, with the intention to accurately produce intended sonic results, requires an expansion of practice.

The first section of this article will review the developments of sonic batons over the last two decades. The second section will present the approaches, technologies, and materials used in the development of the sonic baton. The third section will reflect on experiments and performances by the author using the sonic batons under different performance formats. The final section of the essay concludes by arguing that the sonic baton, applying neural audio synthesis, can indeed expand the practice of conducting and therefore is valuable to the emerging music-science paradigm.

HISTORICAL PRACTICES

Gesture-electronic music performances can be traced back to the invention of the aetherphone in 1919 and subsequently in 1925 the patented theremin [19]. Real-time hand gesture performances that used interfaces and software gained momentum in the 1980s with *The Hands* [20] and Laetitia Sonami's *Lady's Glove* in 1991 [21]. The first of the sonic-inspired conducting batons to be prototyped in 1997 were the Mathews Radio Baton and Improvised Nodes, which tracked conductor gesture motion in three-dimensional space with electrical signals conveyed through MIDI cables using standard MIDI conventions [22,23]. A decade later, artist Joseph Young collaborated with Mike Blow to create a sonic baton for "conducting noise." Movement data, captured by an accelerometer and a custom Arduino board, was transmitted to a laptop running a MAX/MSP patch. This patch acted as the intermediary, controlling parameters within Ableton Live's MIDI-enabled software environment [24].

Das Haus der Musik in Vienna showcased its own virtual conducting installation with a focus on conducting selected classical music repertoire pre-recorded by the Vienna Philharmonic Orchestra. The conductor would take the wand and select a piece to conduct. The selections included *The Blue Danube Waltz*, *Annen-Polka*, and *Orpheus-Quadrille* by Johann Strauss II; *Eine Kleine Nachtmusik* by Mozart; Brahms's *Hungarian Dance No. 5*; or the *Radetzky March* by Johann Strauss I. Some conducting gestures are adaptable to the virtual experience, such that the larger the plane covered in moving the wand, the louder the orchestra played. Using

a time stretch algorithm, the conductor sets and controls the tempo of the music [25].

Another type of virtual conducting experience is the *UBS Virtual Maestro*. It is an interactive conducting system designed and developed by Immersion Music to simulate the experience of orchestral conducting for the public. The *UBS Virtual Maestro* uses similar technology including the Wii Remote, which users hold and move like a conducting baton to affect the tempo and dynamics of an orchestral video/audio recording. An accelerometer is used to generate data based on gesture and is connected to the Wii Remote, which is used to control playback speed and volume in real time [26].

A very different yet similar experience that turns the regular museum visitor into a virtual conductor is the *Mendelssohn—Effectorium* at Mendelssohn-Haus Museum in Leipzig, Germany. Using compositions by Felix Mendelssohn, the installation is made of some 12 speakers. Using Leap Motion, a USB computer peripheral released in mid-2013 that uses infrared cameras to track hand and finger location and gestures with "sub-millimetre accuracy" [27], the tempo of the music can be expressed through gesture when the conductor selects "playback audio with conducting." A touchscreen serves as a control center to provide visualization of the score and set parameters, such as the acoustics and tuning of the instruments, from classical pitch A = 430Hz to modern concert pitch A = 443 Hz, and also allows the conductor to mute and select specific instruments in the score [28].

These virtual conducting systems and sonic batons reflect different approaches to translating physical gestures into musical/sonic expression. The Mathews Radio Baton and Young's sonic baton utilize direct mapping, where specific gestures are linked to predefined sonic parameters. In contrast, the *Das Haus der Musik* and *UBS Virtual Maestro* installations employ time-stretching algorithms and dynamic volume control to create a familiar traditional conducting experience, where some musical elements can be expressed through gesture, such as tempo and dynamics. The *Mendelssohn—Effectorium* takes a different approach by allowing users to manipulate individual instrumental parameters and historical tunings, emphasizing an educational and exploratory aesthetic. Despite their differences, the aforementioned systems and experiences share a common algorithmic aesthetic of real-time responsiveness, aiming to create an immediate and engaging connection between the gestures and the resulting musical/sonic expression, even if the underlying complexity of this connection varies significantly between implementations.

The technologies in the installations provide the public with an opportunity to experience the sensation of traditional conducting applied to recognizable classical music repertoire. These technologies do not expand the practice of conducting, because their novelties are built around traditional repertoire [29]. These installation technologies present users with a traditional symphonic orchestra conducting experience, with limited conductor agency in gestural-sonic response. In contrast, the Mathews Radio Baton and Young's sonic baton could facilitate sonic improvisation with gesture and allow for greater agency in performance.

MAGIC WAND OR CULTURALLY CHARGED OBJECT?

This article presents a new sonic baton designed to address the transportability, scalability, and accessibility limitations observed in previous models. The use of a conducting baton as the foundational tool to attach the sensor technologies is important because the traditional conducting baton is not a sonic object or instrument by itself, but through the act of gesture, it inspires a unified musical outcome. The conducting baton as an object holds significant “cultural charge” [30] and can be argued to embody the authority of orchestral traditions.

The sonic baton in this article’s focus was developed by the author and originated during the Sibelius Academy’s course Symbolic Sound Producing Gesture, overseen by Charles Quivillon in November 2022. The first experiment attached a contact microphone to the conducting baton with the intention of amplifying the conductor movements with the conducting baton (Fig. 1).

While the technologies in this performance experiment were relatively simple, there were several aspects that required further design consideration. For instance, why so many cables and connections in the age of wireless and Bluetooth technology? And what are the possibilities for a wireless sonic conducting baton? These questions led to the second iteration of the sonic conducting baton, and the involvement of the Intelligent Instruments Lab (IIL) at Iceland University of the Arts.

With IIL, the subsequent series of experiments aimed to explore the integration of a number of technologies using different sensors (accelerometer, gyrometer) and neural audio synthesis using Realtime Audio Variational autoEncoder (RAVE) model datasets [31], relayed through the microcontroller on the conducting baton. The wireless sensors capture

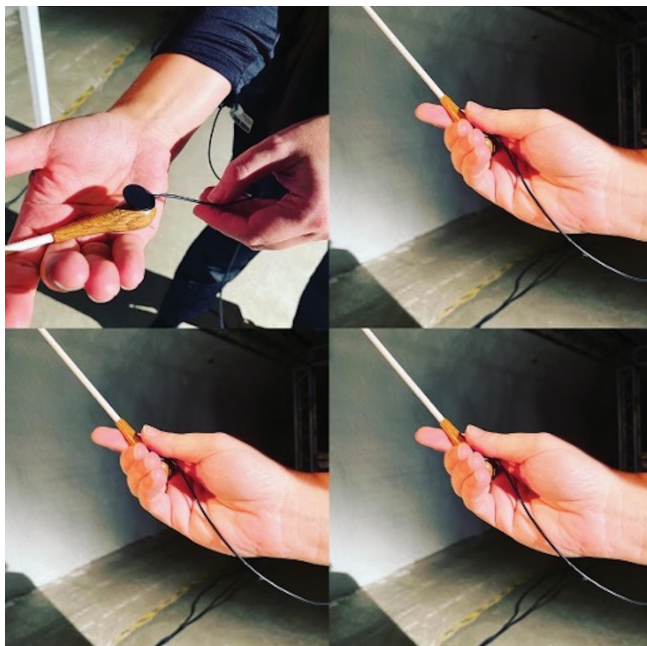


Fig. 1. Contact microphone on conducting baton. (© Majella Clarke)



Fig. 2. Conducting baton with accelerometer, microcontroller, and LiPo Battery. (© Majella Clarke)

the baton’s movements, which are then processed through an Arduino microcontroller to a Max Patch via a wireless router and amplified through a speaker system (Fig. 2).

MATERIALS AND ELECTRONICS

The materials and technologies used in the second version of the sonic baton were the LILYGO TTGO T7 V1.3 Mini 32 ESP32 Wi-Fi Bluetooth Module Development Board, which is a microcontroller based on an ESP32 system-on-chip as its core processing unit [32]. It includes built-in support for both Bluetooth and Wi-Fi. It is used with the Adafruit LIS3DH low-power triple-axis accelerometer (+/- 16g of force). The board has a micro-USB connection with which it can be programmed and recharged [33]. The battery is a small 350 mAh LiPo that provides 3.3V to the sonic baton’s circuit system. The conducting baton is conventional and has a fiberglass shaft with a wooden bulb grip and has been used as a traditional conducting baton with various orchestral performances (Fig. 2).

NEURAL AUDIO SYNTHESIS AND DATASETS

Neural audio synthesis uses artificial neural networks to generate, process, and modify audio signals [34]. This technology requires extensive training on diverse audio samples, using convolutional models that are computationally intensive [35,36].

For the sonic baton project, researchers at the Intelligent Instruments Lab trained RAVE models [37] on three distinct

datasets: human voices, electric guitar, and sea mammals. The datasets can be found in the Intelligent Instruments Lab's RAVE models repository on the AI collaboration platform Hugging Face [38]. For both the second and third iterations of the sonic baton, the RAVE models used were the electric guitar, voice, and sea mammals.

The guitar dataset included 10 guitar recordings made by Victor Shepardson in .WAV format to include a timbre-oriented collection of plucking, strumming, striking, scraping, and other sounds recorded from an electric guitar. The vocal dataset was sourced from Zenodo [39] and consisted of over 10 hours of singers (nine male and 11 female professional singers) vocalizing both standard singing and extended vocal techniques using the five English-language vowels. The marine mammal RAVE model is composed of several different datasets from NOAA [40], the Watkins Database [41], and Freesound users Felix Blume and Gerald Fiebig, as well as sound effects databases. Each RAVE model was trained on the timbral qualities and sonic characteristics specific to its dataset, using a modified RAVE v1 architecture with 48kHz sampling rate, 2048 block size, and 16–20 latent dimensions.

In performance, acceleration data from the baton's sensors were mapped to vectors in this learned latent space. This mapping translates physical movements into coordinates within the latent space. The RAVE decoder then converted these vectors into a continuous audio stream as presented in the sonic baton technical case study [42]. This process happens in real time, allowing for immediate audio feedback based on the baton's movements. This resulted in the spatialization of sound within the latent space that can be used to explore and navigate the RAVE model, thus creating an instrument that can be practiced for reproducing the same sonic effects, like musical scales, but with gesture.

SONIC BATON PERFORMANCE EXPERIMENTS AND REFLECTIONS

This section will reflect on my experiments and performances as conductor, using the sonic batons within different performance formats. From February to April 2023 I experimented with sonifying the conducting baton in collaboration with the Intelligent Instruments Lab at Iceland University of the Arts, as part of my master's of music degree project. The experiments aimed to explore the integration of AI with various technologies using sensors, audio data, and a Wi-Fi router to sonify conductor gesture with the specific aim of being wireless, so that the conductor's movements were not restricted and the sonic baton signals were untethered and wireless. In addition, the sonic-gesture output drew from curated datasets in the form of RAVE models; see Armitage et al. [43]. The first series of experimental performances tested whether and how the sonic conducting baton might be used in an illustrative (nonmusical notation) compositional context. I used the graphic score *May the Whole Universe* by Bergþóra Ægisdóttir [44] to develop two performance experiments that were tested using different performance formats.

The first performance format took place at the Living Art Museum in Iceland for the *Towards Sound Finissage* [45] and

had three performers (conductors?), each with a sonic baton facing inward. Wireless accelerometer and gyrometer sensors and microcontrollers were attached by Sean Patrick O'Brien from the Intelligent Instruments Lab to the three conducting batons to capture movements that were then processed through Arduino signals to Max Patch software. The graphic score *May the Whole Universe* [46] was in the center of the trio facing upward, so that each conductor had a different visual orientation to the composition. The experiment had two objectives. The first objective was to test what happens to intention and enactment of gesture in the context of conducting practice. The second objective of the performance was to capture and reflect on the way conducting gestures are translated into data that is translated into sound as part of an improvised performance, noting interactions and dynamics [47].

The performance experimented with the concept of conducting so that there were three performers (me, Nicola Privato, and Victor Shepard) facing each other in a circle. Each performer used a baton that produced different sounds based on the dataset available on the conductor baton, described above (electric guitar, voice, sea mammals). The performers' movements were expected to be guided by the graphic score, but as the video shows, this was not the case, as performers exercised their own intentions in exploring and responding to the emerging sonic environment. Important questions come from reflection at this point—what makes the difference between a conductor and a performer holding a conducting baton with sonic association? Does this mean anyone can be a conductor? Is conducting about dominance and hierarchy, sonic association, or something more metaphysical, such as presence and gesture aesthetics? The performance challenges the audience and performers to explore these questions as they engage in the sonic baton trio performance.

A second public performance of *May the Whole Universe* [48] was delivered in December 2023 at the Harpa Concert Hall in Iceland. The performance format applied a traditional conducting format, with an ensemble of 15 persons and the sonic baton conductor facing the ensemble. This performance format delivered a very different performance experience, and one aimed to explore the positionality, agency, and intention of the conductor with the sonic baton. The conductor becomes an audible member of the performance ensemble, and the traditional performance hierarchy between conductor and ensemble is ambiguous. While the conductor's agency over their gesture is unconstrained, interaction between the other players and the sonic outcomes vary significantly between the two performances.

The conductor trio poses the question: Can anyone conduct? And what exactly is the role of the conductor in relation to other sonic "conductors"? Is the performance more individual than collective? Or is there a transference of individual versus collective? The traditional ensemble performance format shows that the sonic baton can be used to create a duality of the conductor role, so that sonically, the conductor becomes a performer of the ensemble. Gesturally, however, the

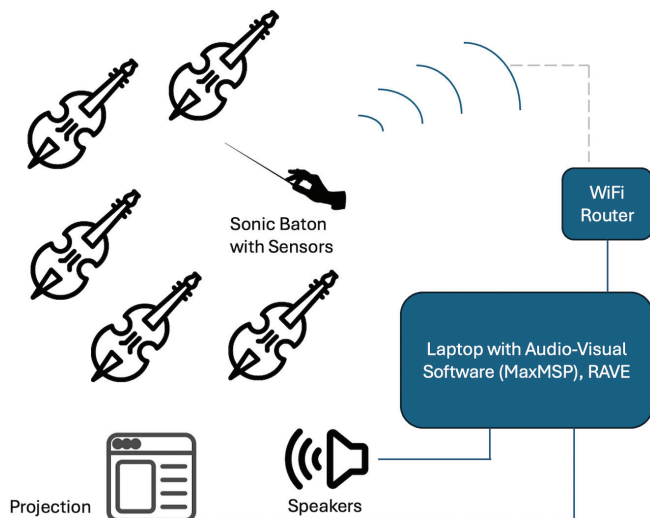


Fig. 3. System setup for the performance of conducting using the sonic baton with an ensemble. (© Majella Clarke)

conductor can use their gesture to guide sonic outcomes in the players, and this later point is very interesting for further exploration in expanding the practice of conducting. Figure 3 shows the system set up for performance.

Following the series of experiments with the sonic baton with Bergþóra Ægisdóttir [49], a collaboration with composer Juan David Bermúdez ensued. The graphic and musical score *Through Stillness I Found Death for String Orchestra and Sonic Baton* was composed by Bermúdez [50] on four layers of translucent paper that utilized a traditional conductor-ensemble facing relationship (Figs 3 and 4). The composition integrated the sonic baton part into a graphic score while utilizing musical and open notations in the string instrument parts. The sonic conducting baton uses the same RAVE model as previous examples, applying sea mammals for its textual sonics in the performance documentation.

The inspiration behind the graphics for the sonic baton part was the use of different representations of earthquake data from four locations. Discussions with Bermúdez revealed that earthquake data was used to present the movement of the living earth at different scales. Earthquakes and volcanos are experienced at the macroscale while these movements of the crust, although experienced as chaotic for humans, make it possible for there to be land above the sea and give us mountains. Scientific instruments show that mountains sway and move on a microscale mostly undetected by humans. The movement of earthquakes, volcanos, or the frequency of a mountain contributes to an essential movement as an impulse of life. As an intriguing side note, the performance was delivered on 18 December 2023 in Reykjavik, on the same day as hundreds of earthquakes and tremors, and which resulted in the first recent volcanic eruption on the Reykjanes Peninsula. The composition is modular, and the string players improvise guided by the open and musical notation in their respective parts. The conductor determines the duration of each module and the composition as a whole and must clearly indicate the general pause at the end of each module, while using the

sonic baton graphic score to guide gesture-sonics. With clearly defined parts for each performer, including the sonic baton, this composition is the first that integrates the sonic baton and conductor into an acoustic ensemble. The experiment demonstrates the potential for the sonification of conductor gesture utilized within the context of, and alongside, traditional ensemble conducting practice and presents new possibilities for expanding traditional conducting practice with a sonic intelligent conducting baton [51].

CONCLUSION

The integration of AI and new technologies into the art of conducting provides a renewed opportunity to propose an expansion of traditional conducting practice that can contribute to the emerging music-science paradigm. Neural audio synthesis and RAVE models present new algorithmic aesthetics for precise gesture-sonic outcomes mapped to the latent space and departing from random, exploratory algorithm aesthetics and sonic outcomes. Performance experiments with the sonic baton raise important points about the essence of conducting. They reveal that expanding conducting practice requires not just the sonic baton but also innovative compositions, diverse performance formats, and meaningful engagement with musicians. While anyone can

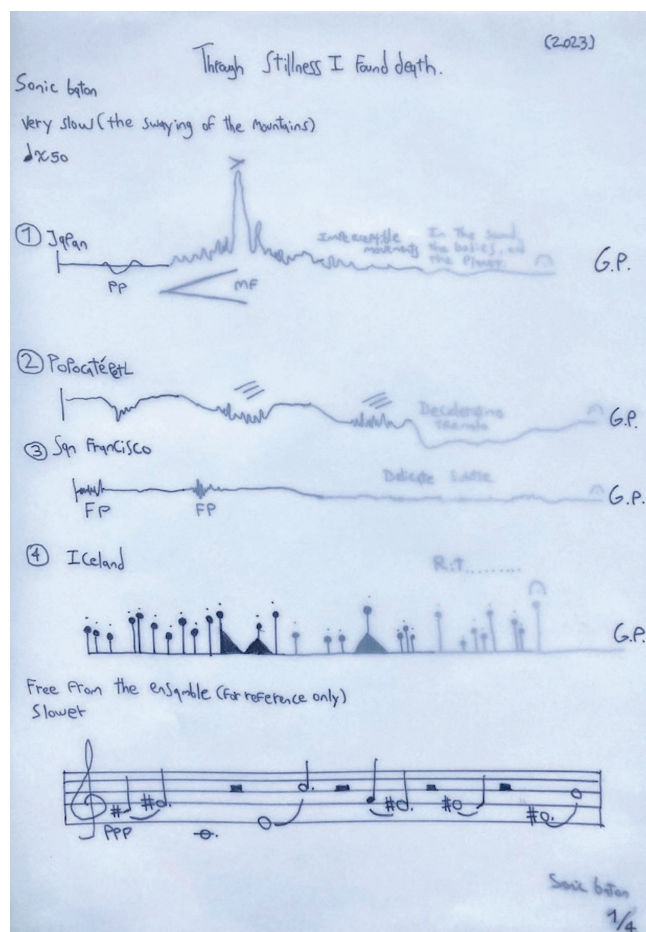


Fig. 4. Score of *Through Stillness I Found Death for String Orchestra and Sonic Baton*. (© Juan David Bermúdez)

hold a sonic baton and move it with their hands to make sound, without the score and performers to unify musically, it becomes a simple magic wand. This research demonstrates that while technology can transform a baton into a cultur-

ally charged sonic instrument, the essence of conducting lies in its ability to unify and guide musical expression, pointing toward new possibilities in orchestral performance and composition.

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