Extraction, analysis, and application of quantitative data in the *mAAVm* (Method for the Analysis of Audios and Videos of Music)

A research project to be developed at CIRMMT – McGill University

Fausto Borém, UFMG (Federal University of Minas Gerais, Brazil)

1- Context and Relevance: Four experiences in my academic career were fundamental for my engagement in multidisciplinary research in Music: (1) the classes I took in the Bachelor's courses in Civil Engineering and Architecture at UFMG (Federal University of Minas Gerais, Brazil); (2) my almost 30 years as a researcher, consultant and coordinator of a multidisciplinary research group with CNPq; (3) my contact with the various areas in connection to music as the Founder and, for 20 years, the Editor-in-Chief of the *Per Musi (*https://periodicos.ufmg.br/index.php/permusi), the only scholarly journal on Brazilian music indexed in SciELO and Qualis A since its inception in 2000; and (4) my work as an organizer and editor of the book series *Diálogos da Pós: Práticas de Performance Musical* (Dialogues in Graduate Studies: Music Performance Practices), a series of books with a national Editorial Council in Brazil (https://musica.ufmg.br/selominasdesom/?page_id=157), which is already in 7th volume, publishing chapters resulting from outstanding research in Musical Performance co-authored by advisee-advisor pairs, all free access.

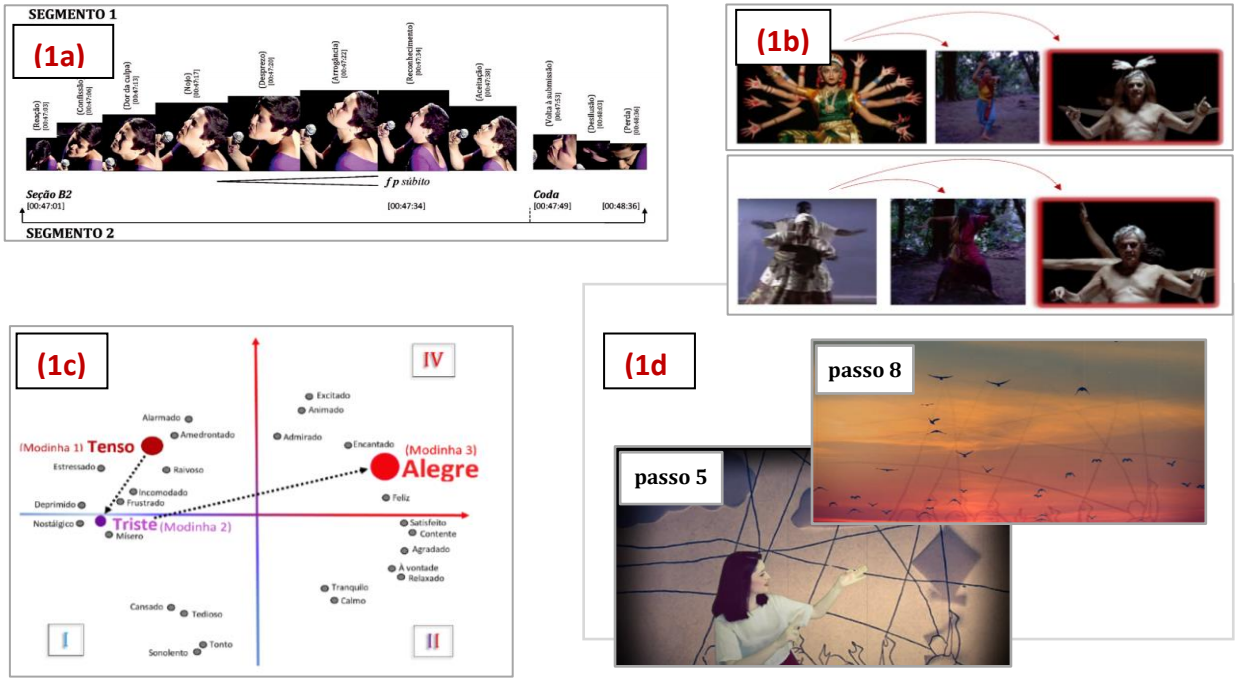
In the field of Musical Performance, an important part of performance practices (musical realization procedures in their technical, historical, and social contexts) is not noticed or described by composers and performers due to the restrictions of their textual notation (scores, lead sheets, tablatures, diagrams, graphs, etc.). Despite its qualitative artistic components, there are inaccuracies that are not welcome in music making, such as being out of tune, playing or singing with sound production failures, performing with insufficient description of a musical gesture, and other technical deficiencies. These inaccuracies can be mitigated by combining three media supports: text, audio, and video. This approach on three sensorial fronts, allows the relations in the trinomial text-sound-image to be made explicit, analyzed, and described with greater precision from quantitative data, either in the reinforcement of meanings, or in the contradiction of meanings or even, in the superimposition of subliminal layers representing meanings that music has the potential to express.

The ***mAAVm*** (Method for the Analysis of Audios and Videos of Music) is a multidisciplinary method that I have proposed for more than two decades and that has been widely used in the PPPMus Research Group ("Pearls and Cucumbers of Musical Performance"), which I have coordinated since 1994 , and also by other research groups in Brazil, as described below in item **(h) Scientific Relevance**.

Almost 25 years ago, Nicholas COOK (1998, p.150) warned of "...the generalized inability of analysts to find anything meaningful to say about the music of music videos, which may have its origin in the lack of an adequate theoretical basis for relating what is heard to what is seen...". A decade and a half after saying that, especially after the efforts in England made at CHARM (Centre for the History and Analysis of Recorded Music) from 2004 onwards and, from 2009 onwards, at the CMPCP (Research Center for Musical Performance and Creative Practice), he recognized the potential of analyzing recorded audios and videos of music as "the ethnographic turn" in 21st century musicology (COOK, 2013, p.251-252). But the lack of a

"musicology of the image" (pointed out ten years earlier by GOODWIN, 1992, p.49-71) remained in this promising line of research in the performing arts (music, theater, cinema, dance, visual arts), especially by the lack of methods and analytical tools that allow understanding the multidisciplinary (and therefore complex) relationships that can be established in the trinomial text (and/or context)-sound-image.

This lack of methodological tools for the analysis of music audios and videos (or audios and videos about music, such as open rehearsals, creative processes and interviews) led me to initially propose the ***MaPA*** tool (Map of Audiovisual Performance, see Ex.1), which aims to match relevant images of the performance (photograms extracted from the video) to its semantic contents, inferred from texts (such as song lyrics, programmatic contents of instrumental works, motivations behind the composer's inspiration, etc.) or contexts (such as the performance environment, historical, cultural or geographical data, stage lighting, costumes, props, etc.).

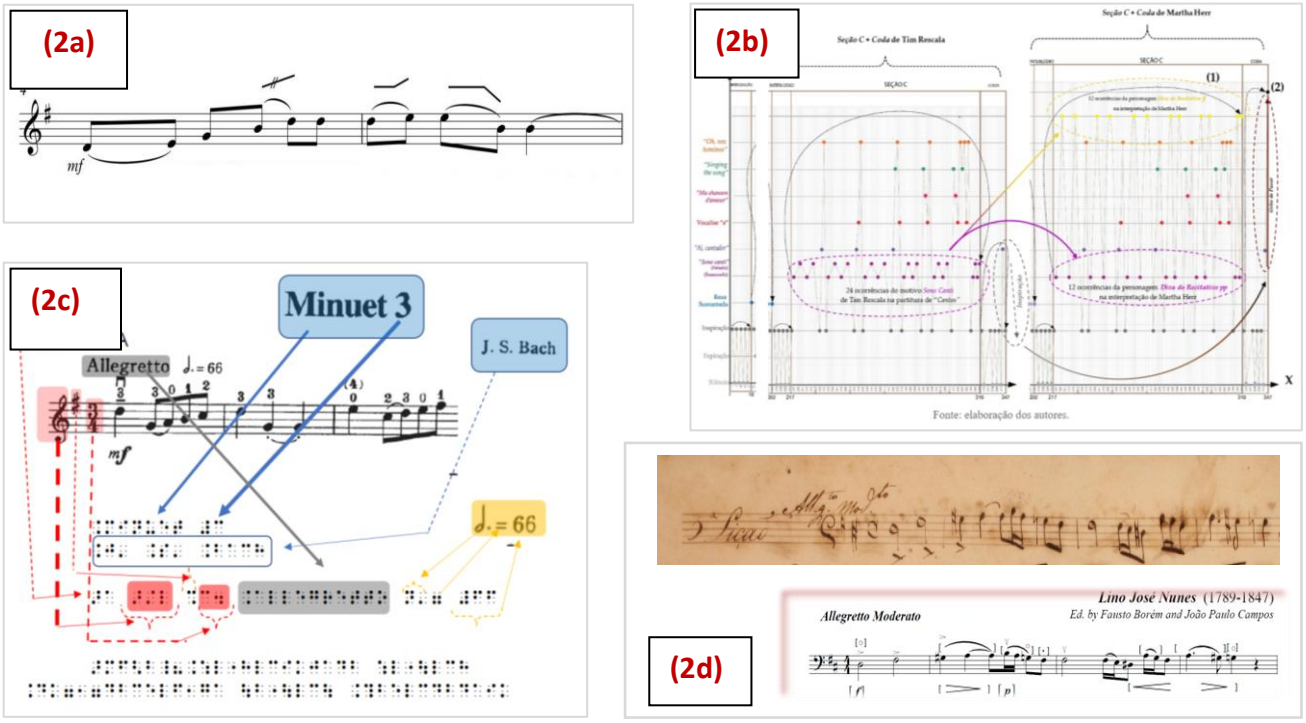


Ex.1 - Examples of ***MaPA*** : **(1a)** scenic trajectory with facial expressions by Elis Regina in "*Atrás da Porta*" ["Behind the Door"] (1973/2006), by Chico Buarque and Francis Hime; **(1b)** religious references in the music video for "*A Bossa Nova é Foda*!" [Bossa Nova is Fucking Great"] (2013), by Caetano Veloso; **(1c)** analysis of the affective atmospheres of Raul Seixas in the recording of the song "*Canto para minha morte*" ["Chant for my Death"] (1976), by Raul Seixas and Paulo Coelho; **(1d)** Performance construction for deaf audience by Andrea Pelicconi and Luciana Monteiro in "*Papagaio Azul*" ["Blue Kite"] (1999) by Edmundo Villani-Côrtes.

Ao mesmo tempo, senti que a notação musical poderia incluir não apenas a visão do compositor (ou do transcritor, como é comum na musicologia e etnomusicologia), mas também do intérprete que, de fato, é quem está no centro da realização musical. Assim, propus a ferramenta ***EdiP*** (Edição de Performance), na qual é possível preservar as ideias originais ou notação original (como nas edições *urtext*) e, ao mesmo tempo, incluir e explicitar as

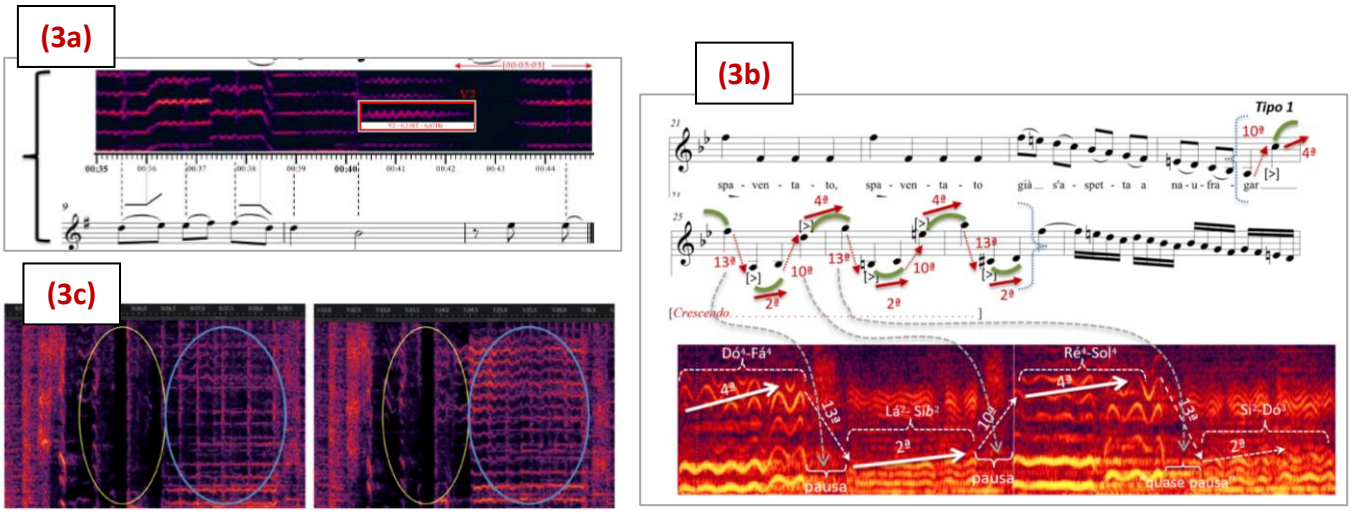
intervenções de performance por meio de sinais que sugerem, acrescentam, corrigem ou facilitam a compreensão do texto original (Ex.2).

At the same time, I felt that musical notation could include not only the composer's point of view (or the transcriber's, as it is common in musicology and ethnomusicology), but also that of the interpreter who, in fact, is at the center of musical realization. Therefore, I proposed the ***EdiP*** (Performance Edition), in which it is possible to preserve the original ideas or original notation (as it happens in *urtext* editions) and, at the same time, include and make explicit the performance interventions through signs that suggest, add, correct, or facilitate the understanding of the original text (Ex.2).



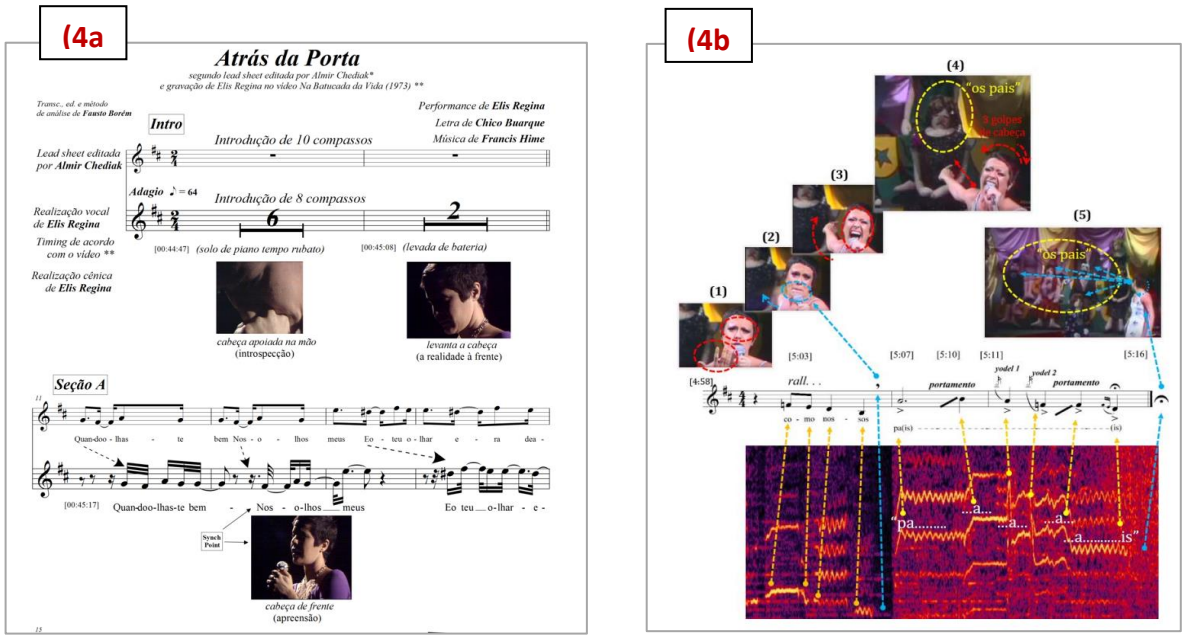
Ex.2 – Examples of ***EdiP***: **(2a)** score with symbols for three types of portamento (intermediate, initial and final); **(2b)** graphic score synthesizing the interactions of the 7 characters and 3 vocal effects in the performance by Martha Herr in the song "*Cantos*" ["Songs"] (1994), by Tim Escala **(2c)** correspondence between the graphic signs of the traditional score and the score in Braille; **(2d)** restoration of "*Lição N.5*" ["Lesson #5"] (1838), by the revolutionary and still unknown Afro-Brazilian Lino José Nunes (1789-1847).

Seeking a more precise analysis and description of the sound phenomenon, I proposed the ***EdEsP*** (Edition of a Spectrographic Performance), which combines images of sound spectrograms selected from a performance to which graphic signals are superimposed to explain quantitative data of the sound envelope (attack, sustain, decay and release). Although processed manually, this data extraction has allowed us to understand techniques, strategies, and performance styles in greater detail than we have not found in the literature (Ex.4).



Ex.3 - Examples of ***EdESP***: **(3a)** spectrogram with a rhythmic realization ruler, and analysis of vibrato rate and amplitude in "*Andante from Op.3*", by Serge Koussevitzky in a recording from 1929; **(3b)** typological analysis of the coloratura of the mezzo-soprano Cecilia Bartoli in the aria "*Agitata da due venti*" [Agitated by Two Winds], by A. Vivaldi and C. Goldoni; **(3c)** systematic choice of vocal sound envelope patterns by Elis Regina in the song "*Upa, Neguinho*" ["Hop, hop little black child"] by Edú Lobo and Gianfrancesco Guarnieri.

Finally, I proposed the tool ***EdiPA*** (Edition of Audiovisual Performances, see Ex.3), which combines different types of musical notation (scores, lead sheets, tablature, graphics, diagrams, Braille, etc.) synthesizing elements from text (and/or context), sound, and images from ***MaPA***, ***EdiP***, and/or ***EdESP***.



Ex.4 – Examples of ***EdiPA***: **(4a)** scenic performance by Elis Regina with planned prop (microphone) and lighting in "*Atrás da Porta*" ["Behind the Door"] (1973), by Chico Buarque and Francis Hime; **(4b)** vocal effects and facial expressions in a scenic performance by Elis Regina with props (circus puppets) in "*Como Nosso Pais*" ["Like our Parents"] (1976), by Belchior.

Gradually, starting in 1994, when I became a researcher of CNPq (the main research agency in Brazil), I adapted concepts and complementary tools from other fields of knowledge to give more robustness to the construction of ***MaPAs***, ***EdiPs***, ***EdEsPs*** and ***EdiPAs***. From the field of Theater and Dance, I resorted to the concepts of Kinesphere and Categorization of Movements for actors and dancers proposed by LABAN (1978; LABAN and RENGEL, 2001), adapting them to optimize the occupation of the stage by musicians. Still in the field of Dance, the studies on the synchronization between body gestures and music by HAGA (2008) allowed me to observe the creation of emphases (through reinforcement or contradiction) in musical realization. The need to refine the description of body gestures led me to resort to the concepts of direction, precision (gross and fine), distinction (discrete, serial, and continuous) and stability of gestures (open and closed circuits) developed in the fields of Motor Behavior (MAGILL , 2000; SCHMIDT and WRISBERG, 2001; SCHMIDT, 1993), Kinesiology, and Biomechanics (HAMILL and KNUTZEN, 2008; HALL, 2005). From psychologist RUSSELL's Circumplex Model of Affects (1980), I proposed its use with color codes and paths in the Cartesian plane to construct theatrical music performances (Ex.1c). On the other hand, studies on changes in emotional behavior (especially the rapid humor changes among babies and children) and the concept of Activation Contour by psychiatrist Daniel STERN (2000, 2004), can be associated with the complexity of character transitions and atmospheres that musicians imprint in their live interpretations.

My studies and that of my students on the naturalness (which we differ from spontaneity) of the singer Elis Regina, led me to seek, resorting to the observations of film theorist and experimental music composer Michel CHION (1994) on the performance of actors and actresses, the idea of a continuum of spontaneity in musical performance (non-spontaneous, quasi-spontaneous, and spontaneous). To better understand the performance on stage of this iconic Brazilian singer-actress, I turned to the long-term studies of psychologist Paul Ekman (EKMAN, 2016, 1992, 1972, 1970, 1969; EKMAN and FRIESEN, 2003; EKMAN, SORENSON and FRIESEN, 1969) on the recognition of facial expressions, based on the contractions and relaxation of 43 muscles of the human face (FOREMAN, 2003). Still within the realm of vocal music, the concepts and descriptions of vocal effects consolidated in the field of Speech Therapy (KOB, 2011; CIELO et al., 2011; WISE, 2007; SUNDBERG, 1994; CASTELLENGO and COLLAS, 1991; HAKES, DOHERTY and SHIPP, 1990; HAKES, DOHERTY and SHIPP, 1987) has been fundamental in the recognition of problems and technical-musical virtues of stylistic patterns of male and female singers in the most diverse musical genres, even if only qualitatively, for now. In the interface of instrumental music with Acoustic Physics, manual measurements in sound spectrograms have allowed the comparison of parameters such as pitch intonation, vibrato rate and amplitude (with one and two fingers in the case of orchestral strings) and portamento typology (RIBEIRO, 2014) . Finally, from the fields of Semiology (PEIRCE, 2005; SANTAELLA, 2005; SANDERS, 2005; PLAZA, 2003) and Linguistics (DOWLING and HARDWOOD, 1986), I sought concepts to synthesize semantic contents in the text-sound binomial (especially in the relations between music audio and song lyrics and/or scores) and in the text-sound-image trinomial (especially in the relationships between videos, sounds and scores and/or song lyrics).

However, despite the adaptation of concepts from these various fields of knowledge to the field of music, the ***mAAVm*** still lacks tools and procedures that allow the automatic extraction of quantitative sound and image data produced by performers (musicians, actors, dancers, multimedia artists, etc.) to better support their multidisciplinary relationships.

2- Objectives: My objective in this research of multidisciplinary nature (music and the other arts, acoustic physics, motor behavior, psychology and computer science) is to learn strategies to extract and analyze quantitative sound data (of descriptors such as frequency, tempo, dynamics, articulation and timbre) and image (of descriptors such as direction, velocity and acceleration) and apply them in studies with the four ***mAAVm*** tools, namely ***EdiP***, ***MaPA***, ***EdEsP*** and ***EdiPA***, described above. It is also my objective, on my return to Brazil, to socialize the learning of this knowledge among researchers and graduate students in the field of Arts at UFMG and at other institutions.

3- Method and Procedures: The scope of this plan work is contained in the extraction and analysis of quantitative sound and image data (the latter in 2D and 3D via object tracking) related to previous studies, and their application in pilot studies with the ***mAAVm*** tools described above, as follows:

1- Control of no-tempered intonation on the double bass (due to its fingerboard with no frets) using tactile and visual in the instrument's body, and possibly, apply it to other members of the violin family (primary source: audio collected at GEDAM/UFMG and, possibly, in the laboratory IDMIL with students from the McGill University School of Music).

2- Study of the interaction between the typologies of two instrumental effects: (a) *portamento* (initial, intermediate, or final) and (b) *vibrato* (rate and amplitude, gradual or continuous) on double bass (primary source: the 1929 historical audio recording of "*Andante from Op.3*" composed and performed by Serge Koussevitzky).

3- Typological comparison between the one-finger *vibrato* and two-finger *vibrato* on the double bass (primary source: audio collected at GEDAM/UFMG).

4- Typological comparisons between vocal effects (*portamento*, *vibrato*, yodel, drive, fry, scoop, *sprechtime*, crepitation and tremor) and facial expressions (the nuances of basic emotions sadness and joy) in singers (primary source: videos of Elis Regina singing "*Atrás da Porta*" ["Behind the Door"] by Chico Buarque and Francis Hime, and "*Me Deixas Louca*" ["You Drive me Crazy"] by A. Manzanero, available on the Youtube platform).

5- Analysis of body movements and subliminal speeches by Cecilia Bartoli (the contradiction) and Kimchilia Bartoli (the gender parody) (primary source: videos of the opera aria "*Agitata da due Venti*" ["Agitated by Two Winds"] by Antonio Vivaldi and Carlos Goldoni, available on the platform Youtube).

The literature review includes previous studies on **(a)** quantitative assessment of perceived timbres associated with semantic categories and emotional valences (REYMORE, BEAUVAIS-LACASSE, SMITH and MCADAMS, 2022); **(b)** extraction of audio descriptors (PEETERS, GIORDANO, SUSINI, MISDARIIS and McADAMS, 2011); **(c)** relationship between instrumental gestures and timbres on the guitar (TRAUBE, DEPALLE and WANDERLEY, 2003) and on the flute (KERELIUK, SCHERRER, VERFAILLE, DEPALLE, WANDERLEY, 2007), whose procedures may be adapted to the violin family, such as contact points on the string, pressure of the bow on the string and excessive bow pressure; **(d)** musical structures and occupation of space in the performance of dancers (NAVEDA and LEMAN, 2010 and 2013); and provision

of collaborative multimodal database (audio, video, motion capture signals collected and processed) (MAESTRE, PAPIOTIS, MARCHINI, LLIMONA, MAYOR, PÉREZ, WANDERLEY, 2017).

Initially, I will familiarize myself with essential data extraction and analysis procedures in audio software (*Sonic Visualizer* and *Timbre ToolBox*) and video/stills (*OpenFace*, *Simi Motion*, E*yesWeb* and *Pose Annotator,* the latter with pending patent). Quantitative data will be extracted from primary sources and then applied in continuation of previous studies, with annotations concatenated with photograms and spectrograms of qualitative data in: **(a)** intonation control in the violin family, in continuation of studies carried out on double bass (BORÉM and LAGE, 2019; LAGE, BORÉM, VIEIRA and BARREIRO, 2007) and on cello (LUDWIG, 2019; LUDWIG and BORÉM, 2021; LUDWIG and BORÉM, 2020), with possible application on the violin and the viola; **(b)** regularity of rate and amplitude of vibrato in double bass with one and two fingers (BORÉM, 2011); **(c)** direction, speed and strength in movements on the double bass articulated in *arco* and *pizzicato* and corresponding cognitive efforts (LOPES, 2020); **(d)** sound envelopes representative of the typology of instrumental and vocal *portamento* and *vibrato* (RIBEIRO and LOPES, 2019; RIBEIRO, 2014); **(e)** data extraction of facial micro-expressions of Elis Regina's; RIBEIRO and BORÉM, 2018); **(f)** qualitative analysis of the contradictory body movements of singers Cecilia Bartoli and Kimchilia Bartoli while performing n opera aria(BORÉM, 2017; PEREIRA and BORÉM, 2017).

4- Schedule: This project includes 5 stages for 2 months each, described below:

Stages (months)	**Tasks**
1 (Dec. 13, 2023 till Jan. 2024)	Study of softwares and extraction of quantitative data from primary sources of audio and video
2 (Feb./March 2024)	Application of image and sound data with the tools *EdiP*, *MaPA*, *EdiP*, and *EdiPA*, papers writing
3 (April/May 2024)	Application of image and sound data with the tools *EdiP*, *MaPA*, *EdiP*, and *EdiPA,* papers writing
4 (June/July 2024)	Application of image and sound data with the tools *EdiP*, *MaPA*, *EdiP*, and *EdiPA,* papers writing
5 (Aug./Sept. 12, 2024)	Application of image and sound data with the tools *EdiP*, *MaPA*, *EdiP*, and *EdiPA*, papers writing

5- Possible Contributions: It is my hope that the results of this research sojourn optimize the tools ***MaPA***, ***EdiP***, ***EdEsP*** and ***EdiPA*** as far as (1) better understanding and describing stylistic traits of emblematic music performers, (2) communicating details of teaching and learning processes in music from beginner to advanced level, (3) providing means to help composers bring the ideas they write down on paper closer to sound reality, and (4) extending the ***mAAVm*** methodological tools to other fields such as theater, dance, cinema, literature and communication in various media.

6- UFMG-McGill Collaboration Potential: There is already a collaboration term dated December 20, 2019, signed between the School of Music of UFMG and the Schullich School of Music of McGill University in the fields of sonology and music technology, including the sojourn of three Senior professors (Maurício Loureiro, Sérgio Freire and Fernando Rocha) and several PhD students from the Graduate Program in Music at UFMG. There was also the visit, in 2011, of Prof. Marcelo M. Wanderley (my Supervisor) as a Visiting Professor at the IEAT (Institute for Advanced Transdisciplinary Studies) at UFMG.

7- Scientific Relevance: Research results that used the concepts and tools of the ***mAAVm*** already include 16 book chapters, 10 scholarly articles, 11 full conference papers, 9 doctoral dissertations defended, 8 doctoral

dissertations in progress, and 12 master's theses defended. In terms of institutional partnership, collaboration in research networks resulted in the publication of works in co-authorship with colleagues from abroad (in Portugal, João Pardal Barreiros, from the Faculty of Human Motricity of the University of Lisbon).

International awards that I received in connection with ***mAAVm*** include works published in interdisciplinary co-authorship ("Grand Prize – Professional Category" at the 2019 International Society of Bassists Research Competition, Indiana University, USA, with Guilherme Lage from the School of Physical Education at UFMG) and with Graduate Students ("Honor Mention" at the 2013 International Society of Bassists Research Competition with UFMG Music Graduate students Alfredo Ribeiro, Gustavo Neves, João Paulo Campos and Rodrigo Olivarez). Single author awards linked to ***mAAVm*** include the 2021 International Society of Bassists's Gary Karr 80-to-90 Project, Nebraska University, USA; and the 3rd Place in the 1st National Contest of Musical Analysis of "Cadernos de Análise Music Journal (São Paulo, 1995).

8- Social Relevance: This study bears in in mind the integration between text, sound and image media and the advent of sophisticated technologies increasingly accessible to the historically enslaved in Brazil, to non-specialists, to non-literates (hence audio and video are fundamental), the less favored economically, and to those with physical limitations have allowed the inclusion of these segments of society usually forgotten by the field of Music. I mention some examples of studies that I took part as a researcher that touches this aforementioned social relevance: **(a)** the historical reparation of Afro-Brazilians in Brazilian music (BORÉM, RIBEIRO, NEVES, CAMPOS and OLIVAREZ, 2015), **(b)** teaching through video classes for children from social projects of music (BORÉM, 2022; BORÉM, 2020), **(c)** music for the blind and deaf audiences (see Ex.1d and Ex.2c above), and **(d)** musical analysis for the so-called non-muses (non-musically literate; TAGG, 2011 in translation by Fausto Borém).

9- Relevance of McGill University and my Supervisor in Canada: The Schulich School of Music (McGill University) has a long tradition of quantitative studies in music and hosts the CIRMMT (Centre for Interdisciplinary Research in Music Media and Technology; https://www.mcgill.ca/music/about-us/research/cirmmt), a world reference with several laboratories in the area of sound and gestures in performance.

My Supervisor, Prof. Marcelo Wanderley (PhD. in acoustics and computer science applied to music from Paris VI, France) is Coordinator of the multidisciplinary laboratory IDMIL (Input Devices and Music Interaction Laboratory; www.idmil.org), a laboratory dedicated to the construction of interfaces aimed at musical interaction. He has a vast scientific production in the interface between music and technology.

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