MUSIC CONDUCTING PEDAGOGY AND TECHNOLOGY:

A DOCUMENT ANALYSIS ON BEST PRACTICES

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

MUSIC CONDUCTING PEDAGOGY AND TECHNOLOGY: A DOCUMENT ANALYSIS ON BEST PRACTICES

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and hereby certify that, in their opinion, it is worthy of acceptance.

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DEDICATION

To my father, Agenor Teixeira de Abreu and mother, Darcy Guimarães de Abreu, thank you for your unwavering love.

To family and friends for your continuous support.

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Abstract

This document analysis was designed to investigate pedagogical practices of music conducting teachers in conjunction with research of technologists on the use of various technologies as teaching tools. I sought to discern how conducting teachers and pedagogues are applying recent technological advancements into their teaching strategies. I also sought to understand what paths research is taking about the use of software, hardware, and computer systems applied to the teaching of music conducting technique. This dissertation was guided by four main research questions: (1) How has technology been used to aid in the teaching of conducting? (2) What is the role of technology in the context of conducting pedagogy? (3) Given that conducting is a performative act, how can it be developed through technological means? (4) What technological possibilities exist in the teaching of music conducting technique? Data were collected through music conducting syllabi, conducting textbooks, and research articles. Documents were selected through purposive sampling procedures. Analysis of documents through the constant comparative approach identified emerging themes and differences across the three types of documents. Based on a synthesis of information, I discussed implications for conducting pedagogy and made suggestions for conducting educators.

Chapter I

Overview and Background

"Conducting gestures are as old as recorded history itself…and have had an array of meaning and context beyond keeping time" (Southerland, 2019, p. 30). The act of conducting has specific characteristics as a music practice, as it is a nonverbal type of communication that conveys meaning but no sound. Despite its historic use since ancient Egyptian civilization, conducting became part of the western popular imagination with the emergence of the large orchestras and legendary composer-conductors of the nineteenth century (Ulrich, 2009; Southerland, 2019). Since these times, conductors (and conducting itself) have been the object of public fascination and scholarly investigation.

Conductors communicate ideas through physical gestures and movements. The brain function that detects bodily positions or movements of muscles is termed kinesthetic. Conducting gestures have developed in various ways as a kinesthetic music practice over time. Southerland (2019) wrote about how conducting gestures evolved historically over the years and noted that "depictions of conducting gestures were etched in hieroglyphics and Pharaonic friezes, recorded in Greek and Roman literature and encoded above Jewish and Gregorian texts as cheironomic neumes" (p. 30).

The capacity of our biological perception system has been expanded with technology because it might function as an extension of natural human organs as intermediaries between us and our lifeworld (DeVries, 2016). The use of instruments has augmented our vision with microscopes and telescopes, our ears with sonars and cochlear implants, our movements with robotic arms, and strength with tractors, many times at a distance. Technology and computer processing research have found their way into music education (Bauer, 2016; Rudolph, 2004; Zhang & Marins, 2014) and in the conducting realm (Chin-Shyurng, 2019; Sarasúa et al., 2019). As technology pervades human life, including education, it is important to ruminate about its impact on teaching and learning processes in a technological world.

Teaching and Learning with Technology

Education technology depends on other disciplines (e.g., communication, psychology, sociology, philosophy, artificial intelligence, computer science) to increase the efficiency and effectiveness of current practices, thus bringing pedagogical changes for the betterment of education (Ahmad & Un Nisa, 2016). Unfortunately, the major factors influencing teachers' beliefs about teaching and technology are extrinsic, including pressure from colleagues, students, and outside sources **(**Fergus, 2004). Alexander et al. (2012) argued that teachers need to remediate their teaching philosophies to accommodate for teaching with technology. They suggested a technology philosophy statement that focuses on the teacher's stance toward values related to technology in the classroom. The statement should address the tools used to teach, why to use these tools, how to situate oneself *vis-a-vis* these tools, and how to reflect upon and assess teaching with technology methods.

Music Teaching and Technology

Technology developments have permeated music education settings in various ways with the potential to expand students' engagement with learning. In this section, I discuss trends about distance learning resources and teachers' and students' perspectives in collegiate music education programs. Lastly, I review studies on pedagogical approaches for the integration of technology into music education, followed by challenges, advantages, successful practices, and closing thoughts on the subject.

To contextualize the use of technology in music teaching settings in the United States and abroad, information, numbers, and terms should be offered. Music organizations are aware of the presence of technology in education. The International Society for Technology in Education (ISTE) is interested in the theme of technology use in education (www.iste.org). ISTE has developed technology-related standards to emphasize that educational systems have the responsibility to create “technology-capable” students (Rudolph, 2004, p. 9). The International Society for Music Education (ISME) recently created an interest group in music technology (Zhang & Marins, 2016).

Music technology is an emerging topic within the field of music education, with interest in technology-based music instruction growing throughout the world (Zhang & Marins, 2016). Technology might assist music educators in different ways by providing direct instruction, adjunct instruction, or facilitating learning skills either by replacing the tutor completely or combining technology with tutoring (Seddon & Biasutti, 2009). Technology-Based Music Classes (TBMCs) are increasing in the United States public high schools. In 2010, 14% of public high schools had TBMCs, with most classes introduced between 2005-2009. Although music teachers thought TBMCs were a valuable part of school offerings and that their school could offer it, funding and lack of lab availability were obstacles to the implementation of TBMCs in the public educational system (Dammers, 2012). Thus, the results of Dammers’ study suggest that during the 2000s it seemed there was a discrepancy between teachers’ perception about the value of TBMCs and its actual implementation in school system.

Interestingly, only 28% of TBMCs were traditional, band, choir, or orchestra students, with 89% of the classes having been designed for non-traditional music students—rock musicians, and students with special needs/learning disabilities (Dammers, 2012). The demographics of TBMCs might provide an opportunity for non-traditional students that are not typically included in band, choir, or orchestra so they can have an alternative opportunity to engage in music activities. Dammers (2012) also found that experienced teachers with a performance background and very little technology education training often initiated and designed TBMCs, which might suggest a lack of system support for the incremental use of technology in music classes.

Lack of institutional support has impacted music students' technological education. Haning (2016) found that students in music teacher education programs did not feel prepared to use technology in their future teaching. Music education students expected different methods of technology instruction, more faculty modeling, and integration with course work in their preparation programs. The results of this study indicated that those born in the digital era preferred working in groups, multi-tasking and hyper-text learning, discovery-based learning, and instant gratification for short-term goals. Besides a culture of digital immersion, it seems digital natives' brains might already function differently, but teachers and methods do not change at the same rate (Herther, 2009). In response to such demands, Marins (2016) found that (a) collaborative activity of music creation using Information and Communication Technologies (ICT) might assist the training of music teachers, and (b) technology tools such as video conference software, social media, and online music editors might facilitate the virtual interaction between students and teachers.

E-learning is a valuable resource in TBMC's, with technological e-human demands and interesting results. Seddon and Biasutti (2009) tested a piano keyboard class with an online tutor to facilitate the interaction between learners and the content material. The main findings were (a) positive participant feelings of autonomy, (b) missing of peer support, (c) the role of the instructor as a facilitator of self-learning, and (d) asynchronous e-learning was effective if e-learning-appropriate material was provided, there are opportunities for interaction with the tutor, and learners can employ their own evaluation criteria. These findings are similar to those of Marins et al. (2016) as to what are the key components of successful e-learning: (a) appropriate technology and pedagogy, (b) organization of content, and (c) opportunity for participants to self-evaluate and interact with the instructor.

Teachers' perspectives have been the subject of inquiry regarding teaching music online. Johnson (2017) investigated social-constructivism and collaborative learning as pedagogical models for online teaching. He discussed how teachers bring their previous teaching philosophies, experiences, traditional constructs of music practice, and music pedagogy to be reconstructed in the online environment. Digital immigrant teachers learned how to teach online as they were assigned ('trial by fire'), with online teaching abilities being developed over time during their teaching. As digital immigrants, teachers have adopted technology, but do not have long-term immersive exposure to it (Haning, 2016).

Research findings indicate that successful online teaching requires specific adaptations from traditional in-person teaching (Johnson, 2017). Experienced online teachers think social constructivism or interactive course design need to be incorporated into planning. "Online learning environments should address the inherent dynamic communication exchange found in the performance and experiential foundation of music" (Johnson, 2017, p. 447). Johnson concludes that as digital immigrants, teachers have their previous teaching philosophies and experiences questioned in the online world, with curricula and teaching methodology unchanged while technology is under-used and poorly integrated into music classrooms.

Technological Pedagogical Content Knowledge Theoretical Framework

Researchers have explored pedagogical models for integrating technology into music teaching. Misha and Koehler (2006) discussed that Technological Pedagogical Content Knowledge (TPACK) seems to be the prevailing theoretical orientation about educational technology. Pedagogical Content Knowledge (PCK) is the integration or the synthesis of teachers' pedagogical knowledge and their subject matter knowledge (Shulman, 1986), and such models which did not include teachers' self-efficacy may not be reflective of current-day music teachers (Doherty, 2019). Different from PCK, TPACK addresses the intersection between technological, pedagogical, and content knowledge as a means of delivering content in appropriate ways (Dorfman, 2016). The competency of music teachers might be improved by integrating currently developed technologies with appropriate learning methods and materials. The implementation of TPACK in music learning can create a more effective music learning process that is interesting to students (Wibowo et al., 2022).

Trends in the use of Information and Communication Technologies (ITCs) found at the 32nd International Society for Music Education (ISME) conference were mostly about combined technologies such as the use of music apps for mobile smartphones (Zang & Marins, 2016). Still, students in music teacher preparation programs reported they did not cover technology-related NAfME standards as a topic in their curricula (Dorfman, 2016). Curricula and teaching remain unchanged while technology is underused and poorly integrated to classroom, perhaps because most technology tools are teacher-centered (planning and organization) and non-pedagogical (Haning, 2016). Nevertheless, in music education, the emphasis should stay on the pedagogical project over the technology tool, as it should be more important to know what to teach and finding how technology can aid in the learning process (Requião, 2006).

There are many questions and challenges in the digital music education world. For example, (a) technology (computers) needs to be made more available as mediation for interaction between students; (b) the choices between synchronous and asynchronous interactions through social media needs more research as to what works best; (c) internet bandwidth is still a notable challenge for synchronous video and audio-video conference software use; (d) how digital tools might support the relationship between students and teachers needs more investigation; (e) websites and social media are popular, but still adapting for application in academia, and integration with traditional education systems; (f) how individual learning styles can be considered within a collective e-learning environment needs more inquiry; (g) online teaching lacks the emotional charge of live action leading to lack of motivation; (h) multiple interactive technologies (e.g., blogs, wikies, and VoiceThread) are required to only partially substitute for live interactions; (i) teachers' time management and ignorance about NAfME's standards for technology use, all of those are open questions and concerns about the use of technology in music education programs (Cernev, 2016; Dorfman, 2016; Johnson, 2017).

Advantages of distance learning apply to specific online music teaching contexts.

Some of them include: (a) 24/7 availability, (b) unlimited number of students, (c) students' self-regulation of learning, (d) schedule flexibility, (e) accommodation flexibility for students with disabilities, (f) inclusion of a variety of digital materials—text, video, audio, and graphic presentations, and (g) the fostering of the collaborative environment—student-student, student-content, and student-instructor (Dorfman, 2016; Johnson, 2017; Requião, 2016).

Although technology is widely used in online courses in general (Dorfman, 2016), few researchers have followed the trend, leading to a lack of research and discussion about the mediation of information and communication technology in music education programs (Zhang & Marins, 2016). Some researchers have reported that e-learning can enhance the quality of students' learning and stimulate their interest (Alexander, 2012), but the availability of technology does not ensure specific results. Technology is a means to an end and can enhance teaching tools. Therefore, the curricula and desired outcomes should guide the selection of the technological devices used to accomplish the pedagogical goals (Rudolph, 2004). It would be better to develop Technological Pedagogical Content Knowledge—TPACK—for incorporating technology in teaching (Requião, 2016). Nevertheless, according to Adileh (2012), "pedagogical methods to design artistically-based courses effectively are not yet abundant, and an overall pedagogy for teaching music online has not yet been established" (as cited by Johnson, 2017, p. 440).

When considering whether to use technology in the classroom, Orman et al. (2017) proposed some basic questions a teacher should always ask:

> First, does the technology do something I am not capable of doing without the technology? Second, does the technology allow me to complete the task easier,

> faster, and with the same or greater accuracy? Third, is it feasible to implement the technology? If the answer to all three of these questions is yes, then one should feel confident implementing the technology. An additional consideration, in this case, is the possibility of repeating the experience as much as desired through the use of technology when this repetition is not practical without the technology. (p.33)

With applied music lessons having now been established in an online format for many online music programs (Dorfman, 2016; Johnson, 2017), there are challenges for the implementation of an e-learning music conducting class. Furthermore, “critical assessment of the effectiveness of technologies should be based on empirical work that start from well informed theories about the alignment of technology with learning” (Nijs, 2018, p. 3). Although there are limitations, researchers have indicated a new arena where teaching and learning music conducting with more recent technologies might be explored pedagogically (Bauer, 2016; Bevilacqua et al., 2007; Marrin, 1996; Rottondi et al., 2016).

The inclusion of interactive and social exchange opportunities for students to learn in digital environments, which requires a teacher’s mindset shift from apprenticeship-dominated pedagogy to a social constructivism approach, is a hallmark of TPACK (Johnson, 2017). Researchers agree that the best approach is to integrate content-based courses with technology instruction, so learners recognize the connection between content and technology (Haning, 2016). In this context, it seems music conducting, given its traditional apprentice-master format of kinesthetic modeling—taught through physical modeling—could be helped through technological advances such as digital or graphical representations of conducting gestures as alternative technological modalities for modeling. Conducting instructors should investigate new approaches—such as remote teaching, virtual human interaction, and/or new human-machine interfaces—for teaching conducting to future music educators, and music educators should keep track of these developments, not only to evaluate the possibility of introducing them in the classroom, but also to reflect upon what is essentially human in the learning-teaching process.

Statement of the Problem

Technological advances have entered the realm of conducting pedagogy. Recent developments challenge conducting practice, pedagogy, and research. What is essentially human in teaching and learning music conducting that only the interaction between human beings can continue to develop and grow? Unfortunately, the knowledge and information experts possess is not meeting the growing demands of aspiring music technologists (Brader, 2009). Although new technologies involving music conducting are being developed and tested by multidisciplinary teams, not much is known about how conducting teachers and pedagogues are perceiving or applying such findings in their teaching practices and pedagogical approaches. A data-based conceptualization of music conducting pedagogy and technology might illuminate and enrich knowledge in the conducting field.

Purpose of the Study

The purpose of this study was to review, analyze, synthesize, and interpret documents to illuminate technological developments that might help inform best pedagogical practices in the teaching of music conducting. I chose a document analysis to provide evidence and suggestions that might assist teachers when developing their own Technological, Pedagogical, and Content Knowledge (TPACK) conducting strategies.

Research Questions

The following research questions guided this document analysis: (1) How has technology been used to aid in the teaching of conducting? (2) What is the role of technology in the context of conducting pedagogy? (3) Given that conducting is a performative act, how it can be developed through technological means? (4) What technological possibilities exist in the teaching of music conducting technique?

Chapter Two

Music Conducting Pedagogy and Technology: A Review of Literature

With the development of artificial intelligence and robotics, our psychological and sociological understanding of what it is that makes us distinctive and unique has evolved. For instance, body language, including facial expression, is an embodied skill which is difficult to describe, but easy to demonstrate. Humans learn by observing other humans performing tasks. Learning action sequences or operation plans—such as when a child observes an adult getting a bottle from the refrigerator and repeats the learned action—is an abstract problem, which supposes a modeling of cognitive skills (Dillmann, 2004). Computers can now learn by observing human behavior instead of having to be programmed to perform. As such, scholars in the field of Machine Learning (ML) have studied these developments.

Human and Machine Learning

There is an ongoing paradigm shift about the way machines learn how to perform tasks going from code programing to human-machine mutual learning. Ansari et al. (2018) encourage us to rethink human-machine learning by arguing that this paradigm shift should cause us to treat human learning differently. It means there is mutual learning in the process affecting both human workers and intelligent machines. How does it work? "From a cognitive computer perspective, artificial models and computational algorithms resemble the ability of human learning and reproduce human skills" (p. 118).

Human-centered ML is programming a computer to perform a task by providing human examples rather than by writing a program code describing the behavior (Gillies et al., 2016). For instance, instead of describing computational procedures that reason about what features make something a human face and translating that idea into program codes, human-centered ML works on face recognition systems out of a large database of face images. While using such a database, ML technology can create virtual characters who use appropriate facial expression to interact with humans by recognizing categories of human actions sensed with sensing mechanisms or create expressive gestural controllers with a particular feeling (Fiebrink, 2011, as cited in Gillies et al., 2016).

Considering this ML paradigm, we should reflect upon how we think about human learning as well. ML involves mutual learning in the process, thus affecting both human workers and intelligent machines. How does it work? “From a cognitive computer perspective, artificial models and computational algorithms resemble the ability of human learning and reproduce human skills” (Ansari et al., 2018, p. 118). So, what distinguishes humans from robots in the learning process? Dillman (2004) suggested that humans (a) navigate through changing environments, (b) adapt recognition abilities to a particular scenery, (c) manipulate a wide range of objects, and (d) teach themselves what to do and how to do it by acquiring relevant information through observation and multimodal dialogs. In addition, humans exchange learning-teaching experiences and distinguish parameters for a particular demonstration specific to the problem’s concept. Finally, we transfer observed information from a specific task to an independent and flexible knowledge structure that can be generalized to new situations. In fact, robots are rapidly learning how to do all of that.

Ansari et al. (2018) argued that the only aspect that distinguishes the capability of humans and machines on performing an assigned task is the subjective quality and performance variations in carrying out such a task. With interactive ML, the user chooses what new examples to label for the algorithm or works together with the computer in controlling the process. The computer is part of the human design process to improve the robot's tasks (Gillies et al., 2016). Importantly, by training algorithms to use high-level human-machine interfaces, users can build and refine systems for real-time gestural control. Although we are refining our understanding about how we learn by teaching machines to learn just the way humans do, the ML concept is already being applied within music conducting and technology research.

Before I review the literature on music conducting and technology in more detail, two concepts need to be explored, as they underpin the body of research on music conducting pedagogy and technology, namely the concept of Music Affordance (MA) and Network Music Performance (NMP).

Music Affordance

Affordance was originally conceived to describe relationships between the environment and an actor—a person who interacts with the environment. According to Tanaka and Altavilla (2012), music affordance (MA) is a configuration of properties that provide a direct link between perception and action related to technological music interfaces. In music, affordance can be configured as screen-based interfaces functioning as music digital instruments because sounds carry information for affordance that cannot be seen (Gaver, 1991).

Gestural affordance has complex, multi-faceted influences like size, form, culture, history, and personal experience. Godøy (2009) explained the theoretical concept of *sound tracing* behind this idea: the sound of an instrument affords gestures that imitate actual musical practice. People imagine the afforded object to be attached to the instrument the sounds refer to. Conversely, unfamiliar objects allow for exploration of what can be done with them as far as producing sounds. Tanaka and Altavilla (2012) also described that a specific musical process, such as music conducting, demands engagement with cognitive and cultural processes which means affordance is also shaped by a person's previous knowledge and experience. In other words, the context of the use affects how affordance of an object is perceived by the actor. Thus, music technologists who explore technology tools to teach conducting likely consider the MA concept in their experiments and tests.

For example, Tanaka and Altavilla (2012) performed a comparative study of gestural interaction with a musical sound. They conducted an interview-based user study involving three accelerometer-based devices: an *iPhone*, a *Wii-remote,* and an *Axivity Wax* prototype—a small, wireless hand device with the size of the head of a baton, with musical sounds including percussion, stringed instruments, and voice recordings. By using computer mappings across different source sounds, and performing them from three different devices, users experienced forms of physical, sonic, and cultural affordance that combined to form MA. Findings were that the least familiar one out of the three accelerometers, the *Axivity Wax* prototype, was perceived as giving more freedom to participants, allowing them to focus on sound production which was disassociated with the object's shape and form. Thus, the researchers concluded that the form and shape of the objects informed MA. Given the brain's capability of mentally rehearsing movements and gestures, MA is a very important concept regarding human-computer interaction. Understanding brain functions when certain aspects of music conducting practice such as arm/hand gestures, torso movement, and eye contact are to be performed might illuminate the teaching of conducting using e-learning processes and devices.

Just as human-computer interaction has developed and affected the concept of MA, human-to-human interaction has also been affected by technology. One prominent example includes the digital interaction among music performers on the internet, with implications for music conducting pedagogy and technology.

Network Music Performance

Network Music Performance (NMP) is a concept about the use of internet applications for music interaction that aims to enable musicians to collaborate remotely through a telecommunication network (Rottondi et al., 2016). NMP is sound without space. In an ideal NMP situation, musicians and audience members are placed in a virtual environment to experience musical events by collaborating and communicating from different locations, all interconnected by high fidelity multichannel networked systems (Sawchuk, 2003). The first goal of NMP is to have musicians in multiple locations around the world performing together in real-time using high-speed internet, with no latency, in front of a live audience (Kapur et al., 2005). Technology developers in the NMP field want to create a complete aural and visual environment that places people in a virtual space where they can communicate naturally from different physical locations, but where there are no technological difficulties.

Challenges for Implementing NMP Systems

Network transmission presents several limitations to virtual live music performances. According to Zimmermann et al. (2008), audio, sound, and potentially haptic data—any technology that can create an experience of touch or any form of technological interaction involving touch (Rodet et al., 2005) —are considered “isochronous media streams” (p. 142), or data that cannot be stored and needs to be transmitted in a critical time fashion for live streaming. That reality imposes a series of technical challenges for NMP such as (a) network delay during audio and video acquisition and rendering due to dropped or delayed packets, (b) contention between network interfaces such as sound cards and CPU units that retain data during network communication, and (c) two-way transmission that causes echo cancelations over the network. These technical events impose signal synchronization strains to the system. They interrupt the natural visual and aural feedback that musicians exchange with each other when performing to guarantee a synchronized execution of the music (Holub, 2012; Kapur et al., 2005; Sawchuk et al., 2003; Zimmermann, 2008).

Latency is one of the biggest challenges concerning NMP. Musicians tolerate latency and jitter below a few tens of milliseconds, estimated between 20-30ms (compared to 8-9 m distance between musicians on stage—the maximum separation they can synchronize without a conductor) (Rottondi et al., 2016). Chamber orchestras can only tolerate 10-40 ms of latency. Jazz musicians can work around 80 ms and still be able to synchronize in concerts, whereas general purpose communication tolerates up to 150 ms of delay (Sawchuk et al., 2003). Latency tolerance is also correlated with the type of instrument and tempo of the music. For example, organists are used to 20-30ms delay between pressing the note on the keyboard and the actual sound coming out of the pipes. Slower tempi are three times more tolerable (150ms delay) than fast music (50ms). In between these extremes, it seems there is a window of 50-100 ms “segmental tempo range” where musicians attempt to synchronize despite latency (Zimmermann, 2008, p. 14). Hearing their instrument delayed causes more discomfort then hearing another musician playing late because they also use eye contact and body language—torso, arm, and head movements—to signal. Because musicians are used to body language to deal with sound delay, conductors are an essential part of the synchronizing process during performance, especially in large ensembles. Conductors become the focal point to where all the musicians look aiming to play together because synchronization is not limited by the sound they hear, but guided for the visual orientation of the anticipated conducting gestures.

Coping with NMP Limitations

Because technological strains in NMP are currently unavoidable, musicians need to learn how to cope with online limitations. Help might come from the real world of music making. There is also inherent audio latency in live music. The distance among choir, soloists, and orchestra musicians from stage to orchestra pit in opera imposes a latency of over 50ms, which would make synchronizing impractical without the conductor (Rottondi, 2016). Sawchuk's (2003) experiments with asynchronous (a cello masterclass) and synchronous (two duets, with and without an audience) virtual interactions demonstrated that networked playing can be comparable to the sound delay found during live orchestral performances in large concert halls (10-50ms for audio). In sum, humans can adapt to latency. The thresholds for musicians' latency tolerance are: (a) optimal, 20-30ms, (b) tolerable, up to 50ms, (c) painful, 50-100ms, and (d) impossible, more than 150ms (Kapur, 2005; Rottondi, 2016; Zimmermann, 2008). For training purposes, music conducting teachers might relate the delay musicians experience to the ones experienced on stage to network latency in a virtual music teaching context.

Researchers are questioning the physicality, viability, and worthiness of novel systems for NMP (Kapur et al., 2005). Technology innovators are experimenting and presenting systems that aim to approximate network performance to a live music performance. A multichannel, multi-modal monitoring and recording network system that can capture, store, and distribute music performance events remotely can benefit the teaching of music conducting (Gu et al., 2005). Imagine a conducting class where the instructor, the musicians, and the conducting students, all from different locations, can participate, record, and perform together in a virtual conducting class? There is technological ground yet to be covered until NMP is fully realized, but from a music pedagogy perspective, remote instruction will only benefit from system developments after they become commonplace and economically affordable. Next, I discuss trends, experiences, and perspectives found in extant research about the use of technology in music conducting.

Music Conducting and Technologies as Pedagogical Tools

"Music is an art form and aural communication that is learned through practical application" (Johnson, 2017, p. 449). Similarly, conducting is an art form and a performance skill with a set of acquired knowledge. Conducting skills include the ability to effectively lead a group of musicians through expressive gestures, facial expressions, body movements, and verbal communication. The knowledge that conductors gather during their preparation reflects their understanding about the score to be conducted according to an interpretation of the composer's intention, the form of the music, and the technique each musician applies to play their specific part. Conducting pedagogy encapsulates best practices to teach such skills to conducting students. Thus, if technology can extend the reach of music conducting teaching and learning, this would serve music conducting pedagogues and students.

Technological advances have been made by simulating the display of tempo and dynamics in conducting gestures through digital interfaces. Digital devices might give novice conductors practice opportunities when an actual music ensemble is not available. For example, when articulating with their bows, string performers interpret the arm movements of conductors (Bevilacqua et al., 2007). The use of musical gestures facilitated by technology software might be a tool to teach string students how to articulate sounds by transferring the virtual interface of arm moving to the practice of bowing. Similarly, researchers have suggested situations in which teaching and learning conducting with more recent technologies might be explored as pedagogical tools (Bauer, 2016; Bevilacqua et al., 2007; Marrin, 1996; Rottondi et al., 2016). Conducting instructors should investigate new approaches—such as remote teaching, virtual human interaction, or new human-machine interfaces—for teaching conducting to novice conductors.

Conducting Gestures, Tradition, and Technology Interfaces

Gestures are a quintessential element of human-to-human communication in music conducting. Forrester (2018), Morrison and Silvey (2022), and Orman et al. (2017) have discussed the use of gestures and how they connect traditional conducting practices. Their research indicates that conducting knowledge is a combination of technical skills, aural image, and kinesthetic awareness—the ability to use the body to communicate musical intent. Music conductors use physical gestures, torso movement, and eye contact as forms of nonverbal communication (Orman et al., 2017). Also, conducting gestures are an interaction between a mental sound image of the score and the sound produced by the players, used in-the-moment to develop rehearsal strategies, modify instruction, assess, and respond to students and sound stimuli, and formulate concepts of sounds (Forrester, 2018; Morrison & Silvey, 2022). In other words, music conducting is a way of responding to sound stimuli while listening and assessing sound production when it occurs.

Specifically, why are gestures so important in music conducting? Morrison and Silvey (2022) explained that gestures might assist performers' understanding of the music being performed because different aspects of movement are discernible to observers. And what are those aspects? They specify that expressive gestures vary in speed, size, and acceleration, and that such gestures are used to inform the form, time signature, articulation, and expressive intent of the music such as phrasing and dynamic variations. These are important concepts to help clarify which aspect of conducting a particular technological tool may assist with when assessing future pedagogical impacts.

Research in capturing performers' gestures through sensors and mapping them to produce computer synthesized sound is represented by the New Interfaces for Musical Expression (NIME) field (Tanaka & Altavilla, 2012). In the NIME field, researchers have developed systems to gain insight into the notion of MA during human-computer music interaction. Fazekas et al. (2013) developed the Mood Conductor, a system that allows the audience to interact with stage performers to create directed improvisations. Participants act as conductors by communicating emotional intentions to the performers through the web-based smartphone-friendly Mood Conductor app. Emotions are represented by colored blobs in a two-dimensional space (i.e., vertical dimension: arousal or excitation; horizontal dimension: valence or pleasantness). Performers receive the audience's directions via this visual feedback system and improvise performance accordingly in real time. Such study represents a research test on the partial substitution of the conductor's role because the audience directly influences the music performance through the manipulation of technological applications.

Music conducting pedagogy regarding the use of the body and gestures to teach musical concepts through technological means has been investigated. Bevilacqua et al. (2007) believe that "physical gesture is a central element for performance but also for the embodiment of music concepts and theory" (p. 124). According to the phenomenon called "kinaesthetic empathy," one can embody others' movements themselves (Koivuen & Wennes, 2011). The researchers explain this further:

> All of our five senses interact so that the contribution of each becomes indistinguishable in the total configuration of perception. Thus, perception concerns the whole sensing body. The unification of the senses comes about through their ongoing integration into a synergic system. This *synaesthetic* system rules our body, but we are unaware of it because we believe in the mechanistic view that we perceive things through the separated channels of perception: seeing by eyes, hearing by ears, and so on. (p. 63)

Therefore, if conducting gestures are perceived by an integrated perception system, perhaps conducting gestures might be used to teach musical concepts through cognitive perceiving empathy in a specific form of "show how" using bodily gestures. The kinaesthetic empathy phenomenon (Koivuen & Wennes, 2011) of embodying others' movements needs to be studied as it relates to the possible connection between conducting gestures and the teaching of musical terms and ideas. Schnell et al. (2011) executed a study around this idea involving gestural control and re-embodiment of recorded sound and music systems. They tested a device in-between complex platforms and a gaming controller called *MO*, a modular motion capture device that if hand-held might be used as an augmented object such as a baton. In the experiment, the developer team demonstrated that the MO wireless sensor module may be hand-held, attached to the body, or used to augment objects such as a ball or a kitchen utility to create new instruments and playing techniques. Those new musical playing metaphors enlarge the possibilities for virtual orchestra conducting.

Conducting instructors should consider investigating new approaches for teaching conducting to future music educators. It is important for conducting instructors to be aware of the full capabilities of technological tools that can help conducting students to better perform and understand music conducting. For example, Marrin (1996) described the development of a device called the Digital Baton, which sends data on position, orientation, acceleration, and surface pressure to an external tracking unit. She detailed that an accompanying software system would process the gestural data and allow the Digital Baton user to conduct a computer-generated musical score.

Sarasúa and Guaus (2014a, 2014b) described the role of intuition on understanding the effect of gestural movements on sound production, writing that untrained participants intuitively associated higher raised and more energetic hand movements to loud parts of an orchestra recording. Furthermore, Southerland (2019) argued that different uses of conducting gestures in history also can point to new pedagogical interventions. Hence, researchers have indicated the possibility of a more naturalistic approach to the teaching of conducting that might integrate technological developments in the area.

With regard to technological advances in music education and conducting pedagogy, the use of video recordings has been essential (Bautista et al., 2019; Grashel, 1991; Silvey & Major, 2014). Grashel (1991) indicated that fundamental conducting competencies could be demonstrated and observed through video. He suggested that baton grip, beat pattern, style, use of left hand, cuing, dynamic indicators, tempo stability, cutoff gestures, and eye contact could be taught through videotaped modules. The premise was that the same content, sequence, and organization of instruction could be distributed equally to all students, not to mention that compared to traditional conducting teaching settings—with the orchestra, videotaped modeling saves time and uses less space.

Once computers progressively gained faster processing power, there was an increased interaction between machines and humans (Ansari et al., 2018). One of the challenges with the use of interactive technologies is the aim for naturalism and intuitive human-computer connections. The constant development of smart phones is the most noticeable and recent example. The use of technology in the realm of music conducting might be organized as such: (a) virtual-robotic orchestras and conductors; (b) gestural controlling systems; and (c) computer-based conducting analytical systems. In the next section, I synthesize experiments in those areas by discussing their contributions for eventual use in conducting pedagogy contexts.

Virtual-Robotic Orchestras and Conductors

A prerequisite for the development of music performance skill is the availability of the instrument. In typical circumstances, music performers have their instruments at their disposal. Even large instruments, like the piano, are available in practice rooms of music schools for students to use. One of the challenges for conducting students is the lack of their “instrument” for practicing—an ensemble. Because of that, part of conductors’ preparation is the development of their “inner hearing” so they can embody conducting movements only by looking at a score, without the actual presence of an ensemble to lead. The lack of an instrument for conductors might be mitigated with the advent of virtual orchestras. Advances in virtual reality (VR), sound synthesizing, gesture recognition, and human-computer interfaces have made it possible to design systems that partially fulfill the vacuum of the orchestra as an instrument for pedagogical use (Ferguson & Wanderley, 2010; Schertenlibe et al., 2004; Segen & Gluckman, 2000).

Visual interfaces are the object of testing for the development of virtual orchestras. Sarasúa et al. (2019) designed a system whereby a digital instrument would function as an orchestra that followed the movements of the conductor in real-time. Results suggested that the system was usable for providing intuitive—in the sense that the users learned to use the system while performing—control over both loudness and timing. The researchers emphasized this aspect of intuitive learning because it broadens its use for the public, not only for trained music conductors.

Another type of virtual orchestra is the use of a multimodal system with 3D sound and computer interface (Shertenliebe et al., 2004). A magnetically-tracked baton is used to control the performance without specific conducting patterns. It is a semi-immersive virtual reality experience—no head-mounted display (HMD) or data gloves—based on a projection screen where virtual animations of musicians play while adapting their performance to the user’s gestural tempo, dynamics, and hand and arm movements. The music is pre-codified in MIDI files. The Personal Computer (PC) server controls 3D scene and sound, processing the gesture input from the magnetic baton, and animating the 3D models accordingly.

In this virtual orchestra system, the sound information in MIDI files is a set of several recordings of the same musical event with variations on dynamics and sections of the music. The sound reflects and blends with the animation of the virtual orchestra. Selected notes within pre-recorded music scores trigger the event, allowing for the manipulations of the animations. Importantly, the system is managed through sound events, not image, avoiding delay in the sound processing because "human senses are more affected by sound distortion then by visual artifacts" (Schertenliebe et al., p. 47). The layout of the architecture design of the virtual orchestra breaks down the complexity of an apparent simple behavior of a conductor which is to control for tempo and dynamics of an ensemble performance. Note that these are only two musical parameters amongst an array of musical aspects that a conductor must encompass during ensemble performance and rehearsal.

A third example of virtual orchestras is Ferguson and Wanderley's (2010) Digital Orchestra (DO). This interdisciplinary three-year-project relied on different components to build their DO. A PC was used as the synthesis engine. Hardware created for the project functioned as the gestural control surface. Finally, the *Mapper*—software developed specifically for the project—performed the mapping between gestural data and synthesis parameters such as the information about the baton grip or the amount of energy used by the performer which are captured by sensors and synthesized by the *Mapper*. The final product was a concert performance of the DO, with music specially composed for the event.

Music in a Universal Sound Environment (MUSE) is a system that captures conductors' musical gestures to drive a MIDI-based music generation system allowing a human user to conduct a fully synthetic orchestra (Carthen et al., 2018). MUSE allows users to control the tempo of a virtual orchestra through basic conducting patterns used by conductors in real time. Their system also aims to further improve a conductor's technique in an interactive environment. The researchers described how the system facilitates learning through an intuitive graphical interface, and how they utilized techniques from machine learning to process inputs from a low-cost sensor that estimates the beat patterns that a conductor suggests by interpreting hand motions.

In addition to the advent of digital orchestras, conductors themselves have also been replaced virtually. Nijholt et al. (2008) presented the *Virtual Conductor*, a system that performs real-time audio analysis of music played by musicians and uses this analysis to animate a virtual conductor. The system detects the tempo and the dynamics of the music, compares the results with the music score, and changes the conducting behavior when the musicians deviate from the desired performance. The virtual conductor is projected on a large screen in front of the orchestra. Algorithms determine what sounds the musicians are playing and how well. The system has a pedagogical intent, as it was designed to train musicians to follow conductors' gestures. The novelty of the system is that the virtual conductor adapts his movements to give corrective feedback to the musicians. Aside from virtual orchestras and conductors, developers are working on interactive systems aiming to control specific aspects of conducting, usually for the pedagogical purpose of practicing gestural techniques.

Gestural Controlling Systems

In the search for a naturalistic interaction between computers and humans, researchers and technology developers typically select some aspects of music conducting (e.g., tempo, dynamics) to control. There are two ways of human-computer interaction for gestural controlling systems: camera-based systems (i.e., distant cameras and computer vision techniques) and sensor-based systems (i.e., motion sensing devices located in users' hands and body) (Argueta & Chen, 2009; Carôt & Schuller, 2011; Cosentino et al., 2012; Sarasúa et al., 2016; Toh et al., 2013). What differentiates music conducting electronic systems is the use of one of these two systems. Does the system use contactless devices or close to the body sensing technology? Next, I discuss systems and how they deal with the challenges of emulating the control conductors have over performing ensembles via human-computer interaction.

One such system was designed by Sarasúa et al. (2014b) to learn conductors' gesture variations for gesture-based interaction. The system was used as an interaction technique in a music conducting scenario where gesture variations drove music dynamics. A model was used to allow the user to configure the system by providing variation examples. The system performance and the influence of user musical expertise was evaluated in a user study, which showed that the model was able to learn idiosyncratic variations, thus allowing users to control dynamics, with better performance for users with musical expertise.

Carôt and Schuller (2011) tested a telematic visual-conducting system that focused on the transmission and representation of the conductor's timing instead of their gestures. The idea was to use a computer mouse as a baton to poll the mouse's x and y coordinates which are interweaved with the actual audio stream. Musicians performed remotely according to visualized mouse data representing the tempo of the music. Thus, there is no video of the conductor's gestures and no jitter resulting from the sum of audio plus video streaming in roundtrip transmission. Cosentino et al. (2012) described a human gesture recognition system developed to enable a robot instrument player to recognize the variations in tempo and in articulation dictated by a conductor's movements. The researchers suggested that the interaction ability would allow the partner musicians, as well as the conductor, to appreciate a joint musical performance because of the naturalness of the interaction. In addition, the possibility for the robot to change its performance parameters according to the conductor directions, thus being synchronized with all the other human musicians, would lead to an improvement in the overall musical performance.

Sarasúa et al. (2016) tested a machine learning (ML) system of personal gesture variations used in music conducting. The idea was to deliver control of music articulation through personal variations of gesture execution using a computer probabilistic model. Participants used a computer mouse and *Microsoft Kinect* as input devices of gesture and articulation. The participant controls a MIDI-performed melody using turned figure-eight gestures with the mouse on legato, tenuto, and staccato styles. Each set of data represents a different articulation of the same gesture which is then paired with outputs encoding the articulation using the probabilistic model. Results were that the model learned the articulations, embedding the user's own expressive gestural qualities. Besides conducting gesture ML, the articulation model offers audio and video representations for user's feedback. The authors explained that audiovisual feedback is an action-perception cycle that might assist users to adapt their gesture to target tasks such as the articulation of the melody, tempo control, and dynamics. This sensor-motor learning represents a new pedagogical approach with possible future research applications. Also using *Microsoft Kinect*, Toh et al. (2013) proposed a real-time interactive system that would overcome the limitation of *Kinect* being designed for large body movements, so refined delicate conducting gestures could also be correctly recognized with high levels of accuracy and low latency. The authors' proposed idea is that their interactive conducting system could mediate the interpretation of a conductor's gesture, thus serving as a training tool for students, and for professional conductors and composers as a low-cost experience to shape music virtually.

Orman et al. (2017) tested an augmented immersive Virtual Reality Learning Environment (VRLE) system to increase eye contact, torso movement, and attention skills in novice conductors. Ten music majors tested VRLEs with head tracking or VRLE without head tracking, including a control group (no VRLEs) in pre- and posttest sessions with a music score. The components of the VRLE were photos taken of an ensemble from the conductor's perspective to create the virtual environment and instrumental grouping of focused attention outlined with red boxes around the ensemble members. The red box would appear around each focus group that needed the conductors' attention. Full ensemble parts had no red box. Results suggested that students using the augmented immersive VRLE with head tracking had more conducting skill improvement than those not using virtual reality.

Although some researchers have concentrated on gesture controlling systems, others focused on the computer-based analysis of movement for pedagogical purpose. In typical university conducting classes, the student conducts the ensemble, and the conducting teacher gives feedback. Technology developers are working on systems which might offer new instruments to assist in the analysis and feedback regarding music conducting. Areas of development in conducting pedagogy and technology are movement analysis and gestures capturing technology (Bevilacqua et al., 2007). In the next section, I report on studies involving computer-based analysis systems.

Computer-Based Conducting Analytical Systems

Movement and gesture analyses have become important aspects in the development of interfaces for gaming platforms and mobile devices (Schnell et al., 2011). In the area of music conducting, researchers have analyzed conductors' nonverbal behaviors. As a compliment to the traditional master-apprentice conducting relationship, researchers have worked in visual, aural, tactile, and multi-sensory feedback modalities to assist conducting instructors with their teaching strategies (Chin-Shyurng et al., 2019; Sarasúa & Guaus, 2014b; Schramm et al., 2015). For example, Sarasúa and Guaus (2014b) proposed a study to analyze (using simple motion capture descriptors—position, velocity, acceleration, jerk, quantity of motion, and contraction index) how participants move when asked to conduct with classical music excerpts, focusing on the influence of the dynamics in the performance. Participants were asked to conduct three classical music fragments while listening to them and were recorded with a commercial depth-sense camera. Results indicated that different tendencies could be found and exploited to design models adjustable to the expectations of the users to control the expressive aspects of a performance by imitating the gestures of conductors.

Chin-Shyurng et al. (2019) proposed a real-time musical conducting gesture recognition system using a camera to capture image inputs and establish a real-time computer-human interaction. The *Kinect* software development kit created a skeleton model by capturing the palm position of the conductor. Different palm gestures were collected to develop training templates for music conducting. Results were that the dynamic time warping algorithm successfully recognized the different conducting gestures at various conducting speeds and achieved real-time dynamic music conducting gesture recognition.

Another example involving music conducting computer analysis systems is a tool created by Schramm et al. (2015) to aid in the study of basic conducting gestures, also known as meter mimicking gestures. It is based on the automatic detection of musical metrics and their subdivisions by analysis of hand gestures. Musical metrics are represented by visual conducting patterns performed by hands. These patterns are recognized and evaluated using a probabilistic framework based on Dynamic Time Warping (DTW). DTW is used for measuring similarities between two temporal sequences at different speeds, a method of comparing sequences of time series data, usually based on data from accelerometers worn or used by a person. In conducting, the method is used to compare the recorded gesture of a conductor to a template of standardized gestures in a computer (O'Rourke & Madden, 2011). In Schramm et al. (2015)'s study, a new metric is proposed for the DTW, allowing better alignment between two distinct gesture movements. The time precision of the conducting gesture is extracted directly from the warping path and its accuracy is evaluated. The authors indicated that the classification scheme represents an improvement over similar approaches.

Armitage et al. (2013) presented *mConduct*, an interactive multimedia system that captures and analyzes conductors' gestures to offer visualization, sonification, and vibrotactile feedback. An accelerometer, a gyroscope, and a magnetometer attached to a baton measure the strength, intensity, and direction of the conductor's gestures. This 3-part measurement system delivers a representation of the baton's movements. The system can stream gestural information which can then be broadcasted and received by computers for processing, analysis, and multi-modal feedback. Visualization software creates a 3D sculpture of the user's gestures. The authors suggested that the virtual avatar encompasses structure, expression, tempo, and time signature of the music. Because people remember information better when it is represented and learned both audibly and visually (Leavitt, 2012), applications for conducing pedagogy might include building mental models by directing attention to visual information regarding conducting technique. Collected digital data and visualizations can be stored. The retrieved data might help students and instructors to analyze how the piece of music was shaped.

Chin-Shyurng (2019) used a real-time video gesture recognition system to foster conducting students' virtual practicing. She employed the *Kinect SDK* (Software Development Kit) to capture images of conductors and the DTW (Dynamic Time Warping) algorithm to recognize and classify the conductor's gestures. The study included promising new perspectives for conducting pedagogy with the use of remote technology such as Kinect SDK and DTW for virtual practice of conducting gestures.

Possible Advantages of Conducting Systems

Conducting systems—hardware-software applications that electronically emulate some aspect of music conducting gesture expressions for the purpose of technique analysis or remote controlling of robot instruments or virtual orchestra—could be used to rehearse technical, less creative, and non-expressive aspects of a performance or be used to explore facets of ensemble playing in a school setting, with children being allowed to have some level of autonomy. Student conductors could experiment with ways of conducting a passage while playing along with their instrument, putting themselves in both positions simultaneously. Time in front of a virtual ensemble could be almost unlimited (Orman et al., 2007). In combination with a virtual orchestra, these systems could detect mistakes and show better ways of conducting (Nijholt et al., 2008).

Besides simulating orchestral conducting, interaction paradigms—if the system is set to follow the conductor or to record the gestures for analysis—can be used to understand conducting gestures as a continuous process where the gestures might be freely chosen. Moving away from already established conducting patterns, gestural movement analysis can be adjusted to different pedagogical purposes such as instrument performance and the understanding of music theory concepts. Additional pedagogical uses might include breathing and understanding music structure such as phrasing and cadences. Ultimately, interactive conducting systems might assist with technique awareness, interpretation, and expression of music (Bevilacqua et al., 2007). Examples include practicing the effect of gesture on tempo according to arm speed and self-observed movement technique with captured and computer processed images of conducting gestures, going beyond traditional video recordings. Although computer-based music conducting systems offer new pedagogical possibilities, such a complex human activity as performing and teaching and learning music conducting presents great challenges until a widespread use of these system prototypes are available in teaching settings.

There are few investigations about the impact of new technologies on conducting pedagogy. I found two studies that investigated the effect of technology-based practice on skill achievement in novice conductors (Hollinger & Sullivan, 2005; Sarasúa & Guaus, 2014). Holinger and Sullivan (2005) listed technology tools that demonstrated positive results: (a) a computer error detection program to train rhythm and pitch error detection (Guner, 1995); (b) a program to aid in score study using a computer-assisted program (Hudson, 1996); (c) the Music Conducting Trainer (MCT) to aid in the steadiness and shape of participants' conducting patterns in four different modes while music followed in the tempo of the beat pattern of participants (Schwaeger, 1984); and (d) a comparison between Marrin's Digital Conducting System (DCS) and Max Matheu's Radio Baton (RB) (Kraus et al., 2004). In general, results showed that computer feedback was effective in improving selected fundamental skills such as preparatory ictus, release gestures, and the learning of legato skills. Unfortunately, Hollinger's analysis is already outdated, as are experiments completed in the 1990s.

Somewhat recently, Sarasúa and Guaus (2014b) conducted a computational comparative study on dynamics in music conducting. Participants conducted pre-recorded fragments of Beethoven's *Eroica* using a musical interface conductor metaphor—imitation of conductor's gestures—of audio, multi-perspective video, and aligned music score. A virtual skeleton that included 15 joints captured and recorded the motion of 24 participants aligned with the audio-video and *Eroica* score. Every joint had position, velocity, acceleration, and jerk—derivative of acceleration—recorded. The movements served as predictors and the loudness of the music served as the independent variable.

Linear regression models indicated that motion capture descriptors correlated to loudness differently among participants. For instance, in loud parts, most participants had greater amplitude movements, but some just raised their hand higher. The authors suggested that although it was very difficult to obtain a model that generalized to all participants, different tendencies might help developers to design tailored models to teach conducting using computational analysis.

More recently, Kshirsagar and Annadate (2017) compared ten music conducting gestural recognition systems using Dynamic Time Warping (DTW). The authors found both pedagogical advantages and technological challenges in each of the ten gestural recognition systems. Gestural interaction systems might substitute partially for conducting real music ensembles and enhance the teaching experience. However, I could find no widespread use or large-scale tests on these systems, especially in educational settings.

The use of technology in music conducting contexts might help pedagogues to consider more thoughtfully how students can be taught conducting using new approaches. When new technologies come along in some aspect of human life—for example, when in the job market a machine substitutes for the labor of a human being—human intelligence and inventiveness cause us to reflect on what is essentially human in social life. That philosophical problem should be considered when conducting instructors reflect upon music conducting coursework and the use of technology as a potential pedagogical tool. In addition, the difficulties inherent during the COVID-19 pandemic regarding physical interaction have changed our lives in an unprecedented fashion, with an ongoing and undetermined impact on education. Music conducting pedagogy will not be unaffected by this worldwide event. We have not found a substitute for human-to-human interaction when it comes to education or the teaching of music conducting. Nevertheless, this temporally-forced social distancing has given an opportunity to investigate how technology can assist us on the teaching of conducting virtually, or when a music ensemble is not available for a conducting student. The use of technology to teach and learn conducting needs to be studied to guarantee that such a traditional artistic and educational practice remains relevant in the ever-developing digital world.

Chapter Three

Method

I chose to use the method of document analysis to ground my research in the context of music conducting pedagogy and technological developments and trends. Document analysis is a process of evaluating documents to produce empirical knowledge and develop understanding of a phenomenon (Bowen, 2009; Corbin & Strauss, 2008). This form of qualitative research uses documents that are interpreted by the researcher to give voice and meaning around a particular topic of interest. Analyzing documents includes coding content into themes similar to how focus group or interview transcripts are analyzed (Bowen, 2009).

Document analysis involves written forms of communication (Kuckartz, 2014) and focuses on what is contained within these documents (e.g., text, figures, and/or tables) (Given, 2008). This process encompasses the analysis of the content of a wide range of documents, such as texts, official publications and reports, letters, and written responses to open-ended surveys (Patton, 2002). Moreover, through the examination of professional and general publications, document analysis facilitates investigating changing trends over time (Fraenkel et al., 2012).

Content is generally not under the investigators' control when performing a document analysis. Therefore, data may need to emerge from the material itself rather than imposed a priori by a theoretical construct. From that perspective, the categories will be grounded in the data within a specific context (Guba & Lincoln, 1981). Similarly, Merriam (1988) explained content analysis as a systematic procedure that "involves the simultaneous coding of raw data and constructing categories that capture relevant characteristics of the document's content" (p. 117). In sum, document analysis enables researchers to investigate human behaviors indirectly by analyzing products such as textbooks, articles, newspapers, advertisements, songs, political statements, novels, pictures—virtually all types of communication (Aktürk et al., 2017). Finally, according to Bowen (2009), document analysis has the potential to function as a stand-alone method because it can be used to generate new document usage.

A better understanding of recent technological developments that appear in conducting pedagogy documents might provide evidence for a set of suggestions for conducting teachers regarding the use of technologies in pedagogical settings. In this chapter, I describe the process of my document analysis. I begin with a rationale for this method, followed by how the research was designed, including which and why certain documents were selected. After explaining that selection and analysis is an inseparable process, I conclude with issues of trustworthiness.

Rationale

This document analysis was supported by naturalistic research theory (Guba, 1985) insofar as the research design emerges in the investigative process from inquiry as a "constant flux" (Guba & Lincoln, 1981, p. 224). Constant flux involves the construction of a conceptual framework in which the content of each analyzed data source will temporarily be fitted, or not, to the concept of the phenomenon being constructed.

When a phenomenon cannot be observed directly, documents can help provide data if analytical procedures are applied. Furthermore, document analysis is applicable to qualitative studies that produce descriptions of a single phenomenon, event, organization, or program where sources of empirical data exist (e.g., some music conductors wrote music conducting textbooks) (Mills et al., 2006; Stake, 1995; Yin, 1994). As Merriam (1988) wrote, “Documents of all types can help the researcher uncover meaning, develop understanding, and discover insights relevant to the research problem” (p. 118).

Specific Use of Documents

Documents can serve a variety of purposes as part of a research inquiry. Bowen (2009) highlighted five specific functions for the use of documents. Of those five, three will be used in this dissertation. First, documents might contain data on the context within researchers operate, which in this case includes music conductors, conducting pedagogues, and music education researchers. Documents are a source of background information and provide a historical record of music conducting pedagogy practices. Second, documents can be used to track changes and development. For example, analyzing conducting syllabi might help to detect the inclusion of technology tools in contemporary conducting classrooms. Third, documents can be analyzed to corroborate evidence from different sources. When there is convergence of information from different sources, readers usually have greater confidence in the trustworthiness (credibility) of the findings (Bowen, 2009). Documents provide background context, ways of tracking change and development, and corroboration from different sources. For instance, comparing information found in extant research findings with the content of music conducting textbooks or syllabi might provide evidence of how and to what extent conducting pedagogues include such technological developments in their classrooms.

Research Design

Although devoting separate sections has been deemed necessary for the reader to understand the detailed processes of data selection and data analysis, such separation might be misleading because those are intertwined processes (Merriam, 1988). Thus, descriptions of components essential to data selection in this dissertation include (a) theoretical sampling, (b) data sources, (c) data selection, and (d) data analysis (Huang, 2007).

Theoretical Sampling

I used theoretical sampling as the data selection strategy in this dissertation. This is also known as a purposeful sampling (Mertens, 1998). According to Strauss and Corbin (1998), theoretical sampling refers to a method of data gathering driven by the concept of making comparisons. The purpose of doing so is to select and analyze documents that will maximize opportunities to discover concepts and to identify categories in terms of their properties and dimension. Creswell (2002) argued that to best help the researcher understand the problem and the research questions, documents should be selected purposefully. Therefore, a purposeful sample of information-rich publications was used to obtain a more in-depth picture of teaching philosophies, beliefs, and practices about the use of technology within conducting contexts.

Data Sources

Primary sources for document analysis include public records, personal documents, and physical evidence (O'Leary, 2014). I used publicly available resources such as *Google Scholar,* university and other related institutional websites, online bookstores, and teachers' shared materials to gather the documents comprising my data. The documents I chose to analyze were (a) conducting course syllabi, (b) conducting textbooks, and (c) research articles. These were chosen so that I could gain insights into the application of technology in music conducting settings.

Conducting course syllabi were chosen because they represent current pedagogical practices of conducting teachers in written form. It is reasonable that what music conducting teachers believe their students should learn is reflected in their conducting syllabus. Conducting pedagogues express their views about how to teach skills through textbooks. These techniques are documented, written by renown pedagogues, and used frequently in music conducting classes. In addition, research articles were peer-reviewed manuscripts that appeared in a variety of music education and technology journals. I selected articles that included the use of software, hardware, and computer systems because they might inform conducting instructors' pedagogical practices. I believe that these three types of documents represented the voice of music conducting teachers, pedagogues, and researchers.

Data Selection

When using document analyses, Bowen (2009) suggests a change in the research language from data collection to data selection since data will not be produced. In principle, data selection and analysis are inseparable in qualitative research (Guba & Lincoln, 1981; Lincoln & Guba, 1985). It is not only "a process of systematically searching and arranging" (Bodgan & Bilken, 1998, p. 157) accumulated data to increase the ability of the inquirer to understand them, but also "an interactive process throughout which the investigator is concerned with producing believable and trustworthy findings" (Merriam, 1988, pp. 119-120).

Syllabi, Conducting Textbooks, and Research Articles Sampling Procedures

A facet of addressing the research questions involved selecting conducting syllabi and conducting textbooks. These documents might include how the use of technology is perceived and enacted by music conducting teachers and pedagogues. Thirteen institutions accredited by the *National Association of Schools of Music* (NASM) in the Southeastern Conference (SEC) were chosen for the selection of music conducting syllabi. The SEC is the NASM area in which the University of Missouri's School of Music is associated, thus sharing geographical and possibly music conducting instructors' commonalities with the associated institutions. I invited conducting faculty members via e-mail to share their basic conducting course syllabi. I searched faculty directories and sent 71 e-mails to music school/departments' directors, conducting faculty, and/or teaching assistants, including those whose specialty was orchestra, band, or choir. I sent a second reminder e-mail four weeks later to non-respondents. I received 19 responses. Fourteen syllabi were returned for subsequent analysis.

I chose five of the most frequently used conducting textbooks by university faculty members of the College Band Directors National Association (CBDNA) (Silvey et al., 2016) to analyze. These textbooks included *Basic Conducting Techniques* (Labuta & Matthews, 2018); *The Modern Conductor (*Green & Gibson, 2004); *Basic Techniques of Conducting* (Philips, 1997); *Conducting: A Hands-On Approach (*Maiello & Bullock, 1996); and *The Art of Conducting* (Hunsberger & Ernst, 1992).

Furthermore, many of the research articles reviewed for this dissertation (see Chapter 2) were considered part of the body of research data. According to Glaser and Strauss (1967), the selection of publication material is the equivalent of a collection of interviews or field notes. Research articles on music conducting and technology were purposefully selected because they represented material that has been systematically investigated. Select articles included in the literature review functioned as the first data source.

Fourteen research articles included in the review of literature and purposefully selected for this document analysis were chosen from peer-reviewed journals such as *Frontiers in Digital Humanities* and *Journal of Music, Technology, and Education*. Other sources included paper presentations at conferences and symposiums about music and technology such as the *International Conference on New Interfaces for Musical Expression (NIME)*, the *International Symposium on Computer Music Modeling and Retrieval,* and the *Institute of Engineering, Electrotechnicians and Electronics (IEEE) International Conferences*.

I searched the *Google Scholar* database while using the following keywords: conducting, music conducting, music conducting pedagogy, musical gestures, gesture recognition, and technology, and used each keyword alone and in combination with one another. To discover additional resources, I performed a manual search in the reference list of relevant articles that I encountered using the same keywords. In addition, I also chose materials that matched one of the following criteria: (a) the articles were perceived to be of pedagogical interest for conducting music teacher educators or (b) the authors of the articles explored the intersection between conducting gesture and the use of technology. To find the most recent research on the topic, my search included articles from 2010-2020.

Constant Comparative Approach

I used the constant comparative method to analyze documents in this study (Glaser & Strauss, 1967; Lincoln & Guba, 1985). Adaptations of the constant comparative method have been applied in previous studies examining music composition strategies (Seddon & O'Neill, 2003) and musical communication (Seddon, 2005; Seddon & Biasutti, 2009). The method of comparison was employed to build and refine categories, define conceptual similarities, and discover patterns (Edwards, 1992). From October 2020 through September 2022, I engaged in searching, analyzing, and drawing conclusions. Agreements, alignment, coexistence, and similar outcomes from documents were synthesized, whereas disagreement and contradiction provided an in-depth explanation about the dissertation topic under different conditions. Within and between documents, the constant comparative method was used to look for "regularities and patterns as well as topics" (Bodgan & Bilken, 1998, p. 171) that could be coded as units of information in the form of words, phrases, or even an extended paragraph (Huang, 2007).

Constant comparative methodology involves five main stages: (a) immersion; 'units of analysis' are identified, (b) categorization; repetitions become 'categories' emerging from the 'units of analysis', (c) phenomenological reduction; 'patterns' and 'themes' emerge from the 'categories' and are interpreted by the researchers, (d) triangulation; support for researcher interpretations of 'themes' is sought in additional data, and (e) interpretation; overall interpretation of findings is conducted in relation to the literature (McLeod, 1994).

Immersion

Immersion involved repeated viewing of the selected documents to acquire a high level of familiarity with the data (Seddon & Biasutti, 2009). Immersion began during my literature review when research articles were identified, selected, and categorized.

Immersion continued through the same process of identification, selection, and categorization with conducting syllabi and conducting textbooks. After this initial stage of studying the topic of music conducting and technology, the selected materials were reduced to relevant data and based on emergent themes which were identified by developing units of analysis.

Raw Data

The term *raw data* refers to information that is gathered for a research study before that information has been transformed or analyzed. *Raw data* terminology can be applied to the data as soon as they are gathered or after they have been cleaned, but cannot be further transformed or analyzed (Lavrakas, 2008). Using data reduction techniques (O'Dwyer, 2004; Huberman & Miles, 1994), I read and reviewed documents, and took relevant notes during and after the study of each document. During the *cleaning* process of raw data, entire sections and paragraphs, directly related to the subject of this dissertation, were extracted from each document, including tables and figures. Only parts of documents that contained the exclusive voice of the authors were considered relevant to the extraction of raw data. Repetitive ideas and mathematical and algorithmic formulas were removed from the original text to form sets of raw data. Efforts were made to maintain the integrity of the data.

Headings, entire paragraphs, sentences, figures, and tables were reviewed before any coding procedure was applied to the material. I added pre-analytical comments and notes to information that at first seemed unclear, confusing, problematic, or contradictory to music conducting tradition or common practice. Another procedure to facilitate further analysis was to place figures and tables right below the text related to it, which was not always the case in the original document. This process was repeated for conducting syllabi and conducting textbooks, resulting in a set of raw data that correlated to a specific document.

Categorization

Documents are context-specific, and they should be evaluated against other sources of information. The researcher needs to demonstrate the capacity to identify pertinent information and to separate it from that which is not pertinent (Corbin & Strauss, 2008). Categorization involves the systematic identification and categorization of themes that emerge from the data (Seddon, 2005; Seddon & Biasutti, 2009). The processes of categorization in constant comparative approach are similar to the process of coding which will be further explored next.

Coding

Coding occurs when “data are systematically transformed and aggregated into units—units of analysis—which permit precise description of relevant content characteristics” (Glaser & Strauss, 1967, p. 203). Each unit represents a piece of distinct information that can be physically separated from other data. The code functions like coordinates on the map frame; when applied to the text, they link features in the text (e.g., words or sentences) to the analyst’s constructs. The code adds information to the text (rather than reducing the text) through a process of interpretation that simultaneously breaks the text down into meaningful chunks or segments (MacQueen et al., 1998). In the process of defining codes, MacQueen et al. (1998) suggests to not assume that anything is obvious by always stating specifically what the code should and should not capture. A code segments complex text into smaller natural units, such as a line or a sentence. This includes defining references that may occur in the text. The researcher should also include all such information in the definition of the code and explanations for its use.

Coding Process

At the beginning of the coding process in this dissertation, I identified themes that were found in the raw data and associated with music conducting pedagogy and technology. According to Strauss et al. (1998), properties of each source should be carefully investigated before the author classifies them into each code. All terms and concepts that represented the same concept are grouped together representing a single idea (Strauss et al., 1998). Because documents were selected to investigate pedagogical practices by focusing on the teaching of technique and use of gestures and technologies (mechanisms for intervention), the coding process involved identifying and coding emerging ideas that underpinned conducting technique (explicit and implicit) and key ideas about teaching conducting with technological tools.

Open Coding Process. This is the initial analytic process though which concepts are identified, and their properties and dimensions are discovered in raw data (Strauss et al., 1998). The open codes were used primarily to signal the presence or absence of pieces of information During the open coding process, data are broken down into discrete parts, closely examined, compared for similarities and differences, then grouped and categorized. Open coding schemes are created separately for the analysis of documents. For instance, open code *S1 – Syllabus One:*

S1	Video record; Canvas; Audio/video recording	Learning activities to meet the objectives	"Students will video record themselves"…"and upload the video to the appropriate assignment page in Canvas"

After identifying sets of meaningful units in open coding, the next step was to sort and shift through each set to identify relationships between paterns and themes, as well as to draw distinctions and common sequences between sub-groups in structural coding.

Structural Coding Process. Structural coding results in the identification of large segments of text on broad topics; these segments can then form the basis for an in-depth analysis within or across topics. The goal was to code the text in such a way that the information could be combined meaningfully with a database. I began structurally coding from the open codes according to the research questions to frame the selected research articles, conducting course syllabi, and conducting textbooks. The purpose of this step was to facilitate analysis by identifying all the text associated with a particular research question.

Phenomenological Reduction

In this stage of constant comparative approach, ‘paterns’ and ‘themes’ emerged from the ‘categories’ and were interpreted by the researchers, I assigned codes to each of the practices, crosscutting concepts, and core ideas according to their titles and subtitles. Then, each code was searched and marked in the related parts of the documents. Lastly, codes found in the conducting textbooks, syllabi, and research articles were counted separately for each of the documents in association with a specific research question (Aktürk et al., 2017). For example, code *BCTRQ2 - Basic Conducting Technique, Research Question Two* means information addressing research question two was found in the *Basic Conducting Technique* textbook:

BTCRQ2	“**Lesson 1**: Class Organization**:** Students will be videotaped and will be expected to view the videotape outside of class and complete a self-evaluation form as part of the grading process. You will be able to learn a great deal about your conducting by studying the videotape.” (p. 3)

Trustworthiness and Reliability

In all types of inquiry, both the researcher and the reader want a set of boundaries to be established that guarantee a level of trust to the study. Trustworthiness in qualitative research is achieved when the credibility of the findings is the result of a convergence of information coming from different resources (Bowen, 2009; Guba, 1981).

Triangulation

Triangulation means the selection of data from a variety of sources, with different formats containing different perspectives, objects, and functions to be confronted for cross-check and data interpretation (Guba, 1981). Document analysis is a process of selecting and choosing bits of information from a set of purposefully chosen documents. These data sources, which included basic conducting syllabi, conducting textbooks, and research articles, were used for cross-check and data interpretation.

Biases either from the authors of the documents or the researcher need to be kept in check with a clear process, evaluative steps, and analyses measures (Bowen, 2009; O'Leary, 2014). For instance, information should be confirmed by at least two distinct sources to be considered valid and trustworthy. Collecting data from a variety of publications with different perspectives tested my biases since every claim had to be supported by at least two different sources. The perceptions of another observer with the same set of data functioned as third-party auditing. This person, who was an instrument and voice pedagogue graduate student with qualitative research experience, verified if themes and consequent interpretations were supported by corresponding documents

(Mertens, 1998). Furthermore, the coding process was essential for the document analysis process; consequently, a system of code checking needed to be constructed.

Code Checking

Codes function as a frame or boundary that the researcher constructs to systematically map the informational terrain of the text (MacQueen et al., 1998). These codes should reflect the researcher's implicit or explicit research questions. I reviewed the codes to determine whether possible inconsistencies were due to coder error (e.g., misunderstanding of terminologies) or to problems with the code definitions (e.g., overlapping or ambiguous inclusion criteria that made it difficult to distinguish between two codes). Once any problems were identified and the codes clarified, I reviewed all previously coded text and, when necessary, recoded so that it was consistent with the revised definitions.

I separated the code into related components or domains and applied one set of codes to one type of reviewed document (e.g., conducting course syllabi first) before moving onto the next items, namely conducting textbooks and research articles. Codes that did not work were thrown out, and I reworked definitions for codes that were problematic (MacQueen et al., 1998). After constructing an initial open coding scheme, all documents were read and analyzed again to combine the open codes into structural codes. This refining process continued until a final set of structural codes resulted for the document analysis. Subsequently, the documents were read again, and the coding was verified against the final version to ensure consistency.

This constant checking of analysis procedures was accompanied by third-party auditing. Codes, themes, and consequent interpretations were verified to determine if they were supported by corresponding document entries. Roughly thirty percent of the documents—course syllabi (N = 5), conducting textbooks (N = 2), and research articles (N = 4) with related codes were verified by the peer auditor. Intercoder agreement between my codes and the peer checker's codes was examined, and coding problems were resolved until consensus was achieved (Creswell & Poth, 2016).

Chapter Four

Results and Analysis

For this chapter, results are separated by the type of documents analyzed: syllabi, conducting textbook, and research articles. For ease of organization, I provided tables summarizing the findings for the documents that I analyzed. There are no hierarchical relationships among the three types of documents. Using the constant comparative approach, I looked for regularities, patterns, and repetitions, as well as topics within and between documents, that could be coded as units of information in the form of words, phrases, or even an extended paragraph, including related figures and images. Through this process, ideas and themes emerged that are synthesized next.

Syllabi

Open Coding Process

This section includes results of my analysis involving 14 undergraduate basic conducting course syllabi. After extracting data from each selected syllabus that was related to the teaching of basic conducting and the use of technology, open codes were assigned to link the specific syllabus to its related raw data (i.e., open code S1 signify that raw data was extracted from a syllabus labeled as *Syllabus One*-S1). Raw data were extracted from each syllabus, separated, and placed in a coded *Word* file. Thus, only relevant material remained for subsequent stages of coding and analysis. At this stage of data selection and analysis, no specific codes were assigned to any word, term, number, or image related to technology usage in music conducting. Caution was taken to maintain the context in which the data were presented in the original document. Table 1 summarizes open coded data.

Table 1

Integrated Results Matrix For Technology-Related Terms Present in Basic Music Conducting Syllabi (N = 14)

Syllabus	Terminology/device used	Section/heading	Context
S1	Video record; Canvas; Audio/video recording	Learning activities to meet the objectives	"Students will video record themselves"…"and upload the video to the appropriate assignment page in Canvas"
S2	Technology; Recordings; Video; CD	Knowledge Practice	"must know how to complement knowledge bases with the appropriate use of…" "must have a rich repertoire of the use of…"
S3	Phone; Record video; SD card; Flash drive; Videotaping	Required materials for class Class schedule	"Use of a personal phone to record video or an SD card or flash drive labeled with your initials."
S4	Audio/video recording; Metronomes; Technological resources; Audio playback; Conducting recordings; e-mail	Required materials Course information Technology requirement(s) Student learner outcome Course assignments & assessments Course schedule	"… and utilization of technological resources (through video recording, metronomes, and audio playback) in the study and preparation of course assignments… The student will expand their knowledge of: 4. Technology by using it where appropriate to further their understanding of the art of conducting." "1. Self-Evaluations of Conducting Recording – submitted via email…"
S5	SD card; Smart phone; Videotaping	Required materials for class Assignments	"An SD Card labeled with your initials, or a smart phone with video capability"

S6	Camera/cell phone/tablet; Remote learning; Recordings—video or audio; Virtual course sessions; Recording; Being recorded	Materials needed Recording policy	"Schools, departments, programs, and individual faculty members, speakers, and artists may have policies governing the creation, use, and/or distribution of…"
S7	Recordings—video or audio; Virtual course sessions; Recording; Being recorded	Recording policy	"Schools, departments, programs, and individual faculty members, speakers, and artists may have policies governing the creation, use, and/or distribution of…"
S8	Video record	Recording materials	"A device to video record your conducting projects"
S9	Technology; recording; Video; Canvas; Conducting recordings	Resources/materi al Course description Course assignments/ projects	"Personal technology device for class and recording purposes." "Supplemental readings/videos, as assigned by instructor." "Canvas is the sole classroom management system for MUS358." "Each student will conduct in front of class 6 times and will utilize online or digital recordings for aides as needed, if a live ensemble is not plausible."
S10	Online; Video recordings; Canvas; Created in sync	Course activities Class schedule	"Students will be assigned specific exercises or pieces for which they will create a video recording of themselves. Details about each demonstration will be provided by the instructor in class and/or through the assignment tool on Canvas. The assignment tool permits video recordings to be created in sync with the specific assignment."

S11	Headphones; Camera with microphone; Phone's camera, mic, screen; metronome; App; E-mail; Videoed; Videos; Internet, Technology; DVD	Required materials Assessment of learning Outcomes/ grading; CMDA technology statement Course changes Recommended resources	"...but you will want a larger screen for optimal instruction and skill development." "If you are experiencing consistent challenges in accessing reliable internet or have other technology concerns which may prevent you from completing the requirements of this course, please contact the Dean's Office…"
S12	Technology; Technologies; Metronome; Spotify; Video; Media device; Phone; Camera; Youtu.be;	College of education conceptual framework Knowledge Practice Course calendar fall 2020	"The faculty in the College of Education at … are committed to assuring the success of students and graduates by providing superior learning…, and technology change." "Educational professionals must… also know how to complement these knowledge bases with the appropriate use of technology." "How to conduct: 4/4, 3/4, and 2/4: https://youtu.be/DdvHUJ88tao"
S13	Dartfish App; Android; Apple; Site; Video; Canvas; Electronic device; Laptop; iPad; Tablet	Required materials Course activities Class schedule	"Students will be questioned about reading, listening, and video analysis." "Listening assignments used for conducting purposes will be available through Canvas as streaming audio files." "August 16 Intro to course (Dartfish) Video of 2, 3, & 4 patterns; Video submissions discussed"
S14	Online; GatorEvals; E-mail; Canvas; Recordings; Files	Objectives Text and materials Schedule	"Handouts, scores, recordings (available online, on Canvas, or in the library)." "10. Polychoral Music (see hand out on Canvas under "Files")."

The use of video and audio recording (and various combinations of these terms) was the most common theme found in these syllabi in relation to technology. Technology terminology was mostly related to equipment, devices, or digital platform usage. The most common was *Canvas*, which was "used as classroom management system" (S9). Hence, digital platforms and webpages were mostly used for storage of materials such as video and audio files, evaluation forms, class/university policies, and instruction documents. Nevertheless, for most of these documents, I could not find any Technological Pedagogical Content Knowledge (TPACK) related to the acquisition of music conducting knowledge. To reiterate, TPACK is the theoretical orientation that addresses the intersection between technological, pedagogical, and content knowledge as a means of delivering content in ways to integrate content-based courses with technology instruction such that learners recognize the connection between content and the use of technology (Dorfman, 2016; Misha & Koehler, 2006). Thus, I found no reference to TPACK in these syllabi related to the teaching/learning of conducting skills.

Furthermore, I did not find a connection between the pedagogy of conducting and the presence of technology terms in these syllabi. For instance, in sections such as *Objectives, Required Materials, Topics to be Covered, Assignments,* or *Course Outline* (where it might be expected that the content of the course is specified), there was no inclusion of technological terms as pedagogical tools. In addition, three syllabi (S2, S4, S12) referred to the use of technology as *a priori* knowledge that the student must demonstrate independently of the course syllabus. Even though S12 included technology changes as part of the College's 'Conceptual Framework' section (e.g., "The faculty in the College of Education at...University is committed to assuring the success of students and graduates by providing superior…, and technology change”), the use of technology was mostly restricted to the sharing of video databases and organizational webpages. There was no evidence of a conceptual framework being reflected in the pedagogical content of the syllabi concerning ‘technology change.’

S4 included technology-related language in six sections, emphasizing the use of technology for assessment and self-preparation “by using it where appropriate to further their understanding of the art of conducting,” “in the study and preparation of course assignments,” and “self-evaluations of conducting recordings.” In this syllabus, again, there was no TPACK concept directly associated with the teaching and learning of conducting skills. However, the learning management platform *Canvas* was used to facilitate assignment collection and communication between instructor and students in S9 and S10, whereby “The assignment tool permits video recordings to be created in sync with the specific assignment.” In the context of these two syllabi, technology was used to help assist with assessment, evaluation, class management, and other non-conducting technique related objectives. In the same manner, audio recordings were “aides” if a live ensemble was not possible. Also, instructors referred students to Information Technology (IT) departments in case of students’ struggles with technology use (S11).

Only one syllabus included the use of a required technology application applicable to the analysis of gestures: “REQUIRED MATERIALS: Dartfish App: for Android and Apple (S13). Dartfish is a “video coaching tool for sports” (https://apps.apple.com/us/app/mydartfish-express/id1040982427). In the syllabus, an explanation for the use of the application in the context of the class was scheduled for the first day of class. For example, "Class Schedule: August 16, Intro to course (Dartfish) Video of 2, 3, & 4 patterns; Video submission discussed" (S13).

The application manipulates videos in many ways that might facilitate gestural assessment. Some recording features include videos that are optimized for slow motion and frame-by-frame replay; two videos can be put together side-by-side for comparison, and videos can be zoomed in and out. These videoing capabilities might help to identify students' areas of strength and weaknesses during gestural assessment. Analysis tools also included the inclusion of drawing and labels, the measuring of angles and times, and breaking down conductors' motions with still shots that can be shared without sending the whole video. In addition, the application permits the adding of the instructor's viewpoint by sharing voice and text notes.

Textbooks

Open Coding Process

This section includes results of my analysis involving five conducting textbooks. The same procedures that I used to analyze conducting syllabi were used again. Because of the bulk of material contained in the textbooks (i.e., 1,434 pages), tables summarizing each of the five textbooks were constructed and appear next. Results for technology-related terms found in textbook *The Art of Conducting* (TAC) (Hunsberger & Ernst, 1992) are presented in Table 2.

Table 2

Matrix for Technology-Related Terms Present in Textbook The Art of Conducting (TAC) (Hunsberger & Ernst, 1992)

Section/Chapter/ Heading	Terminology/Devise Used	Context of Usage

Section one Basic principles of conducting Chapter 1 Style of articulation Aural analysis (p. 14)	Recording; Cassette recorder; Videotaped; Tape	"Make a recording of the class performance... Use the best equipment available, but do even if you can only use a portable cassette recorder. You will be surprised at how much you can hear, even on an unexpensive recorder. If the class is being videotaped, you can use the audio portion of the tape. (…you can then look at the picture after evaluating the sound to discuss how the conducting influenced what was heard.)"
Aural analysis form (p. 15)	Recorded	"Evaluate each of the recorded excerpts for the following: *precision of release; expressive quality of release; tempo; style of rhythm and articulation; balance and blend; and quality of unison…"*
Chapter 10 Administrative responsibilities Rehearsal evaluation (p. 124)	Video/audio tapes; Video equipment	"Videotape or audio tapes of rehearsals should be made and analyzed on a regular basis…Video equipment is ideal for this purpose,"
Chapter 12 Contemporary music Logistical considerations (p. 141)	Prerecorded tape; House speakers; Speakers; Stage lighting; Slide; Film projection	"Contemporary compositions often have logistical requirements, such as the use of nonstandard equipment or special arrangements onstage or in auditorium. Here are some examples…"
Chapter 14 The jazz ensemble Conducting technique (p. 155)	Tape-recording; Playback; Recordings	"Tape-recording and playback during rehearsal are well worth the necessary time and effort. Commercial recordings of the same repertoire can also be played to improve concepts of style."
Section four Appendixes Appendix 1 The conducting course Description and syllabus procedures (p. 387)	Videotaped; Tape	"Many of the classes might be videotaped, and you will be able to learn a great deal about your conducting by studying the tape…Viewing the tape may be an assignment and will be a factor in the final grade."

Videotaping was the main technology resource in *The Art of Conducting* (TAC). Corroborating evidence found in syllabi from the previous analysis, videotaping was also used for self-evaluation. In Chapter 14, despite a technology term appearing in a technique section, the context did not infer the teaching of conducting technique because tape-recording was used merely as a device for listening practice for the student to “improve a concept of style” by listening to commercial recordings of the same repertoire used during class rehearsals (TAC, p. 155).

In TAC, the use of words and terms such as tape, tape-recordings, playback, videotape, audiotapes, recordings, aural recording, prerecorded tapes, house speakers, separate track, click track, speech amplified, stage lighting, and slide and film projection were included in *Aural Analysis* (pp. 14, 15, and 91), *Evaluation* (pp. 28, 124, 125), *Logistical Considerations* (p. 141), and *Procedures* (p. 387). These were not correlated to content in the chapters to which such headings belonged. For example, Chapter 12 had the section in which most technology terms appeared, not related to the pedagogy of conducting technique, though. As the heading suggested, terms were related to equipment and devices for “logistical considerations” (TAC, p. 155). Next, a summary for technology-related terms found in textbook *Conducting: A Hands-On Approach* (CHA) (Maiello & Bullock, 1996) are presented in Table 3.

Table 3

Matrix for Technology-Related Terms Present in Textbook Conducting: A Hands-On Approach (CHA) (Maiello & Bullock, 1996)

Section/Chapter/ Heading	Terminology/Devise Used	Context of Usage
CD tracking sheet	CD	“1. Exercise A-1… 43a. Exercise E-1 Complete…

		98. Exercise L-7”
Introduction (p. 7)	CD; Video	…“This book, accompanying CD and video, will serve those musicians who have the desire or need to conduct, or augment their musical experiences by becoming a musical leader… Present Technology is advancing at an astonishing rate and has a direct impact on the arts, specially the world of music…”
Chapter 1 Welcome to the podium Horizontal and vertical planes (p. 11)	Videotaping	… “Videotaping practice sessions from a frontal view will give excellent, insight and clearly demonstrate the flexibility of this plane…”

The major finding in *Conducting: A Hands-On Approach* (CHA) regarding the use of technology was the introduction of a CD and video as extra materials. The CD contained recordings of the same musical scores found in the textbook and was designed to serve as a listening aid. For example, track 1 is the recording of Ex: A – 1 (p. 28). The author highlighted the need to stay “fresh and current” regarding technology and offered these technology aids (e.g., CD and video) to “serve those musicians who have the desire or need to conduct or augment their musical experiences by becoming a musical leader” because “present technology is advancing at an astonishing rate and has a direct impact on the arts, especially the world of music” (p. 7). There was no subsequent use or application of the term technology, nor evidence of its use for the teaching/learning of conducting technique. The author also suggested videotaping for “practice sessions from a frontal view” to acquire insight and view of the frontal gestural plane to aid in self-observation only (p. 11). Results for technology-related terms extracted from *Textbook Basic Techniques of Conducting* (BTC) (Philips, 1997) are summarized in Table 4.

Table 4

Matrix for Technology-Related Terms Present in Textbook Basic Techniques of Conducting (BTC) (Philips, 1997)

Section/Chapter/ Heading	Terminology/Devise Used	Context of Usage
Contents (pp. vii, vii, ix) Lesson 5, 9, 12, 13, 19, 23, 26, 30 (pp. 45, 73, 105, 109, 151, 175, 197, 227)	Videotaping	"Videotaping #1… Videotaping #8"
Preface (pp. xi, xii, xiii) To the instructor	Videotaping; Tape; Microphone; Taping; Videotape	…"Ten of the thirty lessons…are designated as videotaping session. (Videotaping is an indispensable asset for the teaching of conducting…the instructor may speak quietly on the tape (close to the microphone)…when the student view the tape the remarks will be heard for study and evaluation." "Included in eight of the videotaping lessons is an Evaluation Form for assessment by the instructor and self-evaluation by the student."
Lesson 1 (pp. 3,5) Class organization Assignment	Videotaped; Videotape	"Students will be videotaped and will be expected to view the videotape outside of class and complete a self-evaluation form as part of the grading process." "In some cases the instructor may ask you to purchase your own videotapes."
Lesson 5 (pp. 45, 46, 47) Assignment	Videotaping #1	"For the videotaping, the instructor will collect the evaluation forms and call the names at random. Students will conduct in that order." "View Videotaping #1 in the designed location. Complete Evaluation Form I on both sides and turn in to the instructor on the designated day."

Videotaping was the only technology found in *Basic Techniques of Conducting* (BTC). In comparison to TAC and CHA, videotaping was included in the table of contents not only as a suggestion, but effectively structured for classroom usage. The author indicated that videotaping was "indispensable" for "self-evaluation" and "instructor's assessment," just as in TAC and CHA (p. xii). In BTC, videotaping was used as a rudimental tool to record personal comments in such a manner as "the instructor may speak quietly on the tape (close to the microphone) as each student is conducting" (p. xii). Regarding the use of videotaping for self-evaluation and instructor assessment, the same procedures for lesson 5 were repeated in lessons 9, 12, 13, 19, 23, 26, and 30.

In the preface, the author wrote about the pedagogy of music conducting rooted in the master-apprentice tradition:

> The study of conducting is much like the study of an instrument or voice—it is a psychomotor skill acquired over time. As such, the skill of conducting cannot be learned from a textbook. This text can only serve as a guide; your class instructor is the most important source of help. (Phillips, 1997).

Next, results for technology-related terms evidenced in textbook *The Modern Conductor*

(TMC) (Green & Gibson, 2004) are presented in Table 5.

Table 5

Matrix for Technology-Related Terms Present in Textbook The Modern Conductor

(TMC) (Green & Gibson, 2004)

Section/Chapter/ Heading	Terminology/Devise Used	Context of Usage
Chapter 1 So you want to be a conductor? Exercises for practice: Training the ear Note (p. 7)	Videotapes	"Publication information for the following recommended videotapes may be found on the pages indicated."
Chapter 5 The expressive gesture	Videotapes; Tapes	"it is strongly recommended that these tapes be seen, especially the Kleiber tape."

Exercises for practice: Developing expression in the gesture Recommended videotapes (pp. 57, 62)	"for readers who are interested in the history of the conductor's technique, the following videotape is recommended."

Videotaped references found in *The Modern Conductor* (TMC) were documentaries involving expert conductors and their insights on conducting technique and music interpretation. Those commercially available VHS recordings also portrayed renowned professional conductors. On pages 83, 118, 138, 196, the author of the textbook recommended videotapes as extra viewing material at the end of sections/chapters. Regarding the master-apprentice conducting teaching tradition, the pedagogical goal seemed to be to see how the masters did it and learn the craft of conducting by observing them working. In chapter 16, the author mentioned that self-recording a videotape was not pedagogically oriented. The tape was supposed to be of an already "excellent, professional quality" with the objective of presenting it for prospective job searches.

Importantly, the authors of BTC and BCT included technology use in the content index, which textbooks TAC, CHA, and TMC did not. Hence, the content index was a summary of what was to be taught/learned when using the textbook. It may be that content and index lists reflect the degree of importance that authors give to subjects. What is considered by the authors as the most important topics in their books ought to be highlighted on such lists. I performed a thorough review of the textbooks, including a careful analysis on the content sections and a cross examination with the subject index section, in search for missing terms and words related to technology usage. After this procedure, the application of TPACK theoretical concept along with technology-related terms was not found from analyzing the contents in textbooks TAC, CHA, and TMC. As explained previously, although BTC had technology terms in its content list, it did not include TPACK criteria. Only BCT fulfilled some TPACK postulates. Next, integrated results for technology-related terms encountered in textbook *Basic Conducting Techniques* (BCT) (Labuta & Matthews, 2018) are presented in Table 6.

Table 6

Matrix for Technology-Related Terms Present in Textbook Basic Conducting Techniques (BCT) (Labuta & Matthews, 2018)

Section/Chapter/ Heading	Terminology/Devise Used	Context of Usage
Basic conducting technique (n/p)	Website; Audio recordings; Demonstration videos	"This new edition features: A new companion website, which includes the scores and transpositions for all musical excerpts, audio recordings of the excerpts, and demonstration videos modeling specific techniques for each chapter."
Introduction To the instructor Features of this textbook (p. 1) Developing concepts and skills of execution (p. 2) Video performance and evaluation (pp. 3-4)	Website, Video; Video recording; Videos; Audio files; Score and part files; Video files; Downloaded; Computer; Tablet, Smartphone; PDF parts; Print	" The selected excerpts are reduced to four parts to accommodate classes with limited instrumentation…and the companion website provides a full score for all instrumental excerpts." "Conception refers to the conductor's inner hearing, or "audiation,"…The companion website provides aural examples of the excerpts to facilitate this process." "Video is a powerful teaching tool and indispensable feedback device for the conducting class…Video recording corrects…displaying distractive mannerisms; score-bound students…improved eye contact, location of the beat. Turning off the

		sound is revealing. Students can observe preparatory beats; steady tempos; beat patterns; eye contact; leadership; preparatory gesture after the fermata. The effect of the omission is graphically portrayed in the video. Students can hear performance errors missed while on the podium."
Companion website (pp. 5-6)		"Structural viewing of videos focuses their attention on the important conducting skills they must develop."
Audio files		"Access the *Basic Conducting Techniques*, Seventh Edition website at www.routledge.com/cw/labuta."
Scores and part files		"The audio examples provide the beginning conductor with an aural representation of every musical excerpt in the book. Individual and transposed parts can be downloaded directly to a computer, tablet, or smartphone from the website…"
Chapter 1 The baton, preparation, downbeat, and release (p. 10)	Website; Downloaded; Audio files; Media player; WAV files;	"The audio files can be played on any media player that supports WAV files."
Appendix H: Model video Excerpt chart Video number (p. 284)	Model video	"1. The Baton, Preparation, Downbeat, and Release V 1-1 Holding the baton V 1-2 Preparation Position for Count One in All Meters 1-1 Drill, Beethoven…"

Textbook BCT was the only conducting textbook out of those analyzed that provided a companion website. Textbooks TAC, CHA, BTC, and TMC included scores and musical excerpts in the textbook, and audio and video recordings in somewhat outdated media formats such as VHS recordings and compact discs. TAC, CHA, and BTC utilized the traditional video recording of students' performances for assessment which was also included in BCT. The heading *Video Performance and Evaluation* presented a detailed description and explanation of the conducting technique issues that can be identified and refined through video observation such as displaying distractive mannerisms, leadership, eye contact, clarity of conducting, and beat location (p. 4).

Just as in TAC, BCT included turning on and off the sound of videos as a pedagogical strategy. The author of BCT suggested viewing a video of the conducting student with the sound off to be shown for the class to follow as they play their instruments. In BCT, this pedagogical approach was used to check for items such as preparatory beats, steady tempos, beat patterns, eye contact, and leadership. Thus, the students would have immediate performance feedback from their classmates as they observed themselves on the video. On the contrary, with the sound turned on, listening to the performance would help to improve error detection.

Explanation about the pedagogical value of the companion website and its integration to the textbook can be seen in several sections of the textbook such as *Presentation*, *Preface*, *Introduction*, and at the beginning of *Part One-Conducting Technique*. In the introduction section, the website was mentioned as providing full orchestra scores of selected repertoires for in-class reading and conducting, and aural examples to facilitate the process of developing inner "sound image" or "audiation" (p. 2). Page five contained a detailed description on the use of the supplemental website, including audio, video, score, and parts with transposition files. Similar procedures regarding the use of the webpage in chapter one was used throughout the book. Specifically, model videos and their related addressed techniques were detailed in *Appendix H* (pp. 284-285).

In the next section, codes from conducting syllabi and conducting textbooks are combined and categorized according to the research questions into structural codes. Because of the thematic commonalities found between these two types of documents, integrated structural coding was undertaken before the analysis of research articles.

Structural Coding of Syllabi and Textbooks

I identified segments of text in each syllabus and textbook for in-depth analysis within and across topics so that the information contained in each text could be combined meaningfully into a coded database. Codes were structured from open codes to frame the selected conducting course syllabi and conducting textbook according to the research questions. The purpose of this step was to identify all the text associated with a particular research question while identifying what document that information was extracted from. For example, code *Syllabus One, Research Question One - S1RQ1* means that text which addressed research question one was extracted from syllabus one. Another example, *The Art of Conducting, Research Question Two - TACRQ2* means information addressing research question two was found in *The Art of Conducting* textbook. Thus, structural codes associated with syllabi and conducting textbooks were counted separately for each of the documents while the text from these various sources formed a body of data correlated to the research questions. That information was synthesized in tables that appear throughout this section. Tables were constructed and contain data related to each of the research questions. As in the previous section, further explanation of my analysis follows each table.

Research Question One: How Has Technology Been Used to Aid in The Teaching of Conducting?

Results that summarized textual information found in syllabi and textbooks that I analyzed which addressed question one, *How Has Technology Been Used to Aid in The Teaching of Conducting?*, were integrated in Table 7.

Table 7

Integrated Results Correlating Text in Documents to Research Question 1

Code	Data (heading and related text)
S1RQ1	"**Conducting Gesture Quizzes -** Students will video record themselves performing the assessments and upload the video to the appropriate assignment page in Canvas*;* The student will complete a Conductor's Self-Assessment Form (provided in Canvas) following each of his/her 4 assigned in-class conducting sessions; The student will be assessed on the quality of his/her reflections in each of the assessment subcategories **Score Terminology Terms -** Students will complete a multiple choice and fill-in-the-blank quiz on conducting terms found in the Score Terminology for the Conductor pdf found in Module 1 of the course Canvas page."
S2RQ1	"**Methods of Instruction/Procedures**: Class members will be given opportunities to practice conducting the ensemble. Recordings of these sessions will be used informally, and 4-5 conducting evaluations will be graded during the course of the semester. Self-evaluations may be used as well. Students will often receive "on the spot" verbal critiques from the instructor during practice sessions, including a brief video review of the material just practiced." **Technology:** Students will be evaluated informally using video recordings of their practice conducting rounds. Students will have the opportunity to view selected recordings of their conducting for evaluation on their own."
S4RQ1	"**Student Learner Outcomes:** … and utilization of technological resources (through video recording, metronomes, and audio playback) in the study and preparation of course assignments."
S9RQ1	"**Course Assignments/Projects:** Conducting Recordings - Each student will conduct in front of class 6 times and will utilize online or digital recordings for aides as needed, if a live ensemble is not plausible. Review/assessment of student conducting recordings can occur during designated class times or by individual appointment with the instructor."
S10RQ1	"**Course Activities:** 2) Online conducting assignments: Video recordings *Online Conducting Demonstrations:* Students will be assigned specific exercises or pieces for which they will create a video recording of themselves."
S13RQ1	"**Required Materials**: Dartfish App: for Android and Apple"

TACRQ1	"**Aural Analysis** (pp. 14-15): Make a recording of the class performance of at least four of the excerpts for Chapter 1 in the Anthology.
CHARQ1	"**CD Tracking Sheet**: 1. Exercise A-1; 2. Exercise A-2; … 98. Exercise L-7."
BTCRQ1	"**To the Instructor**: Videotaping is an indispensable asset for the teaching of conducting and is available in most schools…Included in the eight of the videotaping lessons is an Evaluation Form for assessment by the instructor and self-evaluation by the student."
BCTRQ1	"**Basic Conducting Technique:** a new companion website, which includes scores and transpositions for musical excerpts, and audio recordings of the excerpts, and demonstration videos modeling specific techniques for each chapter.

With regard to how technology has been used to aid in the teaching of conducting, I found the following: video recordings were used for (a) self-evaluation (S1; S2; S9; S10; BTC) and (b) instructors' assessments about conducting gestures (S2; S9; BTC), audio recordings were used for (c) audiation and comparative analysis (TAC; CHA; BTC) whereas forms embedded in digital platforms were used for (d) score terminology acquisition (S1; S2), and (e) preparation of miscellaneous assignments (S4). The contents of one syllabus (S13) indicated the use of a sports smartphone application for the recording and analysis of conducting gestures. Tracks on the CD of CHA were linked to scores addressing targeted conducting skills. For example, A-1 is a one-page score entitled "*Basic One Pattern Exercise*" which is recorded on track one of the CD listed as "1. Exercise A-1" (p. 28). One textbook (BCT) included a companion website, which included scores, transpositions, and audio recordings for all musical excerpts as well as demonstration videos modeling specific techniques for each chapter.

Research Question Two: What is The Role of Technology in The Context of Conducting Pedagogy?

Results that summarized information found in syllabi and textbooks addressing question two, *What is The Role of Technology in The Context of Conducting Pedagogy*, were integrated in Table 8.

Table 8

Integrated Results Correlating Text in Documents to Research Question 2

Code	Data (heading and related text)
S1RQ2	**"Conducting Self-Assessments:** The student will be assessed on the quality of his/her reflections in each of the assessment subcategories. Must be uploaded to Canvas…"
S2RQ2	"1. **Knowledge:** They must also know how to complement these knowledge bases with the appropriate use of technology. 4. **Practice** - Educational professionals must have a rich repertoire of research-based strategies for instruction, assessment, and the use of technologies. B. **Critical Listening**: The MLR listening exam will cover material in the MLR Score Reading Program (Level I) …You may check out the CD set from the band office… The MLR portion of this course requires listening to and evaluating musical recordings."
S4RQ2	**"Student Learner Outcomes:** The Student will expand their knowledge of: 4. Technology by using it where appropriate to further their understanding of the art of conducting. **Course Assignment & Assessments:** 1. Self-Evaluations of Conducting Recording – submitted via e-mail; a. One page reflection response, double-spaced, commenting on conducting session and recorded video, including but not limited to strengths and weaknesses."
S9RQ2	"**Resources/Materials:** Personal technology device for class and recording purposes; Supplemental readings/videos, as assigned by instructor. **Course Description:** Canvas is the sole classroom management system for MUS358. Please turn on notifications and stay abreast—daily—of all course communication."
S10RQ2	"**Class Schedule:** *"Practice" exercises are to be video recorded and submitted to Canvas."*
S11RQ2	"**Assessment of Learning Outcomes/Grading: Informal Evaluations:** (e-mail a 1 page description to…your mentor) **Formal Evaluations** (Videoed): #1 Homophonic Anthem/March - Smyth - *Songs of Sunrise* - "The March of the Women." Each evaluation will consist of - Conducting Preparation and Execution **Practice**: Students should regularly conduct in front of a mirror and consult videos from evaluations."

S12RQ2	"**1. Knowledge**: They must also know how to complement these knowledge bases with the appropriate use of technology." **4. Practice**: Educational professionals must have a rich repertoire of research-based strategies for instruction, assessment, and the use of technologies. Ability to record video on a media device (phone, camera, etc...)"
S13RQ2	"**Conducting/Listening**: Listening assignments used for conducting purposes will be available through Canvas as streaming audio files."
S14RQ2	"**General Objectives**: Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Click here for guidance on how to give feedback in a professional and respectful manner. Students will be notified when the evaluation period opens and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals. Summaries of course evaluation results are available to students here."
TACRQ2	"**Rehearsal Evaluation**: Videotape or audio tapes of rehearsals should be made and analyzed on a regular basis…Video equipment is ideal for this purpose. (124) **Conducting Technique**: Tape-recording and playback during rehearsal are well worth the necessary time and effort. Commercial recordings of the same repertoire can also be played to improve concepts of style. (p. 155) **Procedures**: Many of the classes might be videotaped, and you will be able to learn a great deal about your conducting by studying the tape…Viewing the tape may be an assignment and will be a factor in the final grade." (p. 387)
BTCRQ2	"**Lesson 1**: Class Organization**:** Students will be videotaped and will be expected to view the videotape outside of class and complete a self-evaluation form as part of the grading process. You will be able to learn a great deal about your conducting by studying the videotape." (p. 3)
TMCRQ2	"**Chapter 1 So You Want to Be a Conductor?** Exercises for Practice: Training the Ear Note: "Publication information for the following recommended videotapes may be found on the pages indicated. (p. 7) **Chapter 5 The Expressive Gesture** Exercises for Practice: Developing Expression in the Gesture Recommended Videotapes: it is strongly recommended that these tapes be seen, especially the Kleiber tape." (p. 57)
BCTRQ2	"**Preface:** a new companion website contains media files of individual transposed parts, audio examples, and full scores of the instrumental excerpts located in Part III of the text." (n/p)

Analysis of syllabi and conducting textbooks indicated that the role of technology in the context of conducting pedagogy appeared mostly peripheral and complementary. Technology was used as a means of support for performing self and instructors' assessment and evaluation (S1; S2; S4; S10; S11; S14; TAC; BTC); for video/audio critical listening (S2; S9; S11, S13; TAC; TMC; BCT); for communication between student-teacher and student-institution (S4; S9; S10; S11; S14); as a classroom management system (S1; S9; S10; S14); and as *a priori* knowledge to be used at the student's own discretion (S2; S4; S12).

In textbook BTC, technology was incorporated and integrated in such a way that it became a relevant part of the pedagogical material. For example, the companion website expanded the possibilities of material storage. Media files of individual transposed parts and full scores of the instrumental excerpts were made available digitally on the website as complement to the reduced four-part scores in the textbook. Available media files of aural examples were provided to help facilitate the development of an inner sound image.

Research Question Three: Given That Conducting is a Performative Act, How Can It Be Developed Through Technological Means?

Results summarizing textual information gathered from syllabi and textbooks which addressed question three, *Given That Conducting is a Performative Act, How Can It Be Developed Through Technological Means?*, were integrated in Table 9.

Table 9

Integrated Results Correlating Text in Documents to Research Question 3

Code	Data (heading and related text)

S10RQ3	"**Course Activities:** *Online Conducting Demonstrations:* Details about each demonstration will be provided by the instructor in class and/or through the assignment tool on Canvas. The assignment tool permits video recordings to be created in sync with the specific assignment."
S12RQ3	"**Course Calendar Fall 2020**: How to conduct: 4/4, 3/4, and 2/4: https://youtu.be/DdvHUJ88tao; How to conduct: 6/8, 9/8, 12/8, and a fast 3/8: https://youtu.be/2ER0iP2f8DY; Gesture of preparation: https://youtu.be/40P29dJNYaE; Cutoffs: https://youtu.be/Z2IDhrrM-2M; Conductor's posture/preparation: https://youtu.be/wk6UJQhCyWI?t=10."
S13RQ3	"**Class Schedule** – 18: Intro to course; Post Video of 2, 3, 4 Patterns to Canvas. Cond. Exam (PCE) # 1 Assignment (A1-A4)."
TACRQ3	"**Style of Articulation**: … If the class is being videotaped, you can use the audio portion of the tape. (…you can then look at the picture after evaluating the sound to discuss how the conducting influenced what was heard.)" (p. 15)
CHARQ3	"**Horizontal and Vertical Planes**: videotaping practice sessions from a frontal view will give excellent, insight and clearly demonstrate the flexibility of this planes." (p. 11)
BCTRQ3	"**Introduction:** Companion website: Video files: Video files are a new feature of this edition. Students are encouraged to watch these videos that demonstrate the conducting techniques described in the text…Students should take advantage of this important new feature that models and clarifies the written text." (p. 6)

Note: Because syllabi are relatively short documents, page numbers are not provided. Page numbers are only indicated for conducting textbooks.

In response to how music conducting as a performative act can be developed through technological means, I found that the use of online materials augmented the opportunities for teacher-student interaction during the learning process. For example, in S10's section, *Online Conducting Demonstrations*, the students were permitted to create videos on conducting technique to be demonstrated with specific assignments such as posture and preparatory gestures—*Online Conducting Demonstration 1*, or four pattern and release— *Online Conducting Demonstration 2*. Furthermore, in S12's *Resources* section, the instructor included professional demonstrations of specific conducting techniques using online links in a video platform. In S13's *Class Schedule* section, the teacher provided lecture discussions that were made available on the class learning management platform.

Regarding conducting gestures, TAC - Chapter 1, *Style of Articulation* section, contained the use of videotaping with switching the sound off as a pedagogical strategy. The author explained that with the sound muted "you can then look at the picture after evaluating the sound to discuss how the conducting influenced what was heard" (p. 14). In the CHA textbook - Chapter 1, *Horizontal and Vertical Planes* heading, the author, referring to the crossing "X" of vertical and horizontal planes during arm motion, suggested that "videotaping practice session from a frontal view will give excellent insight and clearly demonstrate the flexibility of this plane" (p. 11).

The innovation in BCT, in comparison to the other syllabi and conducting textbooks, was the use of conducting technique demonstration videos that were available in the companion website, all keyed into the text by an arrow icon (e.g., https://routledgetextbooks.com/textbooks/9781138656987/videos.php). In most traditional conducting teaching settings, the instructor conducts a music excerpt to demonstrate specific techniques to the student, resulting in time and location constraints. The video demonstrations provided on the website remove such limitations; the student can view and review an expert demonstrating conducting techniques as much and as often as desired.

Demonstration is a significant part of developing music conducting technique. Online resources, such as websites, expanded access to a variety of materials including video demonstrations. BCT's website companion offered video demonstrations of specific conducting techniques linked to each book chapter. For instance, Videos V 1-1, V 1-2, and V 1-3 demonstrated the technique of "*Holding the Baton,*" "*Preparatory Position for Count One in All Meters and Preparatory Beat and Downbeat*," and "*The Release Gestures*," respectively (Appendix H, p. 284).

The more specific the research question became, such as in the case of question four, the less material I found in the analyzed documents. For instance, Syllabi S3, S5, S6, S7, and S8 did not include sufficient data to address any of the research questions, including question four— What Technological Possibilities Exist in the Teaching of Music Conducting Technique? Also, I found there was a lack of variety in the use of technologies within syllabi and conducting textbooks—most of the technology used in analyzed documents was restricted to videotaping and its application. Exceptions were described previously such as the use of a smartphone application and a textbook website companion.

Research Articles

Specificities on the Reporting of Research Articles

Because research articles are structured according to their objectives and methods, I considered the use of open coding redundant. Although I used a raw data extraction procedure for analyzing these selected research articles, just as I did for the other two types of documents, the intermediate stage of open coding, before structural coding, did not provide additional clarity. Therefore, due to the complexity of data, structural coding was the only stage of analysis that I completed.

As for document analysis procedures, discussion about the design, functionality, and technical parameters related to computer programming language of the systems described in the research articles were beyond the scope of this dissertation. I discussed computer technical issues for the sake of understanding the topics of the articles from the perspective of a conductor-educator and reader in music education.

Research articles (*N* = 12) that included the testing of various systems to aid in the learning of conducting gestural techniques were analyzed to help answer research question four. (See Table 10 for summarized results.) I organized the documents using two sub-headings from the literature review chapter: *Virtual-Robotic Orchestras and Conductors* and *Computer-Based Conducting Analytical Systems*. The features and applications of the systems reported in the articles intersect these categories. Thus, these subheadings highlight the most relevant facets of the article while also serving organizational purposes. I also added graphics, drawings, and figures extracted from each article which visually reenforced and illustrated the text. I believe that including visual information, when available in the article, is a powerful mechanism of synthesizing an array of data contained in such complex article types.

Research Question Four: What Technological Possibilities Exist in the Teaching of Music Conducting Technique?

Syllabi and conducting textbooks did not have enough information that addressed research question four: *What Technological Possibilities Exist in the Teaching of Music Conducting Technique?* Perhaps the nature of such documents which are grounded in pedagogical and teaching specific goals that are not reflective of research toward technological developments, limited data regarding the research question. Only research articles provided substantial data from which research question four could be addressed. Results are integrated and summarized in Table 10.

Table 10

Content Summary of Research Articles

Article/ Author(s)	Technology	Description
Sarasúa, Á., Urbano, J., & Gómez, E. (2019).	Mapping by observation Building a user-tailored music conducting system from spontaneous movements	"We propose a Digital Music Instrument (DMI) based on the conductor metaphor that allows to control tempo and dynamics and adapts its mapping specifically for each user by observing spontaneous conducting movements (i.e., movements performed on top of fixed music without any instructions). We refer to this as mapping by observation given that, even though the system is trained specifically for each user, this training is not done explicitly and consciously by the user. More specifically, the system adapts its mapping based on the tendency of the user to anticipate or fall behind the beat and observing the Motion Capture descriptors that best correlate to loudness during spontaneous conducting." (p. 1)
Carthen, C., Colby, J., Kelley, R., & Harris, Jr., F. (2018)	*Music in a Universal Sound Environment* (MUSE), a system for gesture recognition in the domain of musical conducting	"Our system captures conductors' musical gestures to drive a MIDI-based music generation system allowing a human user to conduct a fully synthetic orchestra ... We describe how our system facilitates learning through an intuitive graphical interface and describe how we utilized techniques from machine learning to process inputs from a Leap Motion sensor which estimates the beats patterns of a conductor through interpreting hand motions. The system consists of a presentation layer that shows information to the user, a midi processor for manipulating the musical output of the system, and a pattern recognition layer where all codes for detecting conducting patterns is placed. MUSE allows users to control the tempo of a virtual orchestra through basic conducting patterns used by conductors in real time … Also, MUSE allows a user to record their performance. When a user goes to select this recorded file again for playback, the user's recording will be played back in the same fashion as before. This functionality could be used as feedback to give the user insight on how well they are doing with their conducting." (p. 1)
Orman, E., Price, H., &	An augmented immersive	"Acquiring nonverbal skills necessary to appropriately communicate and educate members of

Russel, C. (2017)	Virtual Reality Learning Environment (VRLE) to enhance music conducting skills	performing ensembles is essential for wind band conductors. Virtual reality learning environments (VRLEs) provide a unique setting for developing these proficiencies. For this feasibility study, we used an augmented immersive VRLE to enhance eye contact, torso movement, and gestures of novice wind band conductors. Ten undergraduates randomly assigned to no VRLE (*n* = 3), VRLE with head tracking (*n* = 4), or VRLE without (*n* = 3) head tracking received eight treatment sessions over a 4-week period. While participants conducted a live ensemble, their eye contact, torso movements, and gestures were measured. A comparison of pretest and posttest scores showed that students using the augmented immersive VRLE with head tracking demonstrated greater conducting skill improvement than those not using virtual reality." (p. 24)
Cosentino, S., Sugita, Y., Zecca, M., Sessa, S., Lin, Z., Petersen, K., Ishii, H., & Kakanishi, T (2012)	Music conductor gesture recognition by using inertial measurement system for human-robot musical interaction	"In this paper, we describe a human gesture recognition system developed to enable a robot instrument player to recognize the variations in tempo and in articulation dictated by a conductor's movements and accordingly adapt its performance. The enhanced interaction ability would allow the partner musicians, as well as the conductor, to better appreciate a joint musical performance, because of the complete naturalness of the interaction. In addition, the possibility for the robot to change its performance parameters according to the conductor directions, thus being synchronized with all the other human musicians, would lead to an improvement in the overall musical performance." (p. 1)
Carôt, A., & Schuller, G. (2011).	A telematic visual-conducting system	"This application requires an audio coder providing sufficient compression to avoid overloading a connection and delay jitter, and having a very low encoding/decoding delay. Often it is also desirable to have a visual connection, particularly for a conductor of an orchestra. But a parallel video connection often overloads a low delay connection, and usually also leads to more jitter and delay in the audio connection. Hence our approach is to design a special conductor transmission scheme, using a standard computer mouse, for this purpose. We found that the data from this transmission scheme can easily be integrated in the audio data stream without affecting

		jitter and delay. Experiments showed that, depending on the tempo of the music, the conductor and the orchestra could tolerate round trip times of about 75 to 150 ms." (p. 1)
Sarasúa, A., Caramiaux, B., & Tanaka, A. (2016)	Machine learning of personal gesture variation in music conducting; a system that learns expressive and idiosyncratic gesture variations for gesture-based interaction	"The system is used as an interaction technique in a music conducting scenario where gesture variations drive music articulation of a synthesized melody. A simple model based on Gaussian Mixture Modeling is used to allow the user to configure the system by providing variation examples. The system's performance and the influence of user musical expertise is evaluated in this user study, which shows that the model is able to learn idiosyncratic variations that allow users to control articulation, with better performance for users with musical expertise." (p. 1)
Toh, W., Chao, W., & Chen, S. (2013).	An interactive conducting system using Kinect	"In this paper, we propose a real-time interactive conducting system using Microsoft Kinect. The proposed system overcomes the limitation that Kinect is usually designed for large body movements; hence, delicate conducting signals can be correctly recognized without referencing any prior knowledge. The system was evaluated by conductors of all skill levels and had a high level of accuracy and low latency." (p. 1)
Chin-Shyurng, F., Lee, S., & W, M. (2019)	Real-time musical conducting gesture recognition based on a dynamic time warping classifier using a single-depth camera	"We used a single-depth camera to capture image inputs and establish a real-time dynamic gesture recognition system. The Kinect software development kit created a skeleton model by capturing the palm position. Different palm gestures were collected to develop training templates for musical conducting. The dynamic time warping algorithm was applied to recognize the different conducting gestures at various conducting speeds, thereby achieving real-time dynamic musical conducting gesture recognition." (p. 1)
Schramm, R., Jung, C., & Miranda, E. (2015)	Dynamic Time Warping (DTW) for music conducting	"This paper presents a tool to aid the study of basic conducting gestures, also known as meter-mimicking gestures, performed by beginners. It is based on the automatic detection of musical metrics and their subdivisions by analysis of hand gestures. Musical metrics are represented by visual conducting patterns performed by hands, which are tracked using an

	gestures evaluation	RGB-D camera. These patterns are recognized and evaluated using a probabilistic framework based on dynamic time warping (DTW). There are two main contributions in this work. Firstly, a new metric is proposed for the DTW, allowing better alignment between two gesture movements without the use of explicit maxima local points. Secondly, the time precision of the conducting gesture is extracted directly from the warping path and its accuracy is evaluated by a confidence measure. Experimental results indicate that the classification scheme represents an improvement over other existing related approaches." (p. 243)
Sarasúa, A., & Guaus, E. (2014)	Dynamics in music conducting: A computational comparative study among subjects	"The goal of this study is to analyze, using simple motion capture descriptors, how different subjects move when asked to conduct on top of classical music excerpts, focusing on the influence of the dynamics in the performance. Twenty-five subjects were asked to conduct on top of three classical music fragments while listening to them and recorded with a commercial depth-sense camera. The results of different linear regression models with motion capture descriptors as explanatory variables show that, by studying how descriptors correlate to loudness differs among subjects, different tendencies can be found and exploited to design models that better adjust to users' expectations." (p. 195)
Armitage, J., Bakanas, P., Balmer, J., Halpin, P., Hudspeth, K., & Ng, K. (2013)	*mConduct*: A multi-sensor interface for the capture and analysis of conducting gesture	"The aim of this project is to capture and analyse the hand gestures of conducting in order to provide real-time, interactive multimodal feedback in a number of application contexts including visualization. This paper presents the design and development of the interface involving hardware sensors and software analysis modules and discusses the application of visualization for conducting." (p. 229)
Schnell, N., Bevilacqua, F., Rasamimana, N., Blois, J., Guedy, F., & Flety, E. (2011)	"MO"- gestural control and re-embodiment of recorded sound and music	"We are presenting a set of applications that have been realized with the MO modular wireless motion capture device and a set of software components integrated into Max/MSP. These applications, created in the context of artistic projects, music pedagogy, and research, allow for the gestural re-embodiment of recorded sound and music. They demonstrate a large variety of different "playing techniques" in musical performance using wireless motion sensor modules in conjunction with gesture

	analysis and real-time audio processing components." (p. 535)

Virtual-Robotic Orchestras and Conductors

The authors of studies that I analyzed in this category investigated conducting gestures applied to the control of virtual orchestras or robotic musicians using generative music—not performed, but artificially created by a system (mostly in Music Instrument Digital Interface–MIDI format). Gestural controlling systems emulate some aspect of tempo control, volume control, instrument emphasis, and pattern-changing beats recognition. Some characteristics shared by interfaces using virtual orchestras were: (a) they are controlled using gestures that resemble those of a real conductor, (b) the control consists of the modification of an existing musical piece—usually by controlling its tempo and dynamics, and (c) the interaction occurs in real time, with the user being able to hear the effects of their gestures on the musical outcome. In this category, I analyzed articles whose authors experimented with technologies that partially substitute for the conductor-musician direct interaction with computer capturing and consequent controlling of conducting gestures during music performance. Details on how these authors handled these parameters are discussed next.

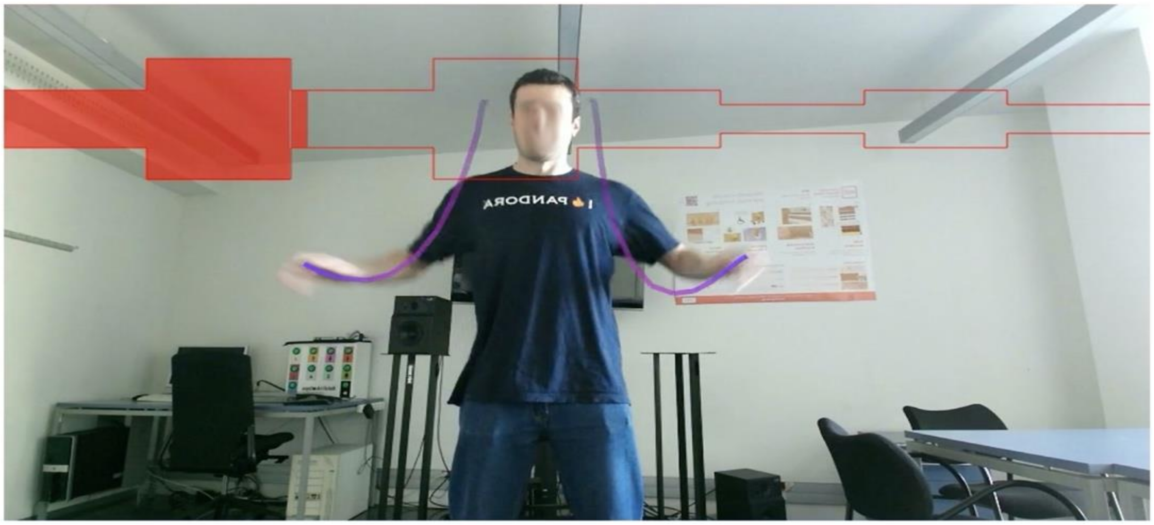
Interface metaphors is a way for humans to interact with the computer that resembles a known activity, giving instantaneous intuition about how the interaction works. A form of interface used in Digital Musical Instruments (DMIs) is the conductor-orchestra metaphor, where the digital orchestra is considered as an instrument controlled by the movements of the user. Sarasúa et al. (2019) evaluated their DMI system in an experiment with participants who did not receive instructions and, instead, were allowed to discover the system by playing it. Users controlled the loudness and tempo of a musical piece using body movements captured by a motion capture device which tracked the position of several body joints. The system controlled the tempo of the performance by capturing the change in movement direction, triggering beats in changes from downward to upward hand movement. Loudness was controlled by means of the gesture size. When a beat was detected, the gesture size was computed as the cumulative distance traveled by the hand where the beat has been detected since the detection of the previous beat.

Figure 1

Excerpt From Beethoven's 9th Symphony Used in the Sarasúa et al. (2019) Experiment (p. 6)

Figure 2

Sarasúa et al. (2019) Visualization of the Performance Task (p. 8)



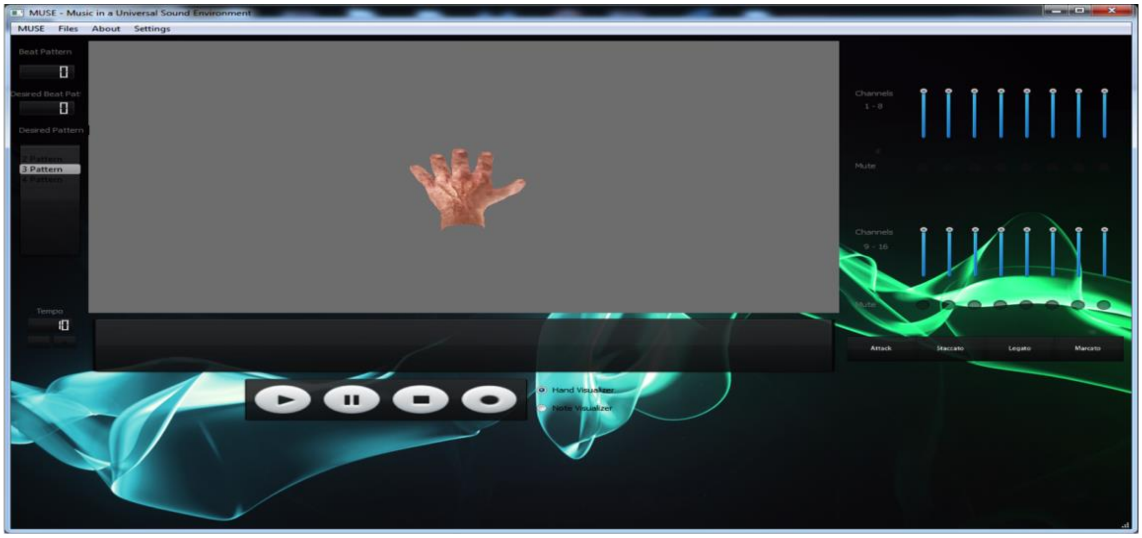
Note. The red parallel lines illustrate the target loudness of each measure of music.

Results indicated that the system automatically learned its mapping from users' movements both in terms of providing an intuitive control over loudness and beat timing, thus the use of the phrase *mapping by observation*. The use of technology in studies such as these anticipate a possible future where a digital orchestra could be an actual instrument available for students to practice their basic conducting skills. This would allow for additional student-teacher interaction time and accelerate the development of more complex and subtle conducting techniques.

Carthen et al. (2018)'s Music in a Universal Sound Environment (MUSE) system was designed to help students learn basic conducting patterns. This application provided a method to keep track of a user's conducting patterns and record their movements. MUSE tested several conducting teaching features such as save and record performances, alter the playing style of music, choose different conducting patterns, select instruments, and control music volume and tempo in a MIDI source output. The user was also able to view notes changing through time, providing a visual representation of the music. Although the feedback from MUSE can be impacted by inaccuracies from the limited range and sensitivity of the sensor, the algorithm developed for the system perceived the conducting patterns and provided the user with feedback. The objective of this system was not to replace the conducting teacher, but to offer a technological extension for the training and feedback when the presence of an instructor was not possible.

Figure 3

Sample Screenshot of MUSE That Demonstrates the Graphical User Interface (GUI) (p. 4)



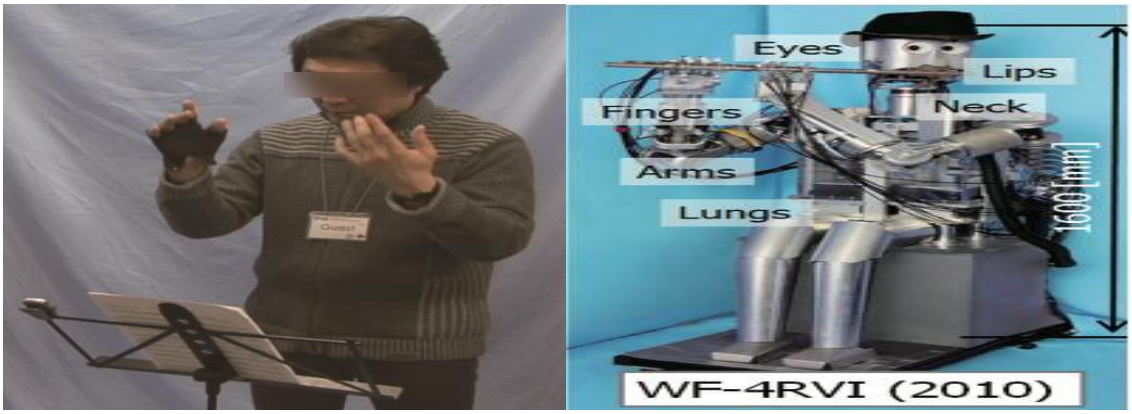
Note: As the song plays, the user may provide gestural input via a Leap Motion controller to guide musical playback. Also, they can alter the performance or even the volume of the instruments which are provided as controls in the GUI. MUSE has components for choosing specific models of conducting and visualization as well as opening MIDI files.

Part of the preparation necessary for novice conductors that deals with music ensembles is acquiring nonverbal skills necessary to communicate and educate ensemble members. Virtual Reality Learning Environments (VRLEs) have the potential to provide a nontraditional setting for developing these proficiencies. Orman et al. (2017) tested VRLE with and without the use of head tracking. Results indicated that head tracking might be a valid technological asset for the training of nonverbal communication, particularly for the development of eye contact, torso movement, and entrance cuing gestures because “head tracking enhances reality by allowing the view to change naturally as one looks in different directions” (p. 32). It is important for conducting instructors to recognize the existence of such technology and its potential as pedagogical tools.

Cosentino et al. (2012) described a system that enabled a musical instrument player anthropomorphic robot, the *Waseda Flutist Robot WF-4RVI*, to recognize musical information contained in a conductor’s hands motion so that it could adapt its performance synchronically. The system used movement sensors attached to a glove that remotely transmitted gestural information that was interpreted and played by the robotic musician. The focus was on a minimum set of motion patterns, the beat, and two distinct musical articulations, *legato* and *marcato*. The robot mechanically simulated the design of the lips and the tonguing mechanism which are fundamental for techniques to reproduce musical articulation. The final discrimination results showed a correct discrimination rate of 90.1% for articulation. In future scenarios, the authors envision a music conducting teaching setting in which a robotic lab orchestra would be available for practicing with no need for live musicians.

Figure 4

Conductor (left) and Waseda Flutist Robot (right) (pp. 1-2)

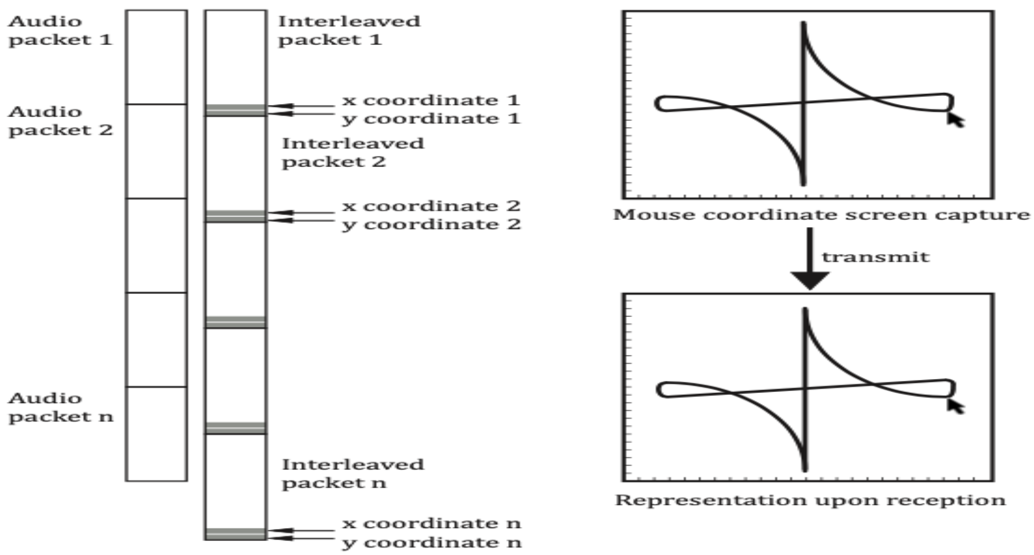


Advances in networking technology (higher bit rates and lower transmission latencies) have enabled new applications where musicians can play together remotely over the Internet. Carôt and Schuller's (2011) study included *Soundjack,* an alternative way to remotely conduct, using a computer mouse to capture conducting data and transmit it synchronically over a regular commercial network. The authors explained that home consumer networks are not able to carry uncompressed video streams. Thus, the *Soundjack* project used low delay audio compression algorithms which made possible the transmission of a high-quality audio stream containing conducting information. In this case, the transmission and representation of the conductor's timing rather than their gestures.

The authors' idea was that conductors could use a conventional computer mouse as a replacement for a real baton. The operating system would poll the actual moving mouse coordinates and subsequently interweave the x and y coordinates with the audio stream packets. Upon reception, the data were extracted, then the audio was played back, and the remote host's mouse was updated with the received coordinates. The receiving mouse pointer was replaced with an appropriate image. For example, using a musical conducting pattern of 4/4 time, the conductor controls the mouse whose coordinates were captured and instantly added to the current audio stream packet. On the receiving musician's end, the original mouse movement was reconstructed to use it as time reference, so the receiving musicians performed according to the visualized time mouse data.

Figure 5

Illustration of Carôt and Schuller's (2011) System Technical Concept (p. 3)

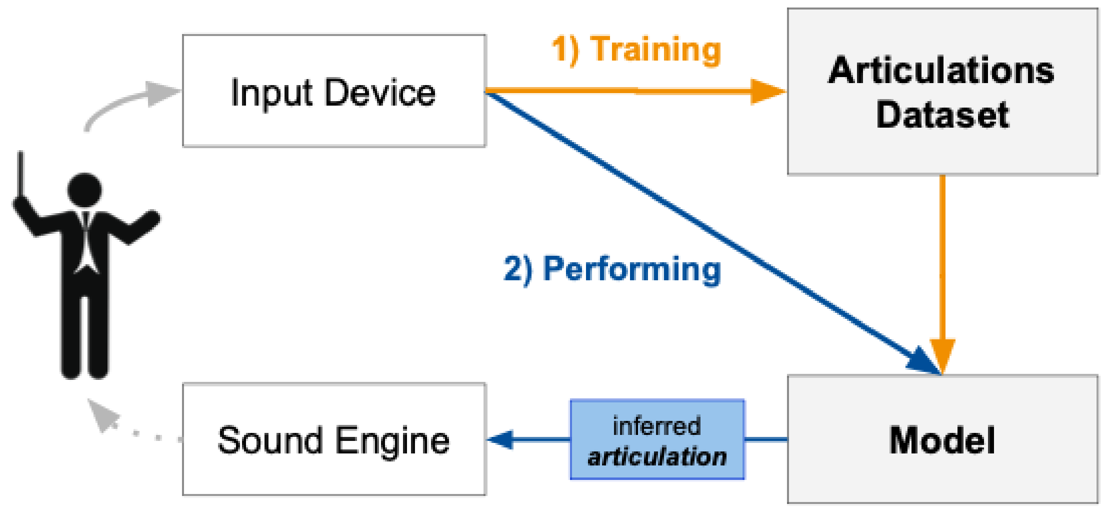


Carôt and Schuller's (2011) study consisted of three test connections established between three musicians (two violins and one cello) and a conductor. The authors reported that participants found it strange to work with a computer mouse instead of a real conductor, but they agreed on the fact that it worked for the performed music. At an average performance tempo (90 bpm to 120 bpm), musicians considered the experiment valid unless the one-way latency was above 50 ms, resulting in a round-trip-latency (RTL) of 100 ms. These results correspond to how musicians perform with a conductor in actual performance settings, meaning the latency threshold depends on the ability to think and synchronize ahead of time as musicians do in ensemble settings. For conducting instructors and pedagogues, the results of this study suggest that musicians are adaptable and can incorporate new technologies and ways of musical interactions. Can conducting teachers incorporate and adapt new technologies similar to this into their pedagogy?

Sarasúa et al. (2016) evaluated if gestural articulations could be learned by a machine and if those gestures could be used to control music by varying users' gestures. The authors tested music articulation input by using a computer mouse in a continuum variation from totally *legato* to totally *staccato*. The system's inferred articulation from the mouse input then controlled the way a synthesized melody was rendered. According to the results, the model succeeded at providing control over articulation from the users' perspective. Despite several technical limitations such as the test of a single gesture at a fixed tempo with an artificial and extraneous input method (i.e., a mouse), this technology represents a step toward the construction of a virtual orchestra that could be controlled by conducting students in the future. The ultimate pedagogical tool would be the creation of a responsive instrument—a virtual orchestra for the student to practice their conducting technique.

Figure 6

Sarasúa et al. (2016) System Diagram (p. 3)



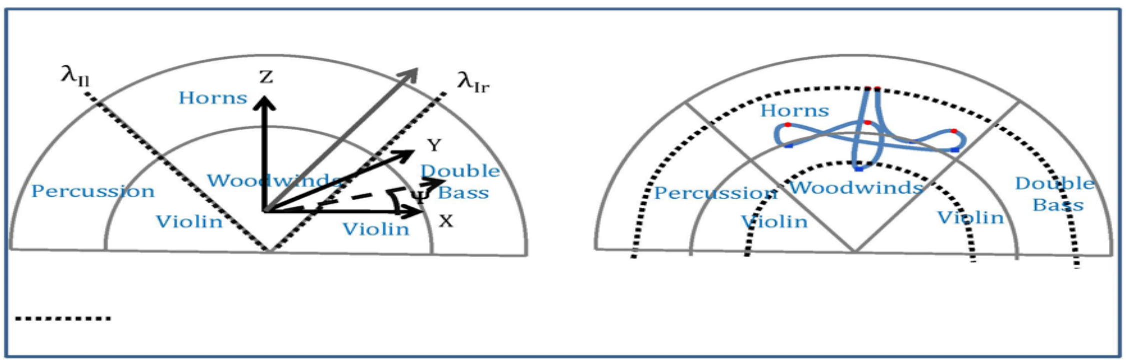
Note: During training, the user teaches the system how they embody different articulations. The model estimates the inferred articulation from gesture dynamic variations, driving the sound synthesis.

In another article, the objective of Toh et al. (2013)'s experiment was to develop an interactive conducting system using *Microsoft Kinect* to recognize fine and complex conducting hand gestures. The system tracked seven important body joints for conducting. They were right wrist, right shoulder, head, center of shoulders, spine, left shoulder, and left hand. The data (termed *conducting data*) received from *Kinect* were then interpreted, which resulted in an adjustment of the performance of the virtual orchestra. Considering the multiple conducting tasks used in the study, it was worthy of the detailed examination that follows.

The system emphasized the extraction of four types of conducting commands: start and stop gesture recognition, tempo control, volume adjustment, and instrument emphasis. While the conductor was conducting, Cartesian coordinates of the conductor's head and hand (i.e., x, y, z) were tracked in real time. The instrument emphasis module employed both horizontal and vertical conducting trajectories, which the authors named *tilt mapping* and *z-axis mapping*. In tilt mapping, the instruments were set in a semicircle arrangement as they usually are in a real orchestra setting. Thresholds divided the virtual orchestra into three horizontal sections: left (percussion and violin), right (double bass and cello), and middle (horns and woodwinds). The *Z-axis mapping* detected multi-row instrument sections. The depth value (z-axis value) captured by *Kinect* was used to identify the specific section of instruments of the vertical orchestra plan. The instrument emphasis module increased the level of reality of the system in relation to others who did not have this feature.

Figure 7

Mapping Process in Instrument Emphasis Module, Tilt Mapping (left), and A-axis Mapping (right) (p. 4)



To evaluate the ability of the system to control music, the authors focused on how accurately the system could interpret user commands. The authors examined the performance of this system for response time, beat pattern recognition, instrument emphasis and volume recognition, and user satisfaction. The validating measurements in the study were *precision* and *recall*. Precision was the percentage of gesturers that were precisely recognized, and recall was the percentage of the gestures correctly recognized.

Results demonstrated that the recognition rates for professional conductors were lower than those with no experience. The authors argued that conducting systems have difficulty in interpreting professional conductors since they usually simultaneously deliver several delicate signals. That was interesting speculation because experience appeared to negatively impact the conducting systems' performance.

For the instrument emphasis and volume recognition metric, users were requested to tune the volume in specific instrument sections at certain times. This volume adjustment test examined whether the output of the system coincided with their actions. Precision was denoted by the accuracy of volume change in specific sections (e.g., violin volume up or down). Except for the percussion and horn sections, the precision and recall rates were 100%. The researchers suggested that the percussion and horn sections were those most distant from the left wrist. Therefore, for some users with shorter arms, it would be difficult to give a signal for those two sections. The horn section also encountered overlapping problems (i.e., conducting gestures of the hands overlapped with other parts of the body). Lastly, satisfaction results, using a 1 to 5 scale, showed that the system response for volume was the highest (4.2) and tempo was the lowest (3.0). Scores given by professionals were lower (3.1) than non-experienced users (3.5). According to the research team, this might be because professional conductors have higher standards.

Computer-Based Conducting Analytical Systems

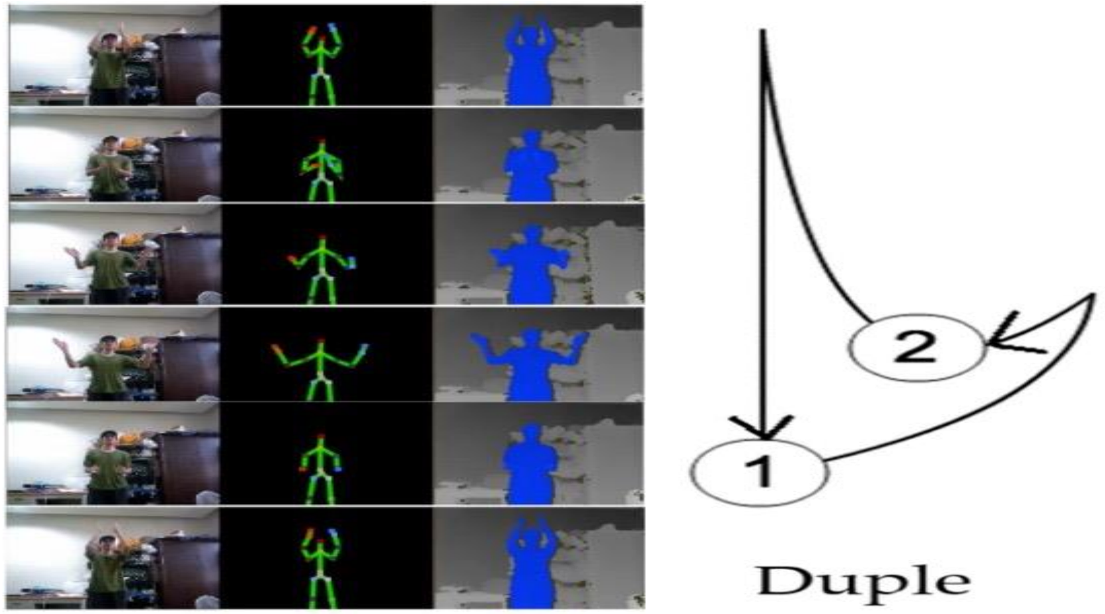
The research articles that I analyzed in this section focused on the capturing, input, recognition, and classification of conducting gestures. In general, these computer systems allowed for visual and graphical portrayal of gestures which were then analyzed as aids for the practice of gestural technique. Technologies involving how systems handled such analytical parameters are detailed next. First, the system proposed by Chin-Shyurng et al. (2019) aided the practice and training of basic conducting gestures at different tempos. Recorded gestures were compared to a template of gestures made by expert conductors. The system used a database of three music selections with basic music gestures—duple, triple, and quadruple conducting patterns in differing tempi. If the gestures were not precise, there was no match, and the system showed the imprecision of the student's hand motion. For instructors, it is interesting that such technology might extend the time and space for gestural demonstration and feedback, always limited in a traditional teaching setting.

Figure 8

Diagram of Chin-Shyurng et al. (2019)'s Proposed Method (p. 3)

Figure 9

Chin-Shyurng et al. (2019)'s Screenshots of a Single Musical Conducting Gesture Being Made While Facing the Camera (p. 11)



Note: The screenshot includes the 2D videos, a skeleton model of the musical conductor, and the depth camera video (p. 11)

Schramm et al. (2015) detailed a system that automatically recognized and analyzed hand gestures while the music student was performing the corresponding conducting patterns. The system evaluated the ability of the student to reproduce basic patterns and to keep consistent tempi. The system captured and tracked conductors' hand positions in time through a camera. After that, the system segmented the movement into periodic sections and classified them. Gesture recognition was performed by comparing the sample captured against templates obtained in the training stage (e.g., the teacher performed each movement once). Given a specific conducting pattern, the goal of the system was to classify the pattern as duple, triple, quadruple, or none (in the case of a badly performed gesture).

The second goal of the system was to check for time beating, or the temporal position of each beat, and report on the timing accuracy of the gesture. Results indicated 94% accuracy for conducting pattern detection and 90.63% for time accuracy. The system simulated a situation where the student could use this tool to take the teacher's gestural demonstration home to practice the learning of meter-mimicking patterns and steady time beating.

Figure 10

Schramm et al. (2015)'s Visualization of the Three Meter-Mimicking Patterns Captured Using Duple, Triple, and Quadruple Patterns (p. 244)

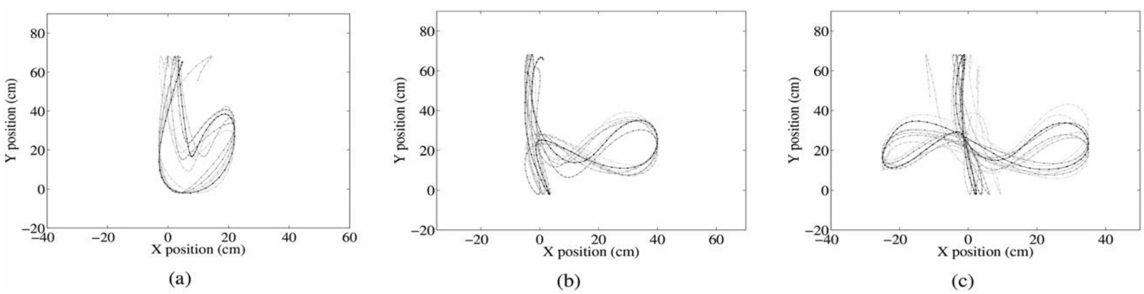
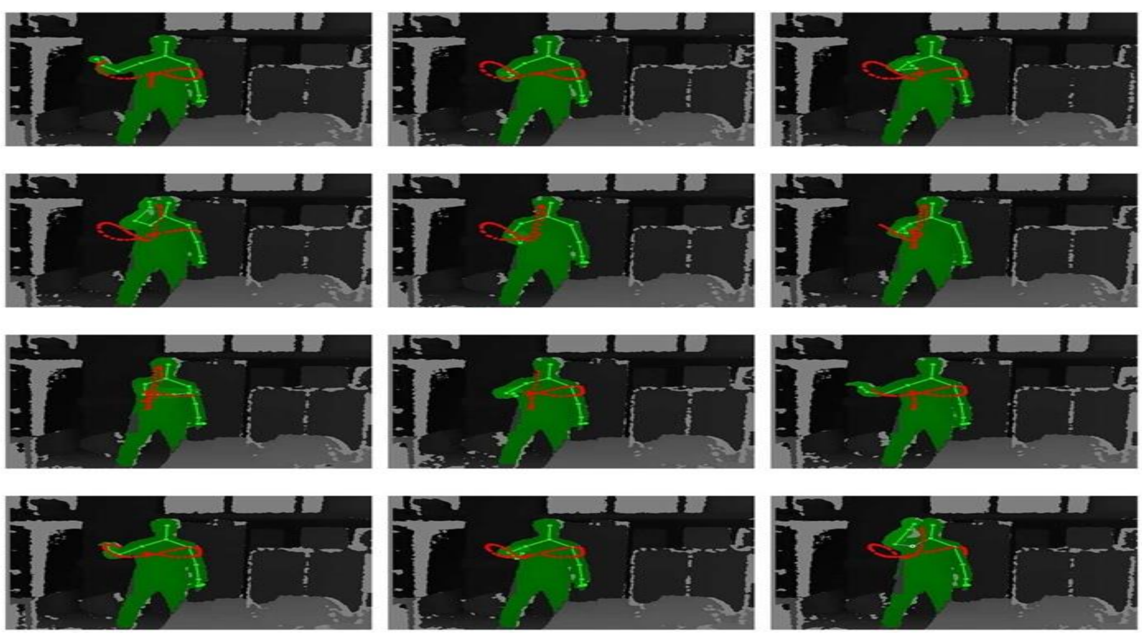


Figure 11

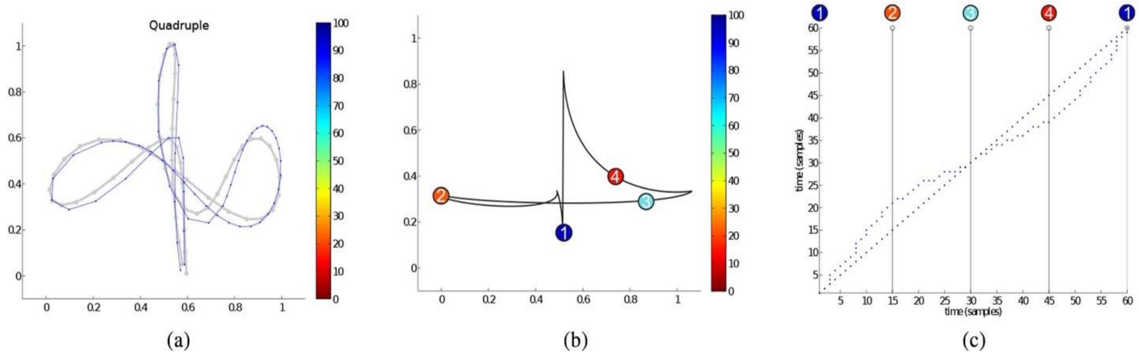
Schramm et al. (2015)'s Frame Sequence Captured by the Camera (p. 244)



Note. The sequence of red points shows the hand tracking along the path of a quadruple gesture pattern**.**

Figure 12

Schramm et al. (2015)'s System Feedback (p. 253)



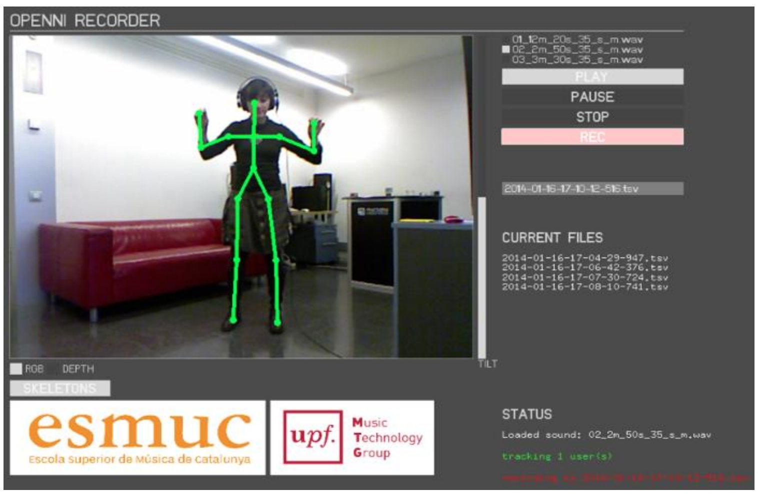
Note. (a) Spatial difference between the meter-mimicking template (gray) and the gesture being analyzed (blue). Color represents the confidence measure. (b) Colors in each circle represent the beat time accuracy confidence. (c) Time misalignment, from the Dynamic Time Warping (DTM) path, between the gesture (blue) and the template (red).

Sarasúa and Guaus (2014) investigated the correlation between a conductor's movements and ensemble dynamics. They inverted the role of the conductor in which the users reacted to the music instead of influencing the performance with conducting gestures. Seventeen participants were asked to conduct fragments of pre-recorded orchestral music in multi-modal format, including audio-only, multi-perspective video, and aligned score. User's spontaneous body response to the music was recorded and analyzed through a skeletal tracking system using 15 joints corresponding to head, neck, torso, shoulders, elbows, hands, hips, knees, and feet.

The authors' objective was to investigate how these descriptors could be used in designing a system for virtual orchestra conducting where the user can control the expressiveness of the performance. Results suggested that it is difficult to obtain a linear model that generalizes to all subjects. Two main responses were clustered. Most users used movements with higher amplitudes, and some just raised their hands higher. A clear influence of the musical background on the conducting style (in terms of loudness) was not found. The results of this study suggest that due to the complexity of music conducting, the development of a fully functional virtual orchestra as a pedagogical tool is a work in progress.

Figure 13

Sarasúa and Guaus (2014b)'s Motion-Capture Recorder (p. 196)



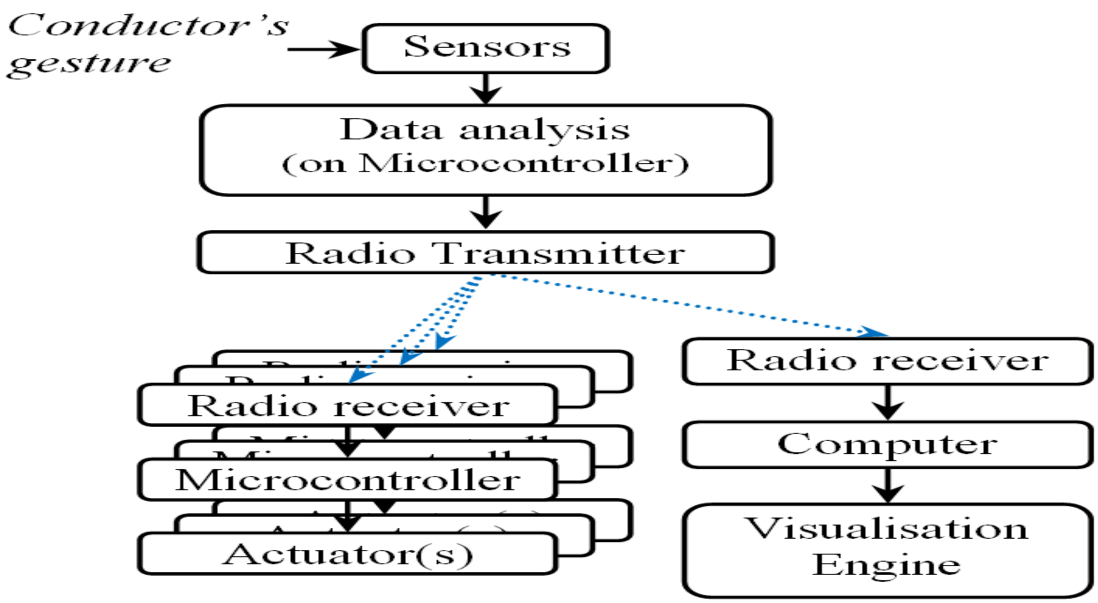
Armitage (2013) described the *mConduct*, a system where several hardware sensors attached to a baton and software capable of detecting and analyzing changes in motion provided a representation of the baton's movement. The system offered multimodal feedback including visualization, sonification, and vibrotactile response. The researchers tested a technological aid for self-assessment on students' development of gestural basic technique. The authors explained further:

> The visuals created by *mConduct* can be used to summarize a conductor's performance. Both conducting patterns and deviations from the normal conducting movements are represented … The project is particularly interested in visualization strategies that emphasizes and highlights differences in conducting

gesture to be able to show different expressions and interpretations … The overall intention of the visualization is to create a three-dimensional sculpture of the user's overall gesture (pp. 232-234).

Figure 14

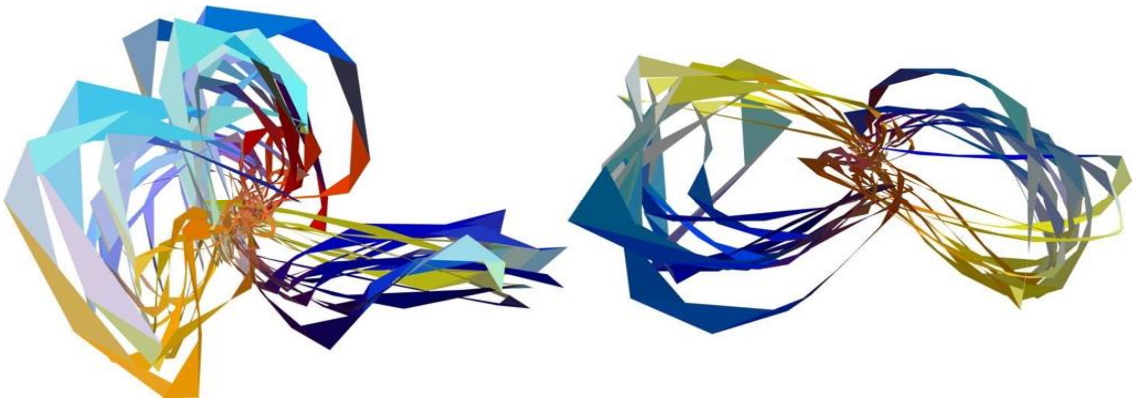
Armitage (2013)'s Overall System Architecture (p. 233)



Armitage (2013) created a 3D graphical sculpture that encompassed musical parameters such as structure, expression, tempo, and time signature (see Figure 16). The shape of the sculpture created a visual distinction between the different time signatures. The number of distinct 'loops' visualized was congruent with the number of beats per measure. The color mapping data showed clusters of color at the same position on different measures. The distribution of color intensity suggested the user's gestural accuracy and consistency.

Figure 15

Visualizations for a Sequence of Gesture in 3/4 Time (left) and 2/4 Time (right) (p. 233)

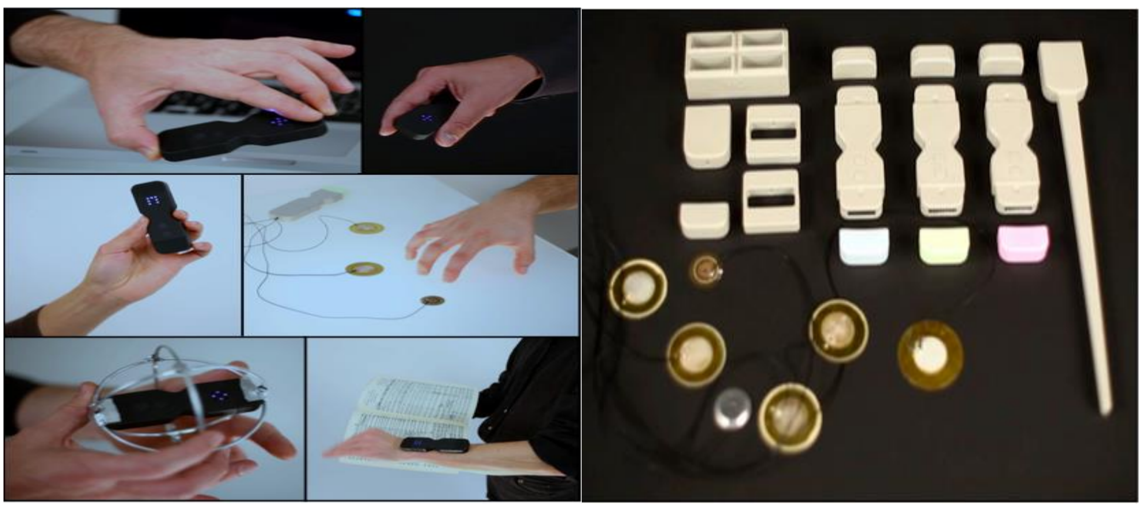


The authors highlighted three major implications for conducting teachers regarding the use of collected digital conducting data for visualizations and analysis. First, the use of visuals helps build mental models by directing attention to important information and organizing data in a meaningful way. Together with live audio, they provide an enhanced mental model of the performance elements including expression, tempo, and time signature. Second, the visualization of gestures can also be used for comparative analysis. The images formed from the visualization can be stored and then compared. This can be used for technology-enhanced learning such that users (a) can evaluate their consistency by comparing visuals from a series of performances of the same piece, (b) track their development by looking at visuals of their conducting over time, and (c) compare the visual of their performance to others in order to study differences in techniques and interpretations. Finally, the system might benefit cultural heritage through performance preservation. Future musicians can retrieve the visualization data and discover how previous conductors shaped a piece.

Schnell et al. (2011) presented a sensor that in conjunction with software and accessories offered performance and analytical scenarios that might fit conducting instructors' pedagogical goals including virtual orchestra conducting, analysis and recognition of gestures, and interactive rendering and transformation of recorded sounds. Attached to a baton of LED lights, the audio processing components provided the re-embodiment of recorded sounds and music by gestures and movements. For gestural analysis, the authors explained that a set of tools enabled automatic extraction of audio as well as graphical visualization and editing.

Figure 16

Schnell et al. (2011)'s MO Modular Wireless Sensor Device Used in Different Playing Scenarios (left), and Device with Different Accessories (right) (p. 535)



Schnell et al. (2011) explored the wireless electronic manipulation of sound, with no video features involved. Furthermore, although the images in figure 17 helped to picture the application of the sensor on conducting pedagogy, no further explanation was provided in the article and many questions were left unanswered. For example, what 'extraction of audio descriptors and segmentation' means, or how was the set up for graphical visualization and editing of sound done? Nevertheless, conducting instructors should familiarize themselves with these studies to better inform their pedagogical choices involving the use of technology as teaching tools.

Chapter Five

Discussion

I conducted this dissertation to better understand the relationship between technology and the teaching of music conducting. I sought to provide conducting teacher educators with information about the use of technology as pedagogical tools in the teaching of conducting. Music conducting syllabi, conducting textbooks, and research articles were purposefully selected to collect information about how conducting teachers and pedagogues might be incorporating technology into their teaching. I also intended to illuminate how the development and use of technological tools by researchers are possibly being perceived and utilized by conducting teachers and pedagogues.

The purpose of this dissertation was to review, analyze, synthesize, and interpret the previously described documents to illuminate technological developments that might help inform best pedagogical practices in the teaching of music conducting. To contextualize the research topic, I provided an introduction about technology and music education (Chapter 1) and completed a literature review about technology and the teaching of music conducting (Chapter 2). Four research questions emerged from the literature and guided this study: (1) How has technology been used recently to aid in the teaching of conducting? (2) What is the role of technology in the context of conducting pedagogy? (3) Given that conducting is a performative act, how can it be developed through technological means? (4) What technological possibilities exist in the teaching of music conducting technique? I employed a document analysis with a constant comparative approach when analyzing data (Chapter 3). To help answer my research questions, fourteen basic conducting course syllabi, five conducting textbooks, and twelve research articles were selected and analyzed (Chapter 4).

Synthesis of Findings

Technology Use in the Teaching of Conducting (Research Question 1)

The first research question was designed to investigate the use of technology as an aid in the teaching of music conducting. Themes that emerged were video recordings for self-evaluation and instructors' assessments about conducting gestures, audio recording for audiation and comparative analysis, and the use of the digital platforms as Learning Management Systems (LMS). The findings of my constant comparative analysis indicated few references to aspects of Technological Pedagogical Content Knowledge (TPACK) about the teaching/learning of gestural technique or conducting skills in the syllabi and textbooks I analyzed. There were exceptions, as three documents fulfilled some TPACK postulates. One syllabus included the mandate to acquire a technology sports application applicable to the analysis of conducting gestures. *Conducting: A Hands-On Approach* (Maiello, 1996) included a CD in which tracks were linked to specific exercises addressing targeted conducting skills. Furthermore, *Basic Conducting Technique* (Labuta & Mathews, 2018) (BCT) incorporated the use of a companion website with various extra materials. I highlighted the insertion of model videos including the demonstration of conducting gestures, which were detailed and specified for each chapter of the textbook. This is consonant with Haning's (2016) results in which he reported that students in music teacher education programs feel more prepared to use technology in their future teaching if they were exposed to different methods of technology instruction, had more variety of faculty modeling, and technology was integrated with course work during their teacher preparation programs. BCT provides a good example on how to incorporate new technological advances such as digitalized materials in webpage format while paying tribute to the traditional content knowledge on conducting technique.

TPACK Theoretical Framework

TPACK was the theoretical orientation that I used to guide my analysis of conducting syllabi and conducting textbooks because it intersected technological, pedagogical, and content knowledge as a holistic means to integrate content-based courses with technology instruction so learners might understand the connection between content and the use of technology (Dorfman, 2016; Misha & Koehler, 2006). With this theory as a guide, I found that the authors of syllabi and conducting textbooks used videotaping most frequently as a technology resource for assessment of conducting skills. Besides videotaping, there was a lack of other TPACK orientations related to gestural technique. A notable exception was that *Basic Conducting Technique* fulfilled some TPACK guidelines, specifically related to the integration and explanation of how the website companion and its functionalities were assets to the textbook concerning the learning of conducting technique. Music conducting instructors should consider thoughtfully how to integrate technological knowledge into their music conducting curricula. *Basic Conducting Technique* provides an example on how to incorporate digital technology in conducting classrooms in a meaningful way.

I suggest that music conducting instructors consider the inclusion of a TPACK theoretical framework into their teaching strategies and music conducting courses. Music conducting students could benefit from technology knowledge being embedded in conducting courses because it has the potential to approximate learning and teaching processes of a traditional art to the technological world we live in currently. Nevertheless, as Requião (2006) defended and I agree, the emphasis should remain with the pedagogical project over the technology tool, as it stays more important to know what and how to teach conducting while finding how technology can aid the learning process.

The Role of Technology in the Context of Conducting Pedagogy (Research Question 2)

My second research question was developed to examine the role of technology in the context of conducting pedagogy. Results indicated that technology played a peripheral and complementary pedagogical role in the documents that I analyzed. Technology was used for (a) performing self and instructor assessment (i.e., video recordings), (b) video/audio professional recordings for critical listening, (c) communication between student-teacher and student-institution, (d) as classroom management systems, and (e) *a priori* knowledge to be used at the student's own discretion. Except for the use of video recordings, I did not find relevant connections between the presence of technology and conducting pedagogy.

According to Dammers (2010), experienced teachers with little technology education training initiated and designed Technology Based Music Classes (TBMCs). Consistent with his findings, *Basic Conducting Technique* (BCT) stands out from the other conducting textbooks I analyzed because its companion webpage was designed to be an integral part of the textbook, including explanations on the pedagogical value of integrating it to the written material. Thus, results indicated that it is the prerogative of conducting pedagogues to decide which and how much technology will be part of their textbooks. In the future, I expect that more music conducting pedagogues follow BCT's example, increasing the inclusion of technology-related content and instruction to their pedagogical materials, and conducting teachers to intentionally search for such novel materials, verifying the possibility to apply them to their courses. In sum, the conducting instructor continues to perform the most important role in conducting pedagogy.

Textbooks, Tradition, and Technology

Consistent with the findings of Silvey et al. (2016), *The Modern Conductor* (Green & Gibson, 2004) was one of the most used textbooks in the fourteen syllabi that I analyzed. Regarding technology use, results indicated that besides VHS tapes as extra reference materials and videorecording, no device, equipment, software, or hardware for pedagogical purposes was recommended in this textbook. In the preface of *Basic Techniques of Conducting* (Philips, 1997), the author wrote about the pedagogy of music conducting rooted in the master-apprentice tradition:

> The study of conducting is much like the study of an instrument or voice—it is a psychomotor skill acquired over time. As such, the skill of conducting cannot be learned from a textbook. This text can only serve as a guide; your class instructor is the most important source of help (Phillips, 1997).

I speculate that the authors of the textbooks *The Modern Conductor* (Green & Gibson, 2004) and *Basic Techniques of Conducting* (Phillips, 1997) exemplify the force of tradition in music conducting pedagogy. For instance, TMC is "a college text on conducting based on the technical principals of Nicolai Malko as set forth in his *The Conductors and His Baton*" (p. i). The co-author of this more current edition is a former student of Green. In the section *Preface and Foreword to the Seventh Edition*, Gibson writes that Malko's explanations of baton technique remained the same model of decades, with only "some holes that needed to be discreetly filled in" (p. xvii). Thus, in

TMC we can see a line of passing-on of traditional knowledge being carried from master to apprentice, from a present conducting pedagogue to the next generation.

Despite the pull of tradition on conducting pedagogical writing, an examination of publication years and technologies introduced in each of the five textbooks that I analyzed indicated that as the year of publication advanced, references to the use of technologies in vogue at the time of the publication also evolved. For example, BCT (2018) included internet and online resource availability with the incorporation of a webpage companion to the book. In addition, the current syllabi that I analyzed reinforced this trend regarding the introduction of online resources into the materials utilized in class as well. The analysis of this sample of documents suggested that the relationship between traditional teaching and the introduction of new digital technologies in the realm of music conducting pedagogy is a topic that evolves with the advent of new and more advanced technologies.

The Development of Conducting Through Technological Means (Research Question 3)

In answering the third research question, “Given that conducting is a performative act, how can it be developed through technological means?,” I identified that authors of some syllabi used online resources to expand opportunities for teacher-student interaction. The most frequently used technology was the posting of students’ conducting videos after they had received teachers’ feedback. Also, the online posting of professional performances as video demonstrations for students to observe was frequent. Furthermore, authors of conducting textbooks offered pedagogical strategies involving videotaping (e.g., switching the sound off to study the influence of students’ conducting gestures to the ensemble performance). The use of videotaping and other materials was novel in that BCT made the material available; in this case, a companion website which included all resources into one digital site. In sum, my analysis of syllabi and textbooks suggested that technology is being used directly and indirectly in the development of undergraduates' conducting skills.

Although teachers and methods may not be changing at the same rate as digital natives' expectations because they were born in a culture of digital immersion (Herther, 2009), the syllabi and conducting textbooks that I analyzed revealed that online capabilities augmented the opportunities for teacher-student interaction in the learning process of music conducting. Alexander et al. (2012) argued that teachers need to remediate their teaching philosophies to accommodate for teaching with technology. The challenges that remain include how to bring technological developments to the center of conducting pedagogy and the actual content of music conducting courses. I suggest that conducting instructors perform intentional marketplace searches for products such as the Dartfish App (see p. 57) that might be adapted to the content of a music conducting course.

Technological Possibilities in the Teaching of Music Conducting Technique (Research Question 4)

My fourth research question addressed what technological possibilities exist in the teaching of music conducting technique. Because of the exploratory nature of this line of research, only research articles were used. Considering Morrison and Silvey's (2022) and Orman et al.'s (2017) arguments about the importance of gestures for nonverbal communication in music conducting, authors of research studies (*N* = 12) that I analyzed about conducting and technology investigated basic conducting techniques such as (a) *time/tempi keeping* (*n* = 8), (b) *beat pattern/time signature/measure mimicking* (*n* = 6), (c) *dynamics/loudness/volume control* (*n* = 3), and (d) *eye contact/torso movement/conducting leadership* (*n* = 2). A few authors experimented with more complex conducting techniques such as *articulation* (*n* = 2), *expressivity* (*n* = 2), *music structure* (*n* = 1), and *instrumental emphasis* (*n* = 1). I organized the findings into two sub-categories: *Virtual-Robotic Orchestras and Conductors* and *Computer-Based Conducting Analytical Systems*.

Virtual-Robotic Orchestras and Conductors

In the *Virtual-Robotic Orchestras and Conductors* category, authors investigated how conducting gestures could control virtual orchestras or robotic musicians for pedagogical purposes. They explored technologies to emulate some aspect of music conducting such as beat pattern recognition in combination with control over tempo, dynamics, articulation, and instrument emphasis. Two methods of gestural recognition and control were tested: contactless systems (i.e., distant cameras) and body-sensor systems (i.e., motion sensing devices located in users' body). Gestures were then mapped and compared to a template of pre-recorded models by computers. Characteristics shared by such interface conducting metaphors were: (a) controlling human gestures resembled those of a real conductor, (b) the control consisted of the modification of an existing musical piece in MIDI format—not performed, and (c) the interaction occurred in real time, with the user being able to hear the effects of their gestures on the musical outcome.

Bevilacqua et al. (2007) and other research teams idealized interaction paradigms where the systems were set to follow the conductor to understand conducting gestures. In their vision, interactive conducting systems could assist with technique awareness, interpretation, and expression of music. Nevertheless, interactive networked performance is still only a dream worth dreaming (Kapur et al., 2005). Although computer-based music conducting systems offered new pedagogical possibilities, my analysis of research articles indicated that a complex human activity such as teaching and learning music conducting skills presents extensive technological challenges to overcome until widespread use of these system prototypes occur. Music conducting educators should consider keeping up to date with the literature in the area until research results in products and materials available in teaching settings.

Computer-Based Conducting Analytical Systems

Tanaka and Altavilla's (2012) idea of Music Affordance—the configuration of properties that provide a link between perception and action related to technological music interfaces—has been tested for the teaching of basic conducting techniques. Increasingly complex combinations of conducting parameters such as musical structure, expression, tempo, and time signatures were also tested (Armitage, 2013). The literature that I reviewed, and my analysis of selected articles, indicated that there are many investigators doing empirical work in this area. Technologies used were graphical Dynamic Time Warping (DTW) systems, Skeleton Tracking Systems using body sensors, motion sensing batons, and 3D in-depth cameras. Results suggested that there are several systems testing beat detection/synchronization through multimodal visual and auditory cues. Such sensors and advanced cameras measure velocity, acceleration, and orientation of gestures that inform the computer systems. The goal was to provide visualization and sonification computer feedback for assessment of gestural conducting abilities.

Computer analytical systems that use visual feedback seem to be a promising area for the teaching of conducting technique. Research findings have indicated that computers can aid the subjective feedback of the teacher by recording data and giving numerical analyses of certain gestural characteristics such as dynamics and time keeping (Sarasúa & Guaus, 2014). For instance, in the system designed by Schramm et al. (2015), graphics can clearly be spotted and visually show beats two and four as the more deviating ones out of the 4/4 pattern template in terms of spatial difference, beat time accuracy, and time. 3D graphical sculpture in the system used by Armitage (2013) allows for a sequence of conducting gestures to be portrayed in a single image. Gestures performed through time are condensed and photographed, so a user can observe several sequential conducting gestures in a single image, which allows for several gestural analysis possibilities. Well-designed and frequently used visuals can help students learn (Leavitt, 2012). Computer vision technology has the potential to present new ways to conducting teachers of discussing their students' technical development. Graphics and images might statically represent gestures with their slight deviations from conducting patterns, objectively offering feedback to students that visually reenforce teachers' orientations.

Unfortunately, no computer seems capable of matching the analytical power that is necessary for a conductor to use while conducting. The interaction between a mental sound image of the score and the sound produced by the players, used in-the-moment to develop rehearsal strategies, modify instruction, assess, and respond to students and sound stimuli, and formulate concepts of sounds, are very complex skills to perform simultaneously (Forrester, 2018; Morrison & Silvey, 2022). Nevertheless, those examples concerning visual information might point to new ways of student-teacher interaction for the discussion of conducting technique by incorporating future computer visual analysis technologies.

Study Limitations

Technology is constantly developing, evolving, and changing. In my dissertation, I chose to limit the selection of documents from 2010 – 2020. Technology used in music education settings continues to modify and replace what even a few years ago could be considered an impossibility. Some of the technological limitations that I found during my analysis of research articles might already have been overcome by authors in newer research studies. For example, the introduction of the internet fifth generation (5G) might be explored currently in the NMP research field with exciting new technological applications already underway within music conducting settings.

Besides the limited time frame of part of my document analysis, the document sampling method is also a limitation of this dissertation. The number and geographical location of the selected syllabi was limiting. For instance, syllabi from other regions of United States or even from other countries might indicate a different set of technologies that have been incorporated by conducting teachers into their classrooms. An analysis of a larger set of conducting textbooks—particularly those written more recently— would also help to illuminate the use of technology in music conducting pedagogical textbooks. In addition, although the conducting textbooks I analyzed appear as the most frequently used by collegiate band conductors in the United States (Silvey et al., 2016), the selection of textbooks by choral and orchestra conductors might contain different material. Furthermore, the publication of new editions might bring new content for the same selected textbooks. The number of available textbooks limited the collection of information and analysis. Thus, extending the sample size of selected documents, including more conducting syllabi and textbooks, would be helpful for those looking to continue this type of research.

Another limitation is the method itself. Document analysis is an indirect method of research about human behavior. Except from research articles, where the intent of the researcher is clearly stated in the manuscript, the conducting syllabi and conducting textbooks that I analyzed were not written with the specific purpose of discussing technological advances in conducting settings. Although this second-hand method served as a proxy for what a small sampling of collegiate conducting teachers believed, a survey of their feelings about the use of technology in the conducting classroom is necessary.

Considering these limitations, the results of this dissertation should not be generalized to all music conducting teacher and pedagogues. Expanding data collection efforts that include the examination of music conducting educators' experiences with technology as pedagogical tools would provide even more information from which to make recommendations and further our understanding. However, the results of this study may be used to inform future investigations and enlighten music conducting teachers about potential pedagogical choices regarding the use of technology.

Perspectives for Future Research

Analysis of research articles about current technology on conducting systems revealed that hardware, software, sensors, and other movement capturing devices, in combination with internet capacities, have not been able to permit conducting from a distance in real time, at least outside of controlled laboratory environments. Visual information cannot travel through existing media at the speed and accuracy necessary for musicians and conductors to synchronize rehearsal and performance online. Furthermore, even if visual information could be transmitted at the speed of light through long distances with zero data loss, no sensors have the capacity of performance close to the human perception system yet. Our human *synaesthetic* system, which involves all five human senses in kinesthetic empathy with the surrounding environment, have no current technological substitute (Koivuen & Wennes, 2011). Hence, the anticipatory gestural communication between conductor and musicians are compromised by technological restraints considering current technology.

In the first decade of the twenty first century, music technologists and computer program developers envisioned an almost unlimited array of possibilities for the use of technology tools in conducting teaching settings (Bevilacqua et al., 2007; Nijholt et al., 2008; Orman et al., 2007). As I wrote in chapter two of this dissertation, conducting systems—hardware-software applications that electronically attempted to emulate some aspect of music conducting gestures for the purpose of technique analysis or remote controlling of robot instruments or virtual orchestra— have been tested extensively (Ferguson & Wanderley, 2010; Nijholt et al., 2008; Shertenliebe et al., 2004). In theory, such applications could be used to rehearse technical, less creative, and non-expressive aspects of a performance, or be used to explore facets of ensemble playing in a school setting, with students being allowed to have some level of autonomy when available. Orman et al. (2007) and Nijholt et al. (2008) discussed those and other situations where these systems could aid conductor students to detect mistakes and show better ways of conducting a passage while playing along with their instrument, putting themselves at both positions simultaneously because time in front of a virtual ensemble could be almost unlimited.

Results of my analysis on research articles from 2010 to 2020 suggest that although technology developers continue to explore possibilities to substitute human-to-human interaction regarding the teaching of conducting, the unlimited possibilities did not become actual technology tools available in teaching settings so far. Although some advances can be observed in specific technologies such Dynamic Time Warping (DTW), the exploration continues restrained to controlled laboratories. More research is needed to understand better an apparent discrepancy between the development of technologies and the applicability of findings within conducting course settings.

Ansari et al. (2018) argued that the only aspect that distinguishes the capability of humans and machines on performing an assigned task is the subjective quality and performance variations in carrying out such a task. In the case of music conducting, authors of the articles that I analyzed suggested that the distance is far too great between computer capabilities and human skills. The subjective quality of brain activity and corresponding kinesthetic awareness a music conductor must perform has only been superficially demonstrated by technology developers. For example, Gillies et al. (2016) demonstrated that it is possible to teach machines to learn human tasks. By training algorithms to use high level human-machine interfaces, users could build and refine systems for real-time gestural control. Nevertheless, research on the ML concept that has been applied in music conducting situations revealed how difficult it is to teach a machine music conducting skills, insofar that only one or two basic aspects of conducting could be isolated and tested.

Considerations for Music Conducting Educators

Based on Orman et al. (2017) and Nijs (2018)'s problematization of educational technologies (see Chapter 1), I have several comments for music conducting teachers and ensemble directors. Results of my document analysis suggested that even with the testing of hardware and software adaptations to music conducting systems, research on the development of technological pedagogical tools in music conducting is in its initial stage. I could not locate studies involving pedagogical tools' application in teaching settings. Considering that for Adileh (2012), pedagogical methods to design artistically based courses effectively are not yet abundant, I would add that much less should be expected in situations involving technological tools.

Although my analysis of research articles revealed that new technologies involving music conducting were being developed and tested by multidisciplinary teams, a cross examination of these articles with conducting syllabi and textbooks indicated a disconnect between research and how conducting teachers and pedagogues might be perceiving and applying such findings in their teaching practices and pedagogical approaches. Although technology developers are looking for possibilities in the future regarding technologies as pedagogical aids in the conducting classroom, authors of the limited syllabi and textbooks that I analyzed suggested that conducting teachers and pedagogues are relying on traditional music conducting instruction to inform their pedagogical choices, with technology not at the forefront of their decision making.

The inclusion of technologies directly related to the teaching of basic conducting technique such as (a) time keeping, (b) beat pattern mimicking, and (c) dynamics control found in conducting syllabi and conducting textbooks was limited. For instance, the use of smartphone applications was an exception because most conducting syllabi did not include technological applications to facilitate the teaching of such basic conducting techniques. Considering that technology is a means to an end and can enhance pedagogy, curricula and desired outcomes should guide the selection of the technological devices used to accomplish pedagogical goals (Rudolph, 2004). In defense of music conducting teachers, the limited use of technologies as pedagogical tools found in my analysis might simply be related to a lack of availability. More inquiry is necessary to clarify the relationship between technology availability and the pedagogical choices of conducting teachers.

The lack of synchrony between research and teaching practices might involve the challenge that technology literacy poses for music conducting educators as well. As digital immigrants, teachers have adopted technology, but do not have long-term immersive exposure to it (Haning, 2016). Most of the research studies that I analyzed were authored by multi-disciplinary teams involving music, engineering, and computer programming. Technology and computer programming are complex knowledge fields, and music teachers may not have enough knowledge to understand such disciplines. Education technology relies on other disciplines to increase the efficiency and effectiveness of current practices, thus bringing pedagogical changes for the betterment of education (Ahmad & Un Nisa, 2016). As the renowned scientist and pedagogue Carl Sagan warned us, we live in a society dependent on technology, in which hardly anyone knows anything about it (1990). Perhaps music conducting teachers should collaborate more with researchers of other disciplines such as artificial intelligence and computer science to investigate pedagogical changes that could be incorporated as technological developments into conducting teaching settings.

Music conducting is a traditional activity based on human interaction that has used mostly unchanged ideologies and practices since the nineteenth century. Nevertheless, Alexander et al. (2012) suggested a change, with technology philosophy statements that focus on the teacher's stance toward values related to technology in the classroom. Therefore, if music conductor educators consider the TPACK framework as a valid teaching choice, I suggest that they use *Basic Conducting Technique* (Labuta & Mathews, 2018) as their textbook. BCT incorporates technologies about technique and pedagogical content and sets an example on how to address the tools used to teach, why to use these tools, how to situate oneself *vis-a-vis* these tools, and how to reflect upon and assess teaching with such technology methods. With regard to the future of conducting pedagogy, two roads seem apparent. One is traditional, based on the well-established passing down of conducting skills to future generations of conductors through the master-apprentice approach. A second path is where technology continues to progressively evolve, is incorporated into pedagogical materials and used by younger generations of conducting pedagogues who adapt courses and curricula accordingly.

As research involving technology and conducting continues, I believe that conducting educators should strive to stay updated with what is available regarding software, hardware, and applications that might be used in music conducting teaching settings. Meanwhile, I suggest that conducting teachers review their personal philosophy, including considering adopting the TPACK theorical framework as a guide to pedagogical choices and the construction of curricula. Lastly, I suggest that conducting teachers and pedagogues increase collaboration with technology developers to implement more research about the application of technologies in music conducting teaching settings. This way we might aggregate enough information to build a pedagogy that meaningfully incorporates technological tools to the learning process in the art of conducting.

Conclusion

I designed this dissertation to better understand the use of technologies as aids in the teaching of music conducting. When a new technology comes along in some aspect of human life, for instance, when it affects the job market such as having a machine substituting for the labor of a human being, human intelligence and inventiveness cause us to reflect on what is essentially human. Music educators should keep track of technological developments, not only to evaluate the possibility of introducing them in the classroom, but also to reflect upon what is essentially human in the learning-teaching process. The possibility of inserting and using technologies in conducting teaching practices has guided researchers to investigate more thoughtfully how students should be taught conducting. In agreement with Brader’s (2009) argument, the results of my document analysis suggested that the findings of music technologist researchers are not yet meeting the knowledge and information conducting teachers and pedagogues have according to TPACK framework. Although there are other pedagogy theoretical orientations, TPACK includes the acquisition of technology knowledge as equally important as pedagogical and content knowledge to the construction of an individual's personal teaching philosophies.

The Covid-19 pandemic temporarily paralyzed almost all social interactions, including those found in music education settings. This temporary social distancing motivated me to investigate if there is a place for technology in the teaching of music conducting that could partially substitute for the direct student-teacher interaction. My results suggest that, in the future, conducting pedagogues will integrate more physical materials such as textbooks with digital and online resources, smartphone applications, and web pages to facilitate the learning process of conducting technique. I also envision that graphical analytical systems are closer to becoming available products than virtual or robotic orchestras. Results indicated that computer technology can now detect and translate music conducting gestures into graphics and figures which then can be used for the analysis and study of conducting gestures. It might be a matter of time until some of these technologies are translated into smartphone applications for general use. Such technologies could partially substitute for the direct student-teacher interaction during the gestural analysis of conducting technique. Nevertheless, only time will tell which systems become actual products available for use in music conducting teaching settings.

Although the authors of many syllabi that I analyzed mentioned the incorporation of technology according to university policies, they lacked the integration of it to content. Conducting pedagogues should continue working towards applying online and other available technology resources to better inform the teacher-student interaction. Many university policies indicate that teachers should aim for narrowing the gap between technology developments and their practices. Therefore, conducting instructors should search for different methods of teaching, assuring students that the integration of technology within course work is beneficial to the learning process. Hopefully, we will observe an increase in technology awareness among conducting instructors concerning their teaching practices. Some of the technology found in experiments may potentially become available products applicable to the teaching of conducting skills.

Recent developments in the world of technology challenge conducting practice, pedagogy, and research. An overarching question is, "What is essentially human in teaching and learning the art and craft of music conducting, and how might technologies aid in the interaction between human beings so music conducting continues to develop and grow?" I believe that information in this dissertation will foster a debate about the use of technology as a pedagogical tool in the music conducting realm. I hope this dissertation motivates conducting teachers to learn more about the subject, and I expect that my research synthesized valuable information that contributes to the choices conducting teachers make regarding the use of technology in their teaching. The findings of this dissertation hopefully provide conducting teachers with information for constructing their own philosophy of teaching regarding music conducting and technology, and to improve the structure and content of their conducting courses.

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GLOSSARY

Algorithm: is a procedure used for solving a problem or performing a computation. Algorithms act as a precise list of instructions that conduct specified actions step by step in either hardware- or software-based routines. Algorithms are widely used throughout all areas of IT.

Articulation: may be indicated by the character of the ictus, ranging from short and sharp for Staccato, to long and fluid for Legato. Many conductors change the tension of the hands: strained muscles and rigid movements may correspond to Marcato, while relaxed hands and soft movements may correspond to Legato or Espressivo (Consentino et al., 2013).

Basic Conducting Patterns: These conducting patterns consist of ictus's or where the beat occurs typically when the conductor's hand switches in a major direction, they are three basic patterns, two bet, three beat, or four beat patterns (Carthen et al., 2018).

Conducting: is a unique gestural language which moves sequentially through a series of patterns which have both discrete and continuous elements. I would describe these elements as fitting into six categories: beat, direction, emphasis, speed, size, and placement. These six groups can be combined in different ways, and form the core of the conductor's gestural language (Marins, 2006).

Conducting Gestures: gestures that contains right arm movement, left arm movement, eye contact, breathing, and other gestures (Peng & Gerhard, 2009).

Conducting Grammar: predefined gestures with a concrete meaning (Sarasúa & Guaus, 2014).

C**omputer-based Conducting Systems**: systems that allow a user to conduct a piece of music using a digital system. Most of them are manipulated using a gestural interface (Peng & Gerhard, 2009).

Digital Content: interactive computer-generated interactive tools that motivate learning in computerized environment (McLoughlin, 2002).

Digital Musical Instrument (DMI): musical instrument that comprises a control surface that controls the parameters of a digital synthesis algorithm in real time (Ferguson & Wanderley, 2010).

Dynamic Time Warping (DTW) is an algorithm used for measuring similarities between two temporal sequences at different speeds, a method of comparing sequences of time series data, in which classifications are typically made with the k–Nearest Neighbour (k–NN) algorithm, usually based on data from accelerometers worn or used by a person. In conducting, the method is used to compare the recorded gesture of a conductor to a template of standardized gestures in a computer (O'Rourke & Madden, 2011; Chin-Shyurng et al., 2019).

Embodiment: the representation or expression of objects in a tangible and visible form (Bretan & Weinberg, 2016).

Gesture Recognition: a human-computer interaction method, a process of capture standing or classifying meaningful movements like human's hand, arm, face and head by a machine, used for educational, medical, and entertainment purposes (Kshirsagar & Annadate, 2017; Chin-shyurng et al., 2019).

"Gesture" in a gesture-fallower device context: is defined by its numerical representation produced by the capture device. Technically, this corresponds to a multidimensional data stream, which can be stored in a matrix (e.g. row corresponding to time index, and column to sensor parameters) (Bevilacqua et al., 2007).

Haptic Demonstrator: any technology that can create an experience of touch or any form of technological interaction involving touch (Rodet et al., 2005).

Hardware: includes the physical parts of a computer, such as the processor, memory modules, and the screen. The Operating System is often described as a translator; it translates the language of the hardware—binary numbers—into the language of the software—written programs—and then displays it in ways such as text, images, and sound (TheSchoolRun.com, n.d.).

Human Computer Interface (HCI): is a broad term including not only the Graphical User Interface (GUI), but also any interaction between a user and a computer system. Various interfaces have been designed and developed over the past few years, such as, Graphical User Interface (GUI), Conversational Interface Agents, Gestural Interface and so on (Peng & Gerhard, 2009).

Human Gesture Recognition (HGR): aims at distinguishing human natural motion carrying communication information, analyzing it and extracting the contained communication concepts. HGR can be used to design extremely natural human-machine interfaces, providing an easy and intuitive way of interaction between humans and automated entities (Cosentino et al., 2012).

Interface Metaphors: commonly used in interface design within Human-Computer Interaction (HCI), provide users with a way to interact with the computer that resembles a known activity, giving instantaneous knowledge or intuition about how the interaction works. (Sarasúa et al., 2019)

Jitter: Small, intermittent delays during data transfer. It is the variation on latency—the perceived delay between when a signal is transmitted and when it is received (Gao, 2009). **Kinect:** Is a motion sensing device developed by Microsoft for video games, which can track the position of several body joints. (Sarasúa et al., 2019)

Mapping: This term is used to define how the input (the movements or actions performed by the user) and output (the control parameters for the resulting sound) are connected (Sarasúa et al., 2019).

MIDI: Music Instrument Digital Interface, an alphanumeric event sequence that falls into the category of data streaming (Kapur et al., 2005; Zimmermann et al., 2008).

MIDI Musical Instruments: instruments that produce event-based data streams with temporal information which can be precisely measured for synchronization analysis amongst music players (Zimmermann et al., 2008).

Network Porridge: any prolonged and perceptually significant audio artefact caused by some aspect of the network transmission. Network porridge is highly crackly and poppy audio resulting from one or more audio frames failing to reach the destination machine in time (Kapur et al., 2005).

Robotic Musicianship: focuses on the construction of machines capable of producing sound, analyzing music, and generating music in such a way that allows them to showcase musicality and interact with human musicians (Bretan & Weinberg, 2016).

Sensors: any wave detector device capable of sensing and capturing image and movement such as cameras, accelerometers, Wii-remotes, and infrared (Peng & Gerhard, 2009).

Software: a general term used to describe a collection of computer programs, procedures, and documentation that perform some tasks on a computer system (Brader, 2009). Practical computer systems divide software systems into three major classes: system software, programming software, and application software, although the distinction is arbitrary and often blurred (diffen.com, n.d.).

Technology: means a systematic, organized application of scientific or organized knowledge to the practical work (Ahmad & Nisa, 2016)

APPENDIX A: IRB APPROVAL

IRB Determination Notice Project #2035885 Review #282885

De: MU RESEARCH ecompliance (ecompliance@missouri.edu)

Para: aa597@mail.missouri.edu

Data: sexta-feira, 16 de outubro de 2020 16:32 GMT-4

MU eCompliance

IRB Determination Notice Project #2035885 Review #282885

Project #2035885
Project Title: Music Conducting Pedagogy and Technology: A Document Analysis on Best Practices
Principal Investigator: Adamilson Abreu (MU-Student)
Primary Contact: Adamilson Abreu (MU-Student)

Dear Investigator,

The MU Institutional Review Board reviewed your application and supportive documents. It has been determined that this project does not constitute human subjects research according to the Department of Health and Human Services regulatory definitions. As such, there are no further IRB requirements.

If you have questions, please feel free to contact the MU IRB office at 573-882-3181 or email at muresearchirb@missouri.edu.

Sincerely,

MU Institutional Review Board

APPENDIX B: RAW DATA EXTRACTION PROTOCOL

Syllabi

Dissertation Topic: MUSIC CONDUCTING PEDAGOGY AND TECHNOLOGY: A DOCUMENT ANALYSIS ON BEST PRACTICES

Objective: the goal of this **DATA SELECTION PROCEDURE** is to remove all technology-related information from the original document—Syllabus, with minimum treatment possible, so the analysis process can proceed using this data in the next phase of the research analysis.

Please, read this procedure guidelines, and attached samples before your data extraction activity!

PROCEDURES

Reading: please, read the entire original document from which you will extract Raw DATA (in Annex), prior to any data extraction procedure in order to acquire familiarity with content.

Formatting: create a *Word* DOC using Times New Roman (12) saved as: RAW DATA-S12-PEER REVIEWER

Basic information: extract (cut and paste) name of the class' instructor(s), the number and name of the course (**in bold**), year and term/semester.

Structuring: extracted the content—all technology-related information from syllabus in the order it appears in the original document, including headings (**in bold),** tables, and figures.

-At the end of of each piece of information you extracted, indicate the page and paragraph number from original syllabus, i.e.: (2.3), page 2, 3rd paragraph.

Inclusion criteria:

1. Extract (cut and paste) and place in your Raw DATA *Word* DOC, any terminology, word, phrase, sentence, paragraph, including graphic, tables or figure, related to the following keywords: conducting, music conducting, music conducting pedagogy, musical gestures, gesture recognition, and technology, each keyword alone and in combination with one another.

2. If the terminology (i.e., a technology device or digital platform) is only one word in the context of a phrase or sentence, keep the entire sentence and underline the technology related word.

2.1 Cancel underlines from original document during extraction of DATA, so it is not confused with DATA selection underlining procedures.

Exclusion criteria:

Omit in your Raw DATA *Word* DOC ANY information NOT related with the use of technology (including headings) such as ‘instructors contact information’, ‘Class Meeting’ times, University/Instructor’s ‘Policy Statements’, ‘Grading Scales’, and any information that might lead to the identification of the institution.

Notes, comments, personal thoughts: your opinion in this data selection procedure is of ut-most importance, after the sigh (=>) to mark your own thoughts, write with letter color (blues*)* in *‘italics’,* so it is clearly separated from DATA.

1. Place your comment right after the information that generated your thought.
2. For general opinions and suggestions to improve RAW-DATA extraction procedure, please, make it as final comments at the end of the selected *Word* DATA DOC.

Annex: attached are the syllabus for you to extract/select Raw DATA (Syllabus Conducting I.pdf), another sample syllabus (Conducting 1 Syllabus Fall 2021-S1), and its related RAW-DATA sample (Raw Data-S1).

Bellow: write your suggestion, concerns, doubts, question regarding the construction of this protocol, please!

=>

APPENDIX C: RAW DATA SAMPLE

Raw Data/Syllabus-S12

Unit of Analysis*: Syllabus*

=> *year/semester not specified*

Catalog Description: Two hours lecture. The elements of conducting, baton technique, and interpretation.

College of Education Conceptual Framework: The faculty in the College of Education at XXX University are committed to assuring the success of students and graduates by providing superior learning opportunities that are continually improved as society, schools, and technology change. The organizing theme for the conceptual framework for the College of Education at XXX University is educational professionals- dedicated to continual improvement of all students' educational experiences. The beliefs that guide program development are as follows: => *NO indication of TPACK in the content sections of this document*

1. KNOWLEDGE - Educational professionals must have a deep understanding of the organizing concepts, processes, and attitudes that comprise their chosen disciplinary knowledge base, the pedagogical knowledge base, and the pedagogical content knowledge base. They must also know how to complement these knowledge bases with the appropriate use of technology. => *there is NO reflection of this statement in the content sections such as* Calendar *or* Course Outline

2. COLLABORATION => *NO TPACK related text in this section*

3. REFLECTION => *NO TPACK related material in this section*

4. PRACTICE - Educational professionals must have a rich repertoire of research-based strategies for instruction, assessment, and the use of technologies. They must be able to focus that array of skills on promoting authentic learning by all students or clients, while exhibiting an appreciation and commitment to the value and role of diversity.

Course Description - *NO TPACK related material in this section*

Objectives: => *NO TPACK related material in this section*

Detailed Course Outline => *NO TPACK related material in this section*

Required Memberships

All students enrolled in MU 3412 must be an active member of the American Choral Directors Association (ACDA). The cost is $35 **$5** for a year's membership. For ACDA membership please go to https://acda.org/membership-central/individual-membership/. It is also expected of MU 3412 students to be an active participant in the MSU Student Chapter of ACDA.

• Syllabus
• Metronome
• NEW deck of cards & a NEW can of tennis balls
• Writing Utensil
• Subscription to Spotify (online music program – FREE) => *platform used as music content resource only!*
• 3-ring Binder/Notebook, writing utensil
• COLORED PENCILS
• Ability to record video on a media device (phone, camera, etc...) *=> the student is expected to already have these technological abilities.*

Course Calendar Fall 2020

- How to conduct: 4/4, 3/4, and 2/4: https://youtu.be/DdvHUJ88tao
- How to conduct: 6/8, 9/8, 12/8, and a fast 3/8: https://youtu.be/2ER0iP2f8DY
- Gesture of Preparation: https://youtu.be/40P29dJNYaE
- Cutoffs: https://youtu.be/Z2IDhrrM-2M
- Conductor's Posture/Preparation: https://youtu.be/wk6UJQhCyWI?t=10

=> *although this was the syllabus that mention the use of technology the most (at least three times), here is NO correspondence of the theme materialized in the pedagogical content of the document! In the section '***Course Calendar'** *the use of technology is related to the sharing of webpage links of videos demonstration to some conducting technique such as meter pattern, preparatory gesture, cutoffs, and posture/preparation.*

APPENDIX D: RAW DATA SAMPLE – PEER REVIEWER

Raw Data/Syllabus-S12PR

Unit of Analysis*: Syllabus*

Catalog Description: Two hours lecture. The elements of conducting, baton technique, and interpretation.

College of Education Conceptual Framework: The faculty in the College of Education at XXX University are committed to assuring the success of students and graduates by providing superior learning opportunities that are continually improved as society, schools, and technology change.

1. KNOWLEDGE - They must also know how to complement these knowledge bases with the appropriate use of technology.

4. PRACTICE - Educational professionals must have a rich repertoire of research-based strategies for instruction, assessment, and the use of technologies.

Required Memberships
For ACDA membership please go to https://acda.org/membership-central/individual-membership/.

• Metronome => *I don't consider the use of the metronome as of technology usage per se, but as a work related tool*
• Subscription to Spotify (online music program – FREE)
• 3-ring Binder/Notebook,
• Ability to record video on a media device (phone, camera, etc…)

13. Videotaping of Classroom Lectures (sample language) => *NO relation to content*

Videotaping of classroom lectures is prohibited without express, written permission from the instructor. The instructor has the right to refuse videotaping requests.

Evaluation of Student Progress
Assignments: ALL ASSIGNMENTS MUST BE COMPUTER GENERATED and emailed to the instructor

12. Vocabulary Quizzes:
There are five (5) such quizzes, each work 5 points each. You will take these quizzes via Canvas. You will have 2 minutes to answer 10 questions. You may NOT use your notes, the web, or any materials to answer these questions. A musical vocabulary list can be found in the Files section of this course, in Canvas.

Resources:

- How to conduct: 4/4, 3/4, and 2/4: https://youtu.be/DdvHUJ88tao
- How to conduct: 6/8, 9/8, 12/8, and a fast 3/8: https://youtu.be/2ER0iP2f8DY
- Gesture of Preparation: https://youtu.be/40P29dJNYaE
- Cutoffs: https://youtu.be/Z2IDhrrM-2M
- Conductor’s Posture/Preparation: https://youtu.be/wk6UJQhCyWI?t=10

=> *No references to technology related terms in this syllabus have direct correlation to the teaching of conducting technique!*

APPENDIX E: RAW DATA SAMPLE - TEXTBOK

Raw Data/Textbook 5 - TB5

Unit of Analysis*:* *Textbook* (transcriptions and page prints)

Labuta, J., Mathews, W. ***Basic Conducting Technique***. 7th Ed., 2018.

Basic Conducting Techniques

Basic Conducting Techniques, Seventh Edition, provides a clear and intelligible introduction to the art of conducting an ensemble. Over the course of fourteen chapters, the authors explicate the elements of conducting, supplementing their teachings with an extensive selection of musical examples from the classical repertoire. Practical and innovative, clear and approachable, this text illuminates the essential skills a beginning conductor should develop to lead and rehearse a performing group.

This new edition features:

- chapters rewritten and redesigned to highlight important information and show connections between different sections.
- a new chapter on expressive conducting, consisting of expanded and updated content.
- select full scores in the "Musical Excerpts" section.
- excerpts with transpositions for each chapter, allowing easy access for class performance.
- a new companion website, which includes the scores and transpositions for all musical excerpts, audio recordings of the excerpts, and demonstration videos modeling specific techniques for each chapter.

=> *this is the only textbook to provide a website companion (details on p.5)! Textbooks TX, TY, and TZ provided scores, musical excerpts, and audio recording in other media (VHS Tapes, CD's) by the other textbooks, the biggest innovation here is the demonstration videos of conducting technique, all keyed into the text by an arrow icon*

Contents (n/p)

Contents

Preface (n/p)

A new companion website contains media files of individual transposed parts, audio examples, and full scores of the instrumental excerpts located in Part III of the text. The website also includes model demonstrations of the conducting techniques presented in Part I. All are keyed into the text.

Introduction (pp. 1-6)

=> *in the section bellow the website is mentioned for providing full orchestra scores of selected repertoires for in class reading/conducting, and aural examples to facilitate the process of developing inner "sound image".*

Features of this Textbook

- This book's first innovative feature is the repertory it provides for the conducting class. Part III consists of carefully selected examples from the musical literature that illustrate the conducting problems students must solve to develop conducting skills. Since students must typically conduct other class members to gain practical experience with a live performing group, these examples from the standard Western literature are essential components in the classroom context. The selected excerpts are reduced to four parts to accommodate classes with limited instrumentation with transposed parts provided in the companion website for ease of use. Most excerpts can be played by a quartet from the same family of instruments, by a heterogeneous quartet, by the entire class, or by a piano with or without additional instruments. The student must solve problems of balance in such varied situations, perhaps designating the instrumentation desired. A few excerpts make use of more than four parts to approximate original sonorities, and the companion website provides a full orchestra score for all instrumental excerpts. However, choral excerpts are limited to four-part, SATB format. If a band, an orchestra, or a chorus is available, or if the composition of the class is adequate, students may also study and conduct the complete, full scores represented by selected excerpts.
- A second unique feature of this book is the use of student competencies. "Competence" refers to the ability to do something. The conducting competencies define precisely what a beginning conductor must demonstrate to complete the course. Appendix A consists of a complete listing of the competencies used in this book, derived through an analysis of the essential skills a beginning conductor should develop to lead and rehearse a performing group. Each competency is the learning outcome the student must demonstrate and the conducting problem he or she must solve. The stated competencies guide student learning and provide a sound basis for instruction and evaluation.
- A third important feature is the built-in provision for continuing student evaluation. The book supplies tests and evaluative criteria, including rating scales, checklists, and analytical guides. Each section contains a self-evaluation test with a checklist for student evaluation, which can be used to inform students of their progress. The video recorder is an important tool for this evaluation and for instruction. However, if no video equipment is available, faculty or peers can administer and evaluate the tests. The final examination is in the form of a "Conducting Competence Rating Scale," designed to evaluate all the stated competencies. The rating scale, located in Appendix B, should be used frequently toward the end of the course sequence.

Developing Conception and Skills of Execution

Solving conducting problems develops conducting skills. Conducting problems are essentially of two types: those of *conception* and those of *execution.*

Conception refers to the conductor's inner hearing, or "audiation," of the correct performance. Students gain a conception of the music through score study and listening to performances. This inner hearing of the score is the only sound basis for interpreting music and for developing conducting/rehearsal technique. According to the late Bruno Walter, one of the world's greatest orchestral conductors, a most important aim of studying the score is the gradual acquisition of a distinct, inner "sound image" or "sound ideal"; this will establish itself in the ear of the conductor as a criterion that exerts a guiding and controlling influence on his or her practical music making.[1] Thus, the physical action patterns that the student is attempting to learn are controlled and guided by the desired musical result. This book helps the instructor evaluate the student's knowledge of the score by providing checklists and other observational techniques, such as having the student sing through each part, arpeggiate the harmony, identify errors, write score analyses, play the score on the piano, and give correct transpositions. The companion website provides aural examples of the excerpts to facilitate this process.

=>The traditional video recording of students' performances for assessment is also present here.

Video Performances and Evaluation

Video is a powerful teaching tool and indispensable feedback device for the conducting class. The following suggestions facilitate video use with the checklists in each chapter, with the culminating rating scale in Appendix B, and with less structured, informal viewing situations.

After the first recording session, let students view their video performance and make informal comments about what they see without using a checklist. This helps them overcome the "cosmetic effect," since they are often distracted initially by personal perceptions such as "I need to lose weight," "I should stand up tall," and so forth. Although they are not required to use a checklist, the instructor's comments can include relevant items from the checklist and lead to its use by the students.

Informal viewing often produces dramatic and instantaneous results. Numerous examples can be cited, but one author particularly remembers a tall, slender, long-armed student who gesticulated like a wounded windmill. When speaking to him on several occasions about his extra-large beats, I explained that his long arms gave him an unusual reach not necessary for clear, concise conducting, and I suggested he confine his beats to a square defined by his shoulders, waist, and head. But nothing I said changed his widely extended conducting style. When he viewed his first

=>Bellow is detailed description and explanation of all the technique issues that can be detected and worked through video observation such as "displaying distractive mannerisms," leadership, eye contact, clarity of conducting, beat location, etc (p.4).
*=> turning on and off the sound is mentioned here as teaching pedagogy just as in **TB1**. Here in TB5 is used to check for preparatory beats, steady tempos, beat patterns, eye contact, eye contact leadership, etc.*
=>Also, a video of the student with the sound off is shown for the class to follow and play. The student has immediate feedback for as he observes himself on the video.
=> only listening the sound helps to improve error detection

video performance, he was shocked. He explained he did not realize his patterns were so large; he really thought he had made his beats much smaller. He corrected this fault immediately—and permanently.

Thus, video recording corrects slouchers, foot stompers, weavers, dancers, bobbers, and others displaying distractive mannerisms. Videos identify the score-bound students who gain leadership and expression with improved eye contact. It proves to many students that the performing group is not always behind the beat; only that their point of beat is not clear, or they do not know where their beat is actually located.

Turning off the sound completely is also revealing. Students can observe their conducting gestures as they sing along with the score and check preparatory beats, steady tempos, beat patterns, eye contact, leadership, and so forth. The most revealing technique requires a student conductor and the class to perform the music while following the student's video performance on a large monitor with the sound turned off. Thus, students perform under their own direction with immediate feedback about their effectiveness as conductors. If they followed the group instead of leading it, or if they hesitated at any time, the results will be apparent. If they ever abdicated leadership it will show.

Videos help improve preparatory beats. Preparations are often weak, out of tempo, or even omitted by the novice. Clear preparatory beats are imperative at the beginning and also at any resumption of music within the composition. The *fermata* is a good illustration: many students cannot seem to grasp the necessity of a preparatory gesture after a *fermata*. The effect of the omission is graphically portrayed on the video.

Students can hear performance errors missed while on the podium. While watching and listening instead of conducting, they can concentrate on the types of ensemble problems and mistakes they should have heard and corrected. The student can use audio recordings each day in class for this purpose.

Students gain direction and motivation from the checklists, rating scales, and analytical guides developed for this book. Structured viewing of videos focuses their attention on the important conducting skills they must develop. The "Self-Evaluations" at the end of each chapter list the techniques to be mastered in that module and define exactly what is expected of the student. The video simply records the performance so that students and instructor can assess the extent to which conducting skills have been attained. From the students' rehearsal of the group, the instructor can infer the extent of practical score preparation.

=> *bellow detailed description on the use of the supplemental website, including audio, video, score, and parts with transposition files!*

Companion Website

A companion website accompanies the textbook to supplement the written text for study, performance and an enriched learning experience. All music excerpts are contained in each chapter folder—Chapters 1 through 11, plus the "Technical Mastery" section. Within each chapter you will find audio files, part files, and video files. Access the *Basic Conducting Techniques*, Seventh Edition website at **www.routledge.com/cw/labuta**.

Audio Files

The audio examples provide the beginning conductor with an aural representation of every musical excerpt in the book. They present preliminary models for students to use as first steps toward conducting, rehearsing, and interpreting music. Although they can help establish an aural concept of the score, the audio examples may be slightly different from the notated excerpts in dynamics, style, or accustomed interpretation. Thus, the student must do more than imitate them as a model performance; score study is essential to establish a valid aural concept. A conductor must first discover, to the best of his or her ability, the composer's intention—the expression or meaning of the music. Individual musicianship and personal interpretation are encouraged as long as the student can demonstrate the chapters' competencies.

Scores and Part Files

Individual and transposed parts can be downloaded directly to a computer, tablet, or smartphone from the website that accompanies this edition.

The PDF part files are provided for classroom performance. The parts include all instruments from a standard full orchestra score. Transposed parts minimize music-reading errors and save rehearsal time in classes of mixed instrumentation so that instruction can focus on the specific conducting techniques to be mastered.

Each excerpt file has transposed parts that can be printed from any PDF reader. The students or the instructor can print instrument parts for the required classroom instrumentation by opening the specific excerpt and choosing to print all the parts or selecting only the individual parts needed. Additionally, by using the file labeled "All," the instructor (or a student) can open all instrumental parts for a complete chapter. This allows the user to print all parts in the chapter by opening only one file.

In the four-stave excerpts in the book, each staff represents soprano (part 1), alto (part 2), tenor (part 3), or bass (part 4) voicings. The following chart indicates the part assigned to each instrument.

Soprano	**Alto**	**Tenor**	**Bass**
Flute 1	Flute 2	Tenor Sax	Tuba
Oboe	Clarinet 2	Horn 2	Cello
Clarinet 1	Alto Sax	Trombone	Bass
Trumpet 1	Horn 1	Viola	Bass Clarinet
Violin 1	Trumpet 2		
	Violin 2		

The instrument part files are available only for the instrumental excerpts. The choral excerpts are complete in the book.

The instrument files also provide a full orchestra score of each excerpt to help students develop the skill of score reading and anticipating what may be a daunting experience when later facing

Introduction

a complete full score. Students can download the excerpts with the full score to familiarize themselves with score structure and organization before studying and using the full scores in Chapter 12. Students can print, study, and conduct from these scores in class. They also can listen to and follow the full score with the audio file. The process facilitates score-reading ability as technical study progresses.

Video Files

The video files are a new feature of this edition. Students are encouraged to watch these videos that demonstrate the conducting techniques described in the text. The videos correspond to the reference numbers in the book; they are identified with a "V" and numbered by chapter and technique, for example, 2-1, 2-2, 2-3. Students should take advantage of this important new feature that models and clarifies the written text.

Note

1. Bruno Walter, *Of Music and Music-Making*, trans. Paul Hamburger (New York: W. W. Norton & Company, Inc., 1961), p. 85.

PART ONE
CONDUCTING TECHNIQUE
CHAPTER 1 The Baton, Preparation, Downbeat, and Release (p. 10)

Check the companion website for transpositions for your instrument.

Full scores, individual parts, and transposed parts for the musical excerpts in Part III are located in the **companion website**: www.routledge.com/cw/labuta. They can be downloaded directly to a computer, tablet, or smartphone. The parts include all instruments from a standard full orchestra score. There are also accompanying audio files of each selection, which provide aural examples of the excerpts in Part I to facilitate your learning. The audio files can be played on any media player that supports WAV files. These aural representations present a preliminary model for students to use as a first step toward interpretation.

Follow this recommended approach to master the conducting techniques in each chapter:

1. Scan the chapter; note particularly the self-evaluation. Can you successfully demonstrate the conducting competencies? What do you need to learn?
2. Familiarize yourself with the objectives (competency statements) to guide your learning.
3. Study information, illustrations, and instructions. Analyze appropriate excerpts to gain aural conception. Read the suggestions and directions preceding the musical excerpts you are conducting to gain insight into score preparation and interpretation. Listen to the audio examples provided on the accompanying website. Download the parts for your instrument if you need transposed music. Do as much as you can to use expressive and musical gestures each time you are on the podium. Always strive to become a complete and competent conductor.
4. Observe your instructor's demonstrations, and listen carefully to his or her explanations.

=> *Same procedures as far as the use of the webpage in chapter 1, are used throughout the book, as detailed on the book's chart bellow!*

Model Video

Excerpt Chart

Video Number

1. The Baton, Preparation, Downbeat, and Release

V 1-1	Holding the Baton	
V 1-2	Preparatory Position for Count One in All Meters	1-1 Drill, Beethoven
	Preparatory Beat and Downbeat	
V 1-3	The Release Gesture	1-2 Drill, Dvořák

2. Beat Patterns and Preparations in Tempo, Dynamic, and Basic Style

V 2-1	General Principles of Meter Gestures	
	The 3 Pattern	Telemann, *Menuet*
V 2-2	The 4 Pattern	2-3 Schubert, *Sym. 9*, 1st Mvt.
V 2-3	The 2 Pattern	2-5 Haydn, *Sym. 101*, 4th Mvt.
V 2-4	The 1 Pattern (Uneven)	2-6 Strauss, *Emperor Waltz*
V 2-5	The 1 Pattern (Even)	2-7 Tchaikovsky, *Sym. 4, Scherzo*

3. Preparations and Releases for All Counts

V 3-1	Prep Position for Counts Other Than One	
	Prep Beat for All Last Counts, the "Pick-Up Note"	Haydn, *Menuetto*
V 3-2	Prep Beat for Count 3 in 4 (12/8)	3-6 Telemann, *La Lyra*, "Gigue"
V 3-3	Prep Beat for Count 2 in 4 (4/4)	3-7 "Londonderry Air"

4. Fractional Beat Preparations

V 4-1	Two-Count and One-Count Preparatory Beats	4-1 Haydn, *Sym. 15*, 4th Mvt.
V 4-2	Two-Count and One-Count Preparatory Beats	4-5 Tchaikovsky, *Sym. 6*, 1st Mvt.

5. Divided Meters

V 5-1	Divided 4, Simple Meter	5-1 Haydn, *Sym. 7*, 1st Mvt.
V 5-2	Divided 3, Simple Meter	5-2 Bach, *Prelude in G Minor*
V 5-3	Compound Meter of 6	5-3 Gossec, *Military Sym. in F*
V 5-4	Divided 4, Compound Meter	5-6 Handel, *Royal Fireworks*

6. Asymmetrical and Changing Meters

V 6-1 The 5 Pattern
V 6-2 The 7 Pattern
V 6-3 Uneven (Lopsided) Patterns
V 6-4 Uneven and Mixed Meters

6-3 Tchaikovsky, *Sym. 6*, 2nd Mvt.
6-5 Stravinsky, *Firebird* Ballet, *Finale*
6-7 Five/Eight Studies: 2 + 3 and 3 + 2
6-14 Stravinsky, *The Rite of Spring* Ballet, "Glorification of the Chosen One"

7. The *Fermata*

V 7-1 *Fermata* with Caesura (Prep Follows)
V 7-2 *Fermata* with a Breath Cutoff (Cut-Prep)
V 7-3 *Fermata* without Release (With Prep)
V 7-4 The Quarter-Note Drill for *Fermatas*
V 7-5 *Fermatas* in Performance

Demonstrations

Figure 7.5
7-7 Herbert, *Mlle. Modiste*, "I Want What I Want When I Want It"

8. The Cue

V 8-1 Left-Hand Cue
V 8-2 Baton Cue
V 8-3 Head Cue

8-3 Mozart, *Sym. 40*, 2nd Mvt.

9. Conducting Musical Styles

V 9-1 *Legato*
V 9-2 *Staccato*
V 9-3 *Marcato*
V 9-4 *Tenuto*

3-2 Mendelssohn, *Midsummer Night's Dream*, "Nocturne"
4-3 Schubert, *Sym. 5*, 4th Mvt.
2-4 Meyerbeer, "Coronation March"
Dvořák, *Sym. 9*, 4th Mvt., Theme
9-7 Elgar, *Enigma Variations*, Theme

10. Expressive Conducting and the Left Hand

V 10-1 Left-Hand Gestures
V 10-2 Quarter-Note Drill
V 10-3 Left Hand in Expressive Performance
V 10-4 *Subito* Dynamic and Style Changes
V 10-5 Phrasing and Expression

Demonstration
Appendix B
11-8 Herbert, *Mlle. Modiste*, Selections
10-5 Beethoven, *Egmont* Overture
3-7 "Londonderry Air"

11. Tempo Changes and Accompanying

V 11-1 *Subito* Tempo Change
V 11-2 *Accelerando* with Meter Change

11-6 Mozart, *Così Fan Tutte*, Overture
11-3 Strauss, *Die Fledermaus* Overture

12. Analysis and Score Preparation

V 12-1 The Three Basic Steps

APPENDIX F: RAW DATA SAMPLE – RESEARCH ARTICLE

Raw Data/Research Article 5 - RA5

Unit of Analysis*: Research Article*

> Schramm, R., Jung, C. R., & Miranda, E. R. (2015). Dynamic time warping for music conducting gestures evaluation. *IEEE Transactions on Multimedia, 17*(2), 243- 255.

Abstract: Musical performance by an ensemble of performers often requires a conductor. This paper presents a tool to aid the study of basic conducting gestures, also known as meter mimicking gestures, performed by beginners. It is based on the automatic detection of musical metrics and their subdivisions by analysis of hand gestures. Musical metrics are represented by visual conducting patterns performed by hands, which are tracked using an RGB-D camera. These patterns are recognized and evaluated using a probabilistic framework based on dynamic time warping (DTW). There are two main contributions in this work. Firstly, a new metric is proposed for the DTW, allowing better alignment between two gesture movements without the use of explicit maxima local points. Secondly, the time precision of the conducting gesture is extracted directly from the warping path and its accuracy is evaluated by a confidence measure. Experimental results indicate that the classification scheme represents an improvement over other existing related approaches.

p. 244-253

I. INTRODUCTION

We have developed a system to aid students to practice by themselves. We present the core technique behind our system, which automatically analyses hand gestures, while the music student is performing the corresponding conducting patterns, eliminating the need of evaluation by a teacher during the conducting practice. It is worth noting that the focus of this paper is on gesture patterns used in training sessions for beginners (meter-mimicking gestures). In this case, the evaluation considers the ability to reproduce basic patterns, and also the ability to keep time under control. Thus, complex gestures including expressiveness and artistic movements are out of the scope of this work. (p. 244.1)

In this work, an off-the-shelf RBG-D camera (namely, the Microsoft Kinect camera) was used to track the 3D hand position in time. After that, the designed system segmented the movement into periodic sections and classified them as duple, triple and quadruple (or rejected the movement). The proposed classification scheme explores Dynamic Time Warping (DTW) [3] with a novel error metric to match patterns, combined with a statistical classifier that is able to reject outliers with a small training dataset when compared to competitive approaches such as [4]. In addition, our technique allows to estimate the timing accuracy of each beat without explicitly using the points of local minima in the trajectory (vertical axis), unlike other traditional techniques [5]–[7]. (p. 244.2)

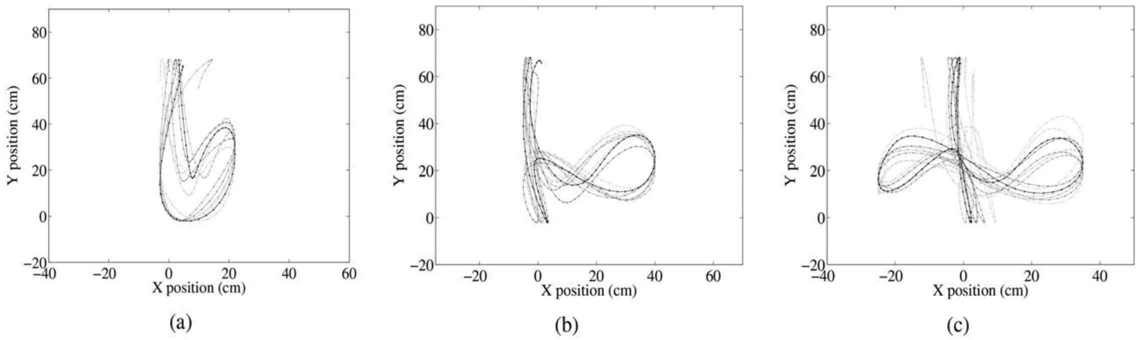


Fig. 2. Visualization of the three meter-mimicking patterns captured using a RGB-D camera. (a) Duple. (b) Triple. (c) Quadruple.

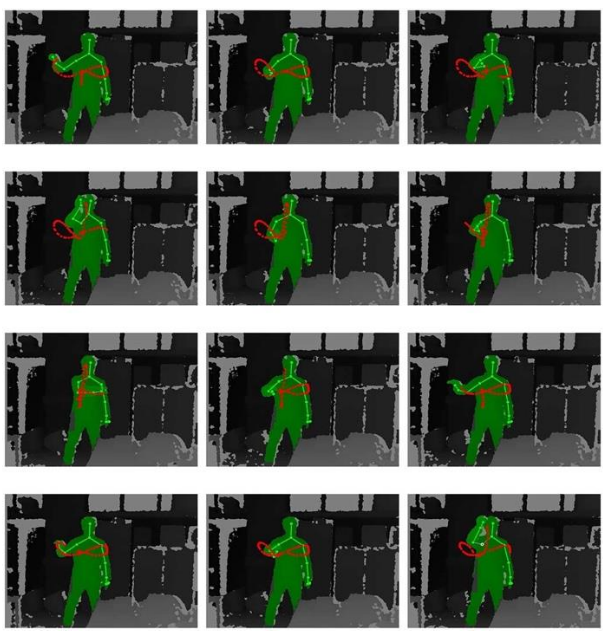


Fig. 3. Frame sequence captured by an RGB-D camera. The sequence of red points shows the hand tracking along the path of a quadruple gesture pattern.

II. RELATED WORK => *to keep the extraction of data consistent, even though this is the literature review section of the research paper, only parts that represent the voice/opinion of the authors were removed from the original text to here.*

There are many studies that use conducting gestures applied to generative music and control of virtual orchestras . . . which directly involves hand detection and tracking algorithms towards conducting gesture recognition … they aim to apply the extracted information on a virtual interpretative context, rather than on an evaluation process … in our research, the focus is on gestures related to music bars, regarding to the student's ability to control and keep the timing of music. (p. 244.5-6)

…It is a consensus among most of the algorithms described above that the rudimentary vertical movement "to down/to up" is actually at the basis of the conducting process by hand gesture, since it controls the tempo of music. The sound volume (or music intensity), when evaluated by these algorithms, is controlled by the amplitude of motion, i.e. the distance between local minimum and local maximum positions obtained from the continuous and repetitive motion of hands… Most of the previous cited techniques use the inversion of the vertical direction (or a combination of different directions) of motion to detect the beat timestamp and, in parallel, another algorithm to identify the pattern of movement, like Hidden Markov Models (HMM), Neural Networks or Finite State Machines. (p. 245.1)

Nowadays, the use of active sensors, especially RGB-D cameras, is a very effective alternative, since they allow to extract articulation points from the body skeleton in three dimensions without any artificial markers, can be bought off-the-shelf at affordable prices, and do not require controlled environments. (p. 245.3)

The gesture recognition task has a well-known issue: the motion velocity variation. Since the classification process is done using data sampled in time, and assuming that the user may perform the conducting movements at different speeds, each trajectory described by the same gesture may have different lengths. This aspect is one of biggest challenges in the development of dynamic gesture recognition systems [14]. Under these considerations and focusing in this kind of characteristic, it is more appropriate to use temporal classifiers which are less sensitive to variations in the speed of movement gestures. The DTW and HMM have been widely used, perform time warping and are robust with respect to the problems mentioned above. There are many examples of works using DTW [17], [27], [18], [14] and HMM [4], [28]–[30] to recognize gestures after tracking points from some motion capture sensor. (p. 245.4)

DTW-based classifiers are exemplar-based methods that use a deterministic matching procedure. The algorithm searches the best warping between two time series (gesture trajectories) using a distance metric for each pair of points from both sequences. On the other hand, HMM-based classifiers work with a statistical approach. In a simple case, the gesture may be represented by a sequence of hidden states and observable features. These features, extracted from the gesture tracking system, generate transitions between states that represent the gesture evolution along time. (p. 245.4) => *best description of conducting systems so far, clear language without high-tech mannerisms, the language used in the entire article is for general public, including laic technology music conductors like me!!!*

HMM-based systems need sufficiently large training datasets to estimate the state transitions and their respective observable probabilities. On the other hand, deterministic models may overcome these issues bringing efficient models up and keeping a rational meaning. This paper takes that into account and presents a new DTW-based approach to evaluate conducting gestures. In fact, the system described in the next section allows the inclusion of new types of gesture patterns with only one single example, which is not a trivial task to most of nondeterministic approaches. (p. 246.1)

III. PROPOSED MODEL

In this section we propose a conducting gesture classifier which is able to recognize gestures from a small training dataset. We separate time warping and classification into distinct steps. The classifier is Bayesian-driven and uses prior probabilities estimated from the DTW outputs when evaluated for each gesture class. Also, the DTW uses a specific and robust cost function which is more suitable to perform signal alignment on this kind of gesture. To discard outliers or non-class gestures the system uses the confidence measure estimated from the respective cumulative density function. Thus, this approach does not need non-class examples in the training stage. Finally, the beat time precision of the conducting gesture is extracted directly from the warping path estimated by the DTW algorithm. (p. 246.2)

A. Trajectory Extraction

Our data acquisition device is an RGB-D camera mounted parallel to the ground plane and facing the conductor. Instead of using a 3D hand tracker directly, we actually explore a skeleton-tracking algorithm [16], which showed more robust results (since it validates the hand coordinates with the whole body). At each frame, we retrieve only the 3D positions, and (horizontal, vertical and depth, respectively) of the hand and discard information related to other joints. Since the conducting patterns in the scope of this paper are mostly planar (i.e. is roughly constant), the trajectory is then represented as a set of 2D points. Examples of the horizontal and vertical trajectories for duple, triple and quadruple patterns are shown in Fig. 4.

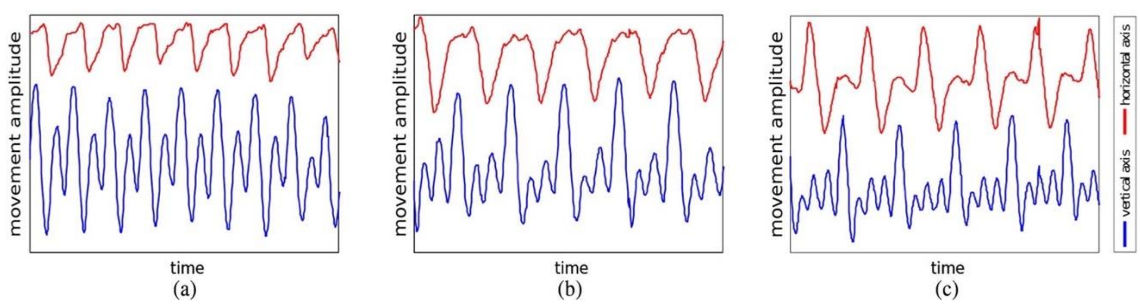


Fig. 4. Time evolution of a sequence of repetitive three gestures patterns: (a) duple, (b) triple, and (c) quadruple. It can be seen that each type of gesture has a periodic behavior. The blue line shows the amplitude variation along the vertical axis and the red line shows the amplitude variation along the horizontal axis. The original data (without low-pass filtering) was rescaled for better visualization.

To reduce possible noise in the signal capturing process, smoothing is performed using a causal low-pass filter.(p. 246.4) => *computer language explanation of 'what reducing noise in the signal' means follows here.*

B. Trajectory Segmentation

The system captures the gesture data from the RGB-D sensor and synchronizes the sequence of points with an external metronome. A set of samples is recorded for each measure (bar). depends on three parameters: time signature (*druple = 2*, *truple* = 3, *quadruple* = 4), sensor frame rate, and metronome *BPM* (music tempo). For example, the performance of a triple gesture along one bar, with *FPS* = 30 and *BPS* = 70, generates 3 x 30 x (60/70) ≈ 77 sample points. (p. 246.5)

Since the conducting gesture is synchronized with the metronome, the sequence of measures is trivially segmented at each first beat of each bar. Despite the fact that the trajectory may have different lengths depending of the parameters described above, every recorded measure set is resampled to a constant size at the training stage. The resampling step is only necessary on the training stage such that gesture templates can be generated, as discussed in the next section. However, there is no need to resample the input data during the evaluation stage. Given that the focus of this work is on evaluation, it intrinsically demands a ground truth, which can be defined as a sequence of several measures with distinct time signatures and tempo. Thus, the evaluation (classification) stage of meter-mimicking does not require a fixed tempo: each portion of the trajectory is segmented according to the tempo provided by the ground truth, and evaluated against the type of gesture also defined by the ground truth. (p. 246.6)

Thus,… (p. 246.7) => *mathematical formula to determine the trajectory M follows*

C. Proposed Classifier

Given a candidate conducting pattern extracted from the segmentation step, the goal of the classifier is to label it as duple, triple, quadruple or none (in case of a badly performed gesture). For that purpose, we propose a statistical classifier based on a modified DTW, as explained next. The first step of the classifier is to build a prototype trajectory *Mr* for each class *r*. As noticed by Wöllner and colleagues [35], choosing an average pattern is more suitable than selecting one of the training samples, since it is easier for people to recognize average prototypes (in particular, the beat points along the gesture path). Furthermore, by using an average prototype we can compute some kind of error between the training samples and the prototype for each class, getting an estimate of the intra-class variation. (p. 247.1)

In this work, we adopted a time-wise metrically trimmed mean of the samples [36], which basically consists of removing samples that are far from the median (possibly related to outliers) and computing the average with the remaining samples… => *mathematical formulas using integer function to determine the gesture samples **P** and* *gesture templates* ***M*** *follows here*…As an illustration, the final template for each gesture pattern (class) using our database is shown in Fig. 5. (p. 246.2)

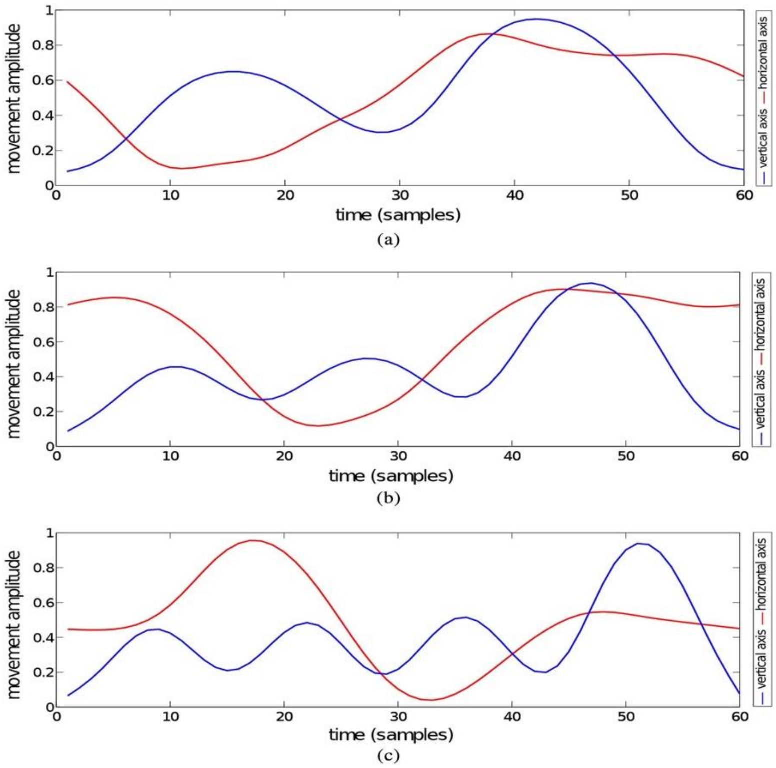


Fig. 5. Gesture templates generated by the training stage and used for classification of movements: (a) duple, (b) triple, and (c) quadruple. The blue line represents the hand position on vertical axis and the red line represents the hand position on horizontal axis.

Gesture recognition is performed by comparing the sample captured against the three templates obtained in the training stage. Our approach uses a pipeline that combines the output of the DTW error with a probabilistic evaluation, allowing to estimate a value of confidence as feedback to the user. In this way, the system is able to return a number that represents the confidence whether the gesture was performed right. Furthermore, the confidence value also allows to reject outliers, which are related to wrongly performed gestures. (p. 247.3)

=> *A discussion on the best method of comparison between the gesture templates with the conducting recorded gestures follows in the next few paragraphs, the mathematical and computer programing language used here goes beyond my analysis capacity!!!*

For the sake of illustration, Fig. 6 shows a comparison between the DTW matching using the traditional Euclidean distance (top) and the proposed error metric (bottom). As shown, our method does a better job at linking trajectory points related to the same beat, also keeping a good correspondence of local extrema along the vertical component of the gesture. (p. 248.4)

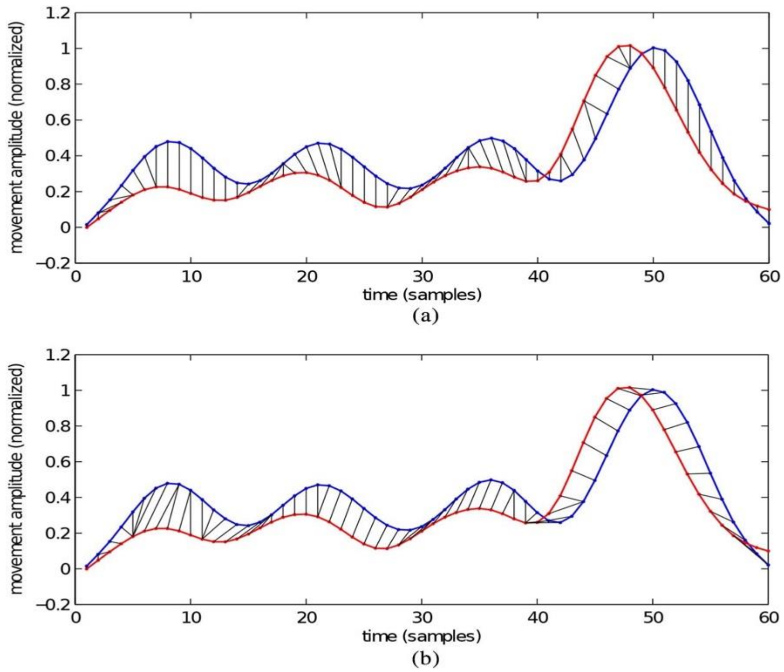


Fig. 6. DTW alignment between two temporal sequences. (a) Euclidian distance as the cost function. (b) Proposed cost function [(5)]. Black lines show the warping path generated by the DTW. Equation (4) reduces the influence of more expressive hand movements by compressing the differences of their amplitudes, as can be seen in (b).

Gesture recognition could be performed by comparing the DTW results between the input signal and the three trained templates. In this case, the gesture with the smallest DTW distance should be the winner. One advantage of this approach is that the model could be implemented using a single sample for each class (e.g. the teacher performs each movement just once), as opposed to traditional classifiers (e.g. SVMs, ANNs, HMMs) that require a good amount of training data. One drawback of the minimum-distance classifier is that if a random movement is performed, then probably all DTW distances will be high, and the smallest value actually does not represent a valid gesture. The simplest procedure to reject outliers in this scenario is the application of a threshold on the output DTW distance, although the selection of such threshold with a very small training database is not easy. Nevertheless, we show in Section IV-A that even this simple classifier can produce good results, particularly when the training set is very small (less than 10 samples per class). (p. 248.5)

When the training set is larger, we can also estimate the intraclass distribution of the DTW distances between each training sample and the gesture template, so that a Bayesian classifier can be devised => *internal computer science language, the text doesn't explain what it is "Bayesian classifier'* . One advantage of this kind of classifier is that it produces a probabilistic output, which can be interpreted as a confidence of the classifier and used to evaluate the "degree of correctness" of the gesture movements performed by beginner musicians. Furthermore, the knowledge of the intra-class distribution also allows a formal way to reject outliers. (p. 248.6)

=>*paragraphs on the difficulty of classifying outlier gestures and how to deal with it computationally and mathematically follows here*

D. Non-Class Rejection => *a purely mathematical 'outlier rejection scheme' is defined in this section*

E. Beat Accuracy Estimation

The second goal of this work is to define a metric that evaluates the temporal accuracy of each beat. In other words, the system also aims at checking whether each beat position along the gesture path matches the expected timestamps of each measure beat. => *paragraphs evaluating methods on representing the beat were used in other studies*

This work uses the warping path of the DTW to compare each beat position from the classified gesture with each beat position of the template, avoiding the explicit use of local minimum. This is possible because each captured gesture is previously segmented in intervals (temporal windows) that contain the whole measure bar as described in Section III-B. Therefore, the ideal positions of the beats are estimated as fractions of the window size with known length, illustrated by the black vertical lines in Fig. 7(a). (p. 249.6)

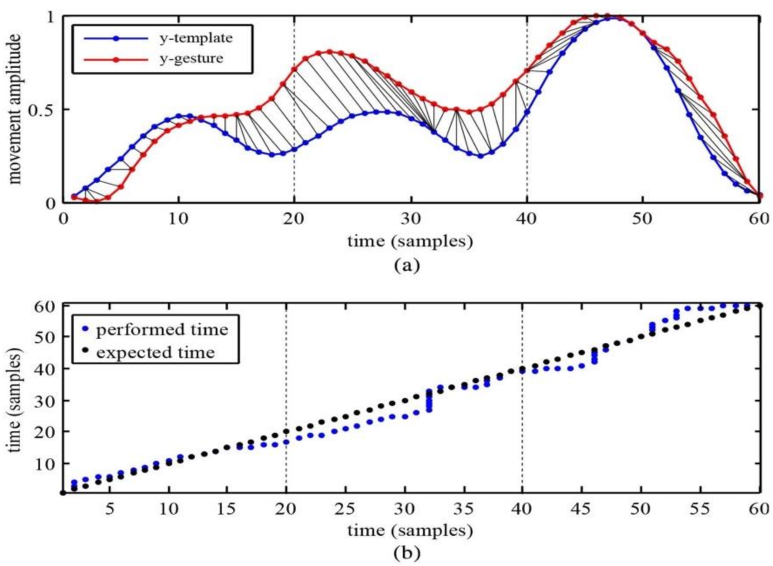


Fig. 7. (a) Black lines connecting the red and the blue lines represent the dynamic time warping. (b) Vertical distance between the blue and the black points represent the time shift between the two gestures along the path.

Another important note obtained from the process of dataset validation is that experts allow some flexibility when they are evaluating the beat time precision, showing that the human perception related to the error threshold might be different among several evaluators. Therefore, in the case of only two possible classes, where the beat time precision should be classified as accurate (class $\partial 1$) or inaccurate (class $\partial 2$), the boundary dividing these two sets is inherently non-deterministic. Considering that even for the specialists the boundary between $\partial 1$ and $\partial 2$ is not a consensus, the challenge at this stage is how to define a measure of confidence that could be used as feedback to the user, reporting how accurate in time the gesture is. (p. 249.7) => *next paragraphs explains how they did it computationally in the system, such as in the sample paragraph below:*

When computing the optimal DTW path, we also obtain an estimate of the time shift between each point in the template and its related point in the candidate gesture. For example, Fig. 7(b) shows the DTW matching points from the template (black dots) to a triple type gesture path candidate (blue dots), where the vertical dashed black stems show each beat timestamp. The vertical distance between the blue and black dots represents the time shift (misalignment) between the captured gesture and the template, assuming that the gesture pattern was detected correctly at the previous stage. In this example, the used tempo was *BPM = 70* and the hand gesture was captured by the sensor at 30 FPS, such that each time shift unit represents approximately 28.57 ms. Thus, the beat accuracy is estimated by relating the DTW distances with a probability score (confidence measure), i.e., a beat close to an expected beat time position tends to have high probability of belonging to class $\partial 1$ and low probability of belonging to class $\partial 2$. (p. 250.1) => *again, what follow here is beyond the evaluation capacity of this inquirer!!!*

IV. RESULTS

To perform an objective evaluation of the gesture classifier proposed in this paper, different classic multiclass classifiers (Artificial Neural Network, Decision Tree, Hidden Markov Models) were compared. Furthermore, the DTW-based and HMM-based techniques were evaluated with the traditional Euclidian distance as the cost function and with the proposed cost function (5). To build our validation database, gesture examples of each type of time signatures (duple, triple and quadruple) were captured from six different users, four of which are musicians with more than ten years of experience, and two are amateurs. Each recording session captured twelve bars, of which the first four were discarded due to warming up. The session was synchronized with a metronome controlled by a MIDI interface system, and some of the gestures were performed in a wrong manner on purpose: incorrect beat times and/or incorrect path (hand movement that does not correspond to any of the three allowed gestures). These recording sessions were repeated several times to generate a large dataset. After that, each recorded sample was evaluated by a set of another ten experts, who labeled the correctness of these measures in terms of gesture type and beat time (an optional "uncertain" label was also available, in case the expert was not sure about the gesture and time correctness). The database relative to gesture classification (not considering the beat validation) had all measures with any uncertain label or disagreement among the experts discarded. The set of remaining samples (validated) was used to build the gesture classifier. A similar procedure was used to generate the final beat time dataset. However, only measures with uncertain labels were discarded. Disagreements among the experts on beat time experiments were kept to ensure that the final classifier would contain the same inherently non-deterministic aspects captured on human evaluation process. (p. 251.1) => *this looks like belonging to methods section to me, yet!*

=> *next paragraph explains how the above procedure was performed in computer science language.*

A. Gesture Classification

The first test compares the two most common approaches for classifying conducting gestures: HMMs and DTW (with and without the proposed distance)… As can be observed, the DTW-P approach yields better results for small training datasets, achieving an accuracy over 94% with only 6 samples in the training set.(p. 251.2)

In the second test, we used the whole database to compare the accuracy of several classifiers… These results indicate that the proposed DTW-based approach presents the best classification results, achieving accuracy over 95% even when just 2 folds are used. In particular, it is interesting to note that the proposed DTW matching cost (DTW-P) performs better than the traditional Euclidian distance cost (DTW-E) and also shows more significant difference when compared with the HMM approach. (p. 253.1)

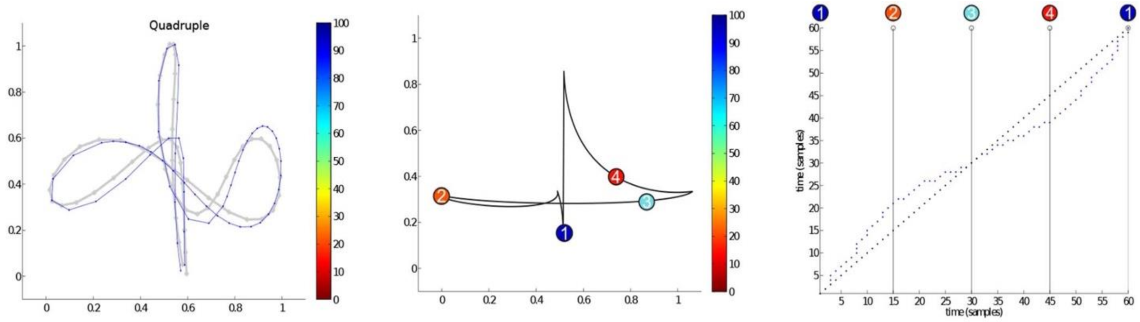
In addition to cross-validation, tests were done with additive white Gaussian noise to evaluate possible overfitting… The main reason is that the duple gesture pattern does not have a significant hand position variation when comparing horizontal axis versus vertical axis. Thus, random movements could be misinterpreted as duple patterns more frequently. Despite this fact, the overall accuracy is still high. (p. 253.4) => *because of mine complete incompetence the evaluate tables, formulas, parameters, and figures showed in this section, results here have to be accepted with face value!!*

B. Time Accuracy Estimation

The evaluation of beat time accuracy was done using the beat dataset validated by experts and the Bayesian classifier described in Section III-E. This validation process of the beat dataset has a high cost because it is a manual process that must be reviewed several times. As the final number of validated samples available for each class and is only 32, tests were performed using leave-one-out cross-validation, ensuring a minimum of 31 points to estimate each Poisson distribution. The implementation without the reject region achieved the average accuracy of 90.63% after 30 trials.

Since the goal of this effort is to create a tool to support the learning process of basic conducting gestures, a high accuracy should be prioritized. For example, the threshold corresponds to the accuracy of 98.18% but it leads to an inability of the system to give feedback in 14.06% of the time. Despite that, it is still more desirable an omission of feedback than a wrong answer.

Fig. 12 shows the visual feedback provided by the system. The first measure, Fig. 12(a), presents the spatial difference between the meter-mimicking template (gray) and the gesture under analysis. In this case, the color of the gesture path represents the confidence measure that the movement is correct. Fig. 12(b) shows the beat time accuracy feedback. Colors in each circle on the sketch represent the confidence that the respective beat time is correct. Fig. 12(c) shows another visualization way of the gesture timing along the bar. The acceleration and delays can be seen by the vertical differences between the template (black) and the current gesture (blue).



(a) (b) (c)

Fig. 12. System feedback. (a) Spatial difference between the meter-mimicking template (gray) and the gesture being analyzed. Color represents the confidence measure. (b) Colors in each circle represent the beat time accuracy confidence. (c) Time misalignment, from the DTW path, between the gesture (blue) and the template (red).

V. CONCLUSION AND FUTURE WORK

This paper presented a novel method to evaluate the performance of meter-mimicking patterns by the analysis of hand gestures. The system is designed to aid students on practicing music conducting. To accomplish this task, meter-mimicking gestures are captured by a RGB-D camera, and a probabilistic framework based on a novel error metric is employed to classify the input data. The system allows the classification of the hand's movement related to duple, triple and quadruple bars with high accuracy. In fact, experimental results showed that the accuracy rates using the proposed method are above 95% (10-Folds Cross Validation), being better than competitive approaches and traditional classifiers. Also, new templates can be addressed by using a training process with a small number of gesture examples. (p. 253.8)

In addition to gesture classification, the system allows the estimation of time precision along the gesture path. As in the gesture classification procedure, the system provides a confidence measure for each beat time, allowing a complete feedback to the user, which is desirable in a tool designed to aid the learning of meter-mimicking patterns, especially for beginners. (p. 253.9)

VITA

Beginning in the fall of 2023, Adamilson Guimarães de Abreu will be Professor of Music at the School of Music of the Universidade Federal do Pará – EMUFPA in Belém-Brazil. At EMUFPA, he will teach courses in music conducting, voice performance, conduct School of Music's choirs, research, and provide community service. Previously he taught music education at the Escola de Aplicação of the Universidade Federal do Pará – EAUFPA.

Mr. Abreu's research has been presented at state, national, and international conferences including the *IX Jornada de Etnomusicologia, VII Colóquio Amazônico de Etnomusicologia e do IV Encontro Regional Norte da Associação Brasileira de Etnomusicologia – ABET* (2022), the *XXII Encontro Internacional IFNOPAP* (2018), and the *IX Fórum de Pesquisa e Extensão da EAUFPA; XIV Seminário De Educação Especial: Por Uma Sociedade Inclusiva; I Colóquio De Educação Étnico Racial* (2018). His research interests include conducting pedagogy and technology, and music conducting teaching strategies. He is published in the *International Choral Bulletin* (2019). In adition, he has adjugated for the Theatro da Paz's *III Curso De Formação Em Ópera* (2021), and for the *Teste de Habilidade Específica em Música – THEMUS do Processo Seletivo 2019, Edital no. 5 – COPERPS* (2018).

Mr. Abreu will receive his doctorate in Music Education from the University of Missouri-Columbia in the Spring of 2023. He received his master's degree in music and his bachelor's degree in general studies also from the University of Missouri-Columbia.