The Musicology Lab: Teamwork and the Musicological Toolbox[1]

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Abstract

Musicology is a small discipline within the wide spectrum of human knowledge, yet it is already divided into various branches, each with its own societies, conferences, journals, jargons, degrees, prejudices, …, and jobs. Although they share their object of investigation – "the art of music as a physical, psychological, aesthetic, and cultural phenomenon" [4, p. 153] –, these branches very often ignore one another. Research in musicology is mostly a solitary task, as investigations, papers, and publications are commonly signed by single authors, in contrast with STEM disciplines where teamwork is the rule. This is in part the result of tradition – the "Musicological Toolbox" [22] – but also the aftermath of the job market and financing programs.

Large funding schemes such as the European Research Council (ERC) grants are becoming a major disruptive factor in many disciplines in the humanities, including musicology. Scholars in all fields now have the opportunity to build research teams, and most of their members receive their salaries to exclusively work on the project. In other words, we are starting to build what could be called a Musicology Lab, learning along the way how teamwork is reshaping and transforming the Musicological Toolbox, the look and feel of our discipline, the way we work as well as the way we publish and disseminate our results.

This paper presents some of the key features of the ERC Didone project, one of its principal tasks being to create a digitally encoded corpus of some 3,000 arias in MusicXML format from about 180 musical settings of a small number of opera librettos by Pietro Metastasio. It focuses on some of the project's research tasks, emphasizing how the skills of a team of eighteen scholars with very different expertise – historical musicology, music theory and analysis, cultural history, librettology, archival research, music performance, music engraving, MIR, computer science, and statistical modeling – combine to explore the potential answer(s) to the main research question of the project: *How are emotions expressed through music?*

Introduction

In a seminal article published in 1992, Don Randel presented the principles of what he ironically called the "Musicological Toolbox", the research tools and conventions that "ensure familiarity and consistency" in our field and maintain the purity of the discipline to avoid any deviation from the academic canon. Like a computer's interface, the primary function of the Musicological Toolbox is to "help reduce the time and effort required to produce the scholarly product" as well as to preserve the inherited rules, the look and feel, and the focus of our academic production [22, p. 10–13]. In the same volume, Robert Morgan observed that the history of Western music theory and analysis is deeply rooted in the conviction that "music constitutes a well-formed and coherent 'language' … that there is a right way of understanding and realizing musical relationships, and correspondingly a wrong way as well". Underlying music theory is "the belief in an unchanging eternal order surpassing time-bound stylistic transformations", a conviction that is essentially at odds with any historical perspective of music [16, p. 44–45].

The rise of different approaches to the study of music, either ethnomusicology, critical musicology, or computational musicology, was more the result of a change in methodology than a change in the object of inquiry;

1 A recorded version of this keynote is available online: https://music-encoding.org/conference/2021/keynotes/. In this published version of the keynote presented on July 20 at MEC2021, we use the first person singular to keep the format of the conference, in which Álvaro Torrente presented this co-authored work.

in other words, it was a change of toolbox, a transformation of the look and feel.[2] The maturity of any branch of knowledge is confirmed precisely by the establishment of its own toolbox, involving its own societies, conferences, journals, jargons, degrees, prejudices, ..., and jobs. To a large extent, disciplines are a matter of power, a means to administrate the limited resources available in academia, as already observed by Bourdieu [2].

Despite this critical perspective, it is only fair to acknowledge that new methodologies normally result in the enrichment of knowledge, and this should be our main goal as academics. But it is also true that, when working in isolation within the scope of our restricted academic environment, the fruit of our investigation has obvious limitations. The rise of interdisciplinarity in the late twentieth century derived from the awareness of the constraints of isolated knowledge [25]. If separate disciplines must join forces to grow, this is even more true within the disciplines themselves, the branches of which, at least in theory, investigate the same object. A good and positive example in our field has been the interaction between historical musicology and ethnomusicology. The rise of the cultural history of music in the last few decades was a consequence of the adoption of the methods of ethnomusicology to study the music of the past. Quoting Randel again, "musicology and ethnomusicology begin to look a great deal more alike when we recognize that there is not such a thing as a work without a context" [22, p. 11]. Sometimes, the mimicry in historical musicology went so far as to study the context while entirely overlooking the musical work.

One of the reasons for the relative isolation of the various branches of musicology is that, to a great extent, music research has been an individual enterprise. Most articles and monographs, and even most conference papers, are commonly signed by a single author, or two at the most. This is certainly a consequence of the discipline's tradition – the Musicological Toolbox – but also derives from the methods for evaluating academic careers. At Anglo-American universities, career promotion is always dependent on the individual publication of journal articles and at least one monograph. In Spain, the evaluation of a publication signed by two or more authors is very often rated much lower than individual contributions; in other words, collaboration is penalized.

A collateral consequence of such individualized research is that each publication is normally confined to the specific branch of its author's expertise. I am primarily a historical musicologist, and most of my publications essentially belong to that field. It is true that I frequently apply methodologies from other disciplines and branches in individual publications, such as philology, history, music analysis, or ethnomusicology, yet my own speciality usually prevails, and it is not unlikely that scholars from those other fields might find my use of their methods somehow naive, if not entirely flawed.[3]

As we all know, this is not the case in other academic disciplines, particularly in STEM (science, technology, engineering, and mathematics), where the rule is to acknowledge the contribution of several authors, usually not fewer than three and very often more than a dozen. Obviously, this is the consequence of different academic conventions and mostly derives from the predominance of teamwork in STEM research. For example, the "Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals"[4] state that authorship of scientific papers should be based on four criteria:

1. substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work;
2. drafting the work or revising it critically for important intellectual content;
3. final approval of the version to be published; and
4. agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

If we were to apply these criteria to musicology, publications deriving from master's and doctoral theses should always include the signature of the supervisor, as it happens in many other fields. However, no academic musicologist would dare to do so, under the risk of being accused of appropriating their student's work. Also, if we

2 A very good example that anyone will easily grasp is the spectacular increase in the use of LaTeX for writing academic papers, as it is becoming compulsory in many fields and areas of research: If you do not write your paper in LaTeX, your work will not look or feel adequate.

3 For example, one of my recent publications focuses on the study and critical editions of two poems dedicated to the *zarabanda*, yet I do not discuss the *zarabanda* itself; the result is a combination of historical studies and philology, yet it was published in a musicological journal; see [26].

4 http://www.icmje.org/recommendations (accessed August 12, 2021).

were to apply medical conventions, the contribution of music engravers, data collectors, database compilers, and research assistants should also be recognized in some way. Yet, in our field, all these contributors are usually accommodated in the acknowledgment page only, if at all.

Beyond traditions, conventions, and concepts of authorship, the prevalence of individual, isolated research in certain disciplines is also an aftermath of funding schemes. In STEM fields, research structures and funding resources favor collaboration, as scholars usually work in teams associated with laboratories where every member is paid to contribute their knowledge to the common goal. This working structure is thus reflected in their academic output. This is rarely the case in the Humanities, where collaboration, if any, is the result of individual eagerness and enthusiasm rather than of the existence of any professional structure. To put it bluntly, scholars in the Humanities collaborate in their spare time after having completed all their compulsory duties.

1 The Musicology Lab

Major funding schemes, such as the European Research Council (ERC) grants, are fostering a dramatic shift in the research procedures and structures of many disciplines. Almost for the first time in history, musicologists and other scholars are having the opportunity to build research teams in which most members receive their salaries to work exclusively on the given project; they are not paid to teach, nor to earn a degree, or to pursue their own research interests, but to best devote their time and energy to the main goal defined in the project. In some ways, thanks to these large schemes, musicology is starting to move from the individual desk to the lab, from the Lone Ranger to the squad, from the *prima donna* to the choir, from the ivory tower to the interaction of specialists of several branches and disciplines.

The possibility of building a musicology lab has one fundamental benefit: It allows us to think differently, in new dimensions; it allows us to imagine how to apply methodologies and techniques that are beyond the capacity of the individual scholar. In short, building a Musicology Lab ultimately represents a change of paradigm, a new toolbox, a window of opportunity to expand our methodologies and, more important, to implement true interdisciplinarity. Yet, it also has consequences that can hardly be truly evaluated when writing your application to the scheme. Teamwork requires defining procedures and protocols for both research and publications, to ascribe tasks to every team member, to establish milestones, to coordinate and supervise achievements, and to confront problems. Team members need to realize that, although they have been chosen because of their skills and commitment, they have become part of a group with a common target, which sometimes requires them to leave aside their individual, personal goals and interests to join forces with their working community. And, in individual disciplines such as musicology, this confronts the *divo* character that we researchers tend to have.

I do not think that we have properly assessed the implications of this shift for our discipline yet. In my case, I have been Principal Investigator of the Didone project, funded by an Advanced Grant by the European Research Council, for over two years, and I am only now beginning to grasp how teamwork is changing my own procedures as well as those of my colleagues, and how some of my early decisions failed because I was not aware of the paradigm shift required. This is the experience I would like to share in this paper.

2 The Didone Project

Applying to a funding scheme of the magnitude of the ERC Advanced Grants is like writing a letter to Santa Claus: You are invited to imagine, to request everything you have been longing for, to assemble a true Dream Team to work with you. In academia, this starts with the declaration of the primary research question. In my case, it all started with a question that had been in the back of my mind since I began to study music some forty years ago: *How are emotions expressed through music?* Please note that this question does not refer to the psychological dimension of music, the aesthetic level – how music might move emotions in us –, but to the poietic and neutral levels. What I was looking for is to understand the resources used by composers to create works aiming to be expressive of specific emotions. Whether these compositions would eventually arise those emotions in the listener would be a completely different matter. In other words, I wanted (and still want) to know what makes music so powerful to “affect the minds of all, to get inscribed in the soul of man, to be fixed

in our memory in such a way that we do not have to think, and we are driven like waking up from a dream"[5], in the words of the medieval theorist Glarean.

I am aware that this question may not sound very original, as emotions have become one of the hot topics of our times. From politics to entertainment, from advertising to music, from television to computer science, we have suddenly discovered the importance of emotions in our lives, how emotions shape and drive essential decisions, how the gurus pulling the strings of modern society influence our behavior to buy certain goods, vote for specific candidates, or plan our holidays by moving the emotions of our souls. The novelty of the Didone project lies not so much in its research question itself, but in the materials used and the methodology chosen to find answers to that question, as I shall explain below.

The connection between music and emotions has become an important academic topic in the last two decades, with hundreds of related publications.[6] However, this relationship is as old as musical thought itself. Indeed, the belief in the capacity of music to move human emotions can be traced back to Ancient Greece. The same conviction, based on the research of the Italian erudite Girolamo Mei – whose name, by the way, does not seem to be related to the Music Encoding Initiative (MEI)[7] –, was the trigger that moved the members of the Florentine cameratas to invent, in the late sixteenth century, the form of drama with music that we now call opera [18]. A few years later, the father of modern philosophy, René Descartes, opened his first treatise, written in 1618, with the following statement: "The aim [of music] is to delight and to move various emotions in us"[8]. He was neither the first, nor the last.

Today, there is a scholarly consensus that emotions play a central role in Western music, and particularly in Italian opera. As expressed by the musicologist Carl Dahlhaus,

> If we regard *the affects* [emphasis added], the emotions, and the emotional conflicts expressed musically onstage in the form of arias, duets, and ensembles *as the "true" musical drama* [emphasis added], dramaturgical analysis of an opera should not start with the way a narratable action is reflected in music. Rather, quite the reverse, it should try to show how an action constituted as a drama of affects, primarily by musical means, comes to be based on a story line in order to take shape on a stage [3, p. 73–74].

At this point the question arises: If emotions are one of the main features of the most distinctive musical unit in opera, the aria, if emotions are "the true musical drama", shouldn't we be able to study, analyze, categorize, and tabulate them in a systematic manner, as we can do with key, harmony, musical form, verse structure, and so many seemingly "objective" elements in musical structure? How can we discuss the meaning and function of the operatic aria, how can we discuss musical drama at all without taking into account its emotional semantics? Indeed, understanding the emotions expressed in arias should be a precondition to study opera.

3 Mapping Emotions in Eighteenth-Century Italian Opera

This is precisely the point of departure of the Didone project: to study how emotions are expressed in opera. Walking this path requires several steps:

1. to identify and select a corpus of music that is expressive of emotions;
2. to define a conceptual and taxonomical framework for human emotions;
3. to develop a methodology to classify musical works by the emotion expressed;
4. to establish a procedure to compile musical data, which involves:
   a. collation and pre-processing of sources,
   b. encoding,
   c. manual annotation of some features;
5. to build a database to connect source and historical data with analytical evidence;

5 "Qui omnium mentes afficiat, qui hominis animo insideat, qui denique ita haereat memoriae nostrae, vt saepe, ne cogitantibus quidem nobis subrepat, in quem perinde atque e somno experrecti prorumpamus" [7, lib. II, ch. Xxxviii, p. 174].

6 For a good synthesis, I recommend the recent book by Patrick N. Juslin [12].

7 https://music-encoding.org (accessed August 12, 2021).

8 "Finis ut delectet, variosque in nobis moveat affecttus" [5, p. 5].

6. to define a large-scale method of analysis;
7. to develop code to automatically extract data from the encoded musical corpus;
8. to interpret the results.

3.1 The Selection of a Musical Corpus Expressive of Emotions

One of the main characteristics of the Didone project is that we do not use existing audio recording or symbolic notation corpora. On the contrary, we have identified a historical body of music that we believe to be expressive of emotions, a collection that is only available in manuscripts disseminated in dozens of libraries and archives around the world: Metastasian *opera seria*.

Our point of departure is the well-established assumption that, in eighteenth-century Italian *opera seria*, "arias were thought capable of suggesting one or two emotions chosen from a wide range of subtly varied passions" [9, p. 385]. Opera structure and aria form were relatively stable during most of the eighteenth century: Operas consisted of an alternation of recitatives and arias, while choruses, duets, and ensembles were seldom used. The action took place during the recitatives, while arias were closed, self-contained, and independent musical units that suspend the dramatic time to express, in the form of a monologue, the emotions experienced by the character on the stage. Most aria poems have two stanzas, each one set to different music and the first part usually repeated after the second, either in *da capo* or *dal segno* form, or, as the century progressed, in other ternary schemata. In short, most arias have a tripartite form where the third section is a repetition or variant of the first one: ABA'. The consistency of form and function of operatic arias during this period makes it possible to compare them in order to identify coincidences and differences, and eventually to trace features that may be related to the expression of emotions.

The second important singularity that makes *opera seria* particularly suitable for our goal is the preeminence of the leading librettist of the period: Pietro Metastasio. His 26 librettos were set to music nearly one thousand times by more than three hundred composers over the course of more than a century. Metastasio's influence was so overwhelming that, during the 1750s, settings of his librettos represented over 30% of all the operas performed in Europe. Many of his *drammi per musica* were set to music over 50 times, and one of them, *Artaserse*, nearly reached 100 different musical settings. In the Didone project, we have chosen his five most popular librettos, for which 30 or more versions survived: *Didone abbandonata* (1724), *Alessandro nell'Indie* (1730), *Artaserse* (1730), *Adriano in Siria* (1732), and *Demofoonte* (1733). It is true that most librettos underwent changes in each production, changes that implied the suppression of some arias and the replacement of others. In most later versions, only a handful of arias from the original libretto survived, while there are dozens of substitute arias that would need a case-by-case investigation.[9]

Even considering these circumstances, our research confirmed that dozens of settings of a high number of arias from the same Metastasian librettos have survived in manuscript form. The advantage of this corpus is that we can easily compare the musical settings of different composers for the same aria poems, written for the same character at the same point in the plot, and, thus, presumably aiming to express the same emotion.

3.2 The Definition of a Conceptual and Taxonomical Framework for Human Emotions

One of the major challenges of the Didone project was to adopt a conceptual framework for human emotions. No academic consensus has been reached, even within the realms of psychology, physiology, or neuroscience, on the very concept of emotion, nor on its categories, dynamics, or signification [11]. For example, the psychologist Robert Plutchik writes that "almost everyone agrees that the study of emotion is one of the most confused (and still open) chapters in the history of psychology" [21, p. 344]. The obvious reason is that emotions are not clear and distinct objects that can be identified, measured, described, and compared. Emotions cannot even be observed; we know of their existence indirectly, through their reflection on the body – heartbeat, face color, breath, muscular tension, face gesture, or neural stimulation –, through individual behavior, or through verbal description. Any attempt to describe emotions is biased by their subjective character and by the absence of a shared and accepted scientific language.

9 The works of Giuseppe Sarti have been explored in detail regarding this issue: https://sarti-edition.de (accessed August 12, 2021); see also [20].

For this reason, and after a thorough revision of historical and modern theories of human emotions, we decided to apply a cognate theory of human emotions, this is to say, a theory "which shares its fundamental basis, assumptions, and vocabulary with the theory of the period … but which answers to modern requirements for degrees of thoroughness, consistency, and precision that are generally not found in the theory of the period when viewed from a modem perspective" [10, p. 112]. In other words, we have adopted the taxonomy and conceptual framework of emotions familiar to eighteenth-century individuals involved in opera production, as defined by René Descartes in *Les passions de l'âme* (1649) [27]. This treatise is the first systematic attempt to explain the physiological dynamics of human emotions from a scientific point of view, as well as the most comprehensive and organized classification of human passions in that period. More importantly, *Les passions de l'âme* was the reference work on this matter during the eighteenth century, including contemporary music theorists such as Johann Mattheson,[10] and the conceptualization was reportedly applied by Metastasio in the creation of his dramas.

Descartes' taxonomy identifies six basic and 43 further passions that are either derived from or combinations of the basic ones. Descartes also identifies further features for each emotion: 1) the basic passion from which it derives; 2) its positive, negative, or neutral valence; and 3) its temporary reference: past, present, or future.

3.3 A Methodology to Classify Musical Works by the Emotion Expressed

However, the Didone project is not about philosophy, but about music, and identifying the emotion expressed by a piece of music is an even more subjective task than interpreting Descartes' theory. Most experiments to classify music emotionally assess judgements expressed by groups of listeners [6]. This is a standard procedure in psychology that can attain notable results regarding how emotions are perceived by listeners, but has two major drawbacks for our project: First, as I explained earlier, the aim of the Didone project is to explore *not the emotion perceived but the emotion expressed* in a work of music; and second, the emotional perception of modern listeners, with or without musical training, can hardly be equated to that of an eighteenth-century audience because their personal and musical backgrounds and experiences are radically diverse.

For these reasons, we needed to pursue a different path. The advantage of operatic arias is that they are not abstract pieces of music – as it happens with instrumental works –, but do have a poetic text sung by well-defined characters whose personal circumstances are clearly explained in that they occur within specific points in the development of the plot. All the elements of the drama, from the *characters* and the *action* to the *words* they use, are like a magic torch that illuminates the emotional semantics of each aria.

In this context, our methodology to label the emotions of each aria basically consists in the close reading of the librettos under the light of Descartes' taxonomy, in order to identify one or several passions that are suggested by the poet at a specific point of the plot. To reach this goal, we needed to examine six main features:

1. the constellation of characters and their specific circumstances: age, gender, social status, and dramatic function;
2. the relationship between characters, particularly kinship and emotional ties;
3. the implications of the eventual concealment of identity of one or more characters;
4. the succession of actions in the plot that provoke changes in the emotional status of one or more characters;
5. the addressee of the aria;
6. the actual words of both the aria poem and the recitative preceding it.

The combined analysis of these six features for each of the arias in the librettos allows their systematic classification. In this manner, each aria receives several labels, namely for:

- the emotion or emotions expressed;
- the valence (positive, negative, or neutral);
- the basic passion associated;
- the temporary reference (past, present, or future).

10 "The doctrine of temperament and emotions, concerning which especially Descartes is to be read because he has done much in music, serves very well here, since it teaches one to distinguish well between the feelings of the listener and how the forces of sound affect them" [15, part I, ch. 3, art. 51, p. 130–131].

Limiting our scope to just the five librettos by Metastasio mentioned above makes the process much simpler compared to looking at a total of (about) 3000 arias from (some) 180 scores: This way, only 182 original aria texts had to be classified according to the procedure just explained. In those librettos, we have identified a total of 25 different emotions out of the 49 categories from Descartes' taxonomy.[11] Here I would like to illustrate the process with just two examples:

Son regina e sono amante

At the beginning of the opera *Didone abbandonata* (Act I, Scene 5), Iarba, King of the Moors, disguised as his own ambassador, visits Didone, the Queen of Cartago, in her own palace. There he claims that she must marry him, otherwise she would become his enemy and be destroyed. Didone's reply in the aria "Son regina e sono amante" is a straightforward, proto-feminist statement, declaring herself to be a queen and a lover, and that no one will rule her throne or her bed. We could spend hours discussing the nuances of the emotions expressed in this aria, yet most people would agree that it is a statement of *pride*, as Didone expresses her female autonomy from male control, as well as of *boldness*, since she is bravely confronting her eventual (male) antagonist and slayer.

Misero pargoletto

In the opera *Demofoonte*, Timante, believed to be the son of the ruling king, is secretly married to Dircea, thought to be the daughter of the prime minister Matusio. Their offspring is the little boy Olinto. At the beginning of the third act, Timante finds out that Dircea is in truth Demofoonte's daughter, implying that he would have unconsciously committed the most terrible of all sins, incest, as he married his own sister and be the father of his own nephew. After a moment of despair (Act III, Scene 5), Dircea, who is unaware of this information, brings the little boy in front of the father, thus inspiring the aria "Misero pargoletto" sung by Timante to his son. The confrontation with his abhorrent crime is portrayed in an aria expressive of both *terror* for the horrible consequences of his acts, as well as *pity* towards a boy that is the fruit of unconscious evil [28]. Shortly after this aria, they find out that Timante is in fact the son of Matusio and not of Demofoonte, and therefore has not committed incest, bringing the opportunity for the *lieto fine*.

As illustrated by these two examples, our emotional labeling process is built on a careful analysis of the libretto which considers all the factors involved in the drama.

3.4 The Compilation of the Data: Towards Encoding and Annotation

The step with the biggest workload in our project is the compilation of the socio-historical data and the creation of the corpus. Most team members participate in this task, and many devote all their time to it. Among them, there are four music engravers working full-time (Carlota González, Alberto Cubero, Iván González, and David Almazán), three part-time practical musicians involved in the correction of the copies (Javier Ulises Illán, José Antonio Montaño, and Teresa Casanova), one research assistant (Gorka Rubiales), and three researchers: the musicologist Tatiana Aráez, the librettologist Valentina Anzani, and the technical supervisor and co-author of this paper, Ana Llorens, who organizes and supervises the whole procedure. Most of these team members have both music and musicology degrees, including several instrumentalists and three conductors specialized in early music: Cubero, Illán, and Montaño. The process involves several phases:

a Sources

The first phase consists in compiling a complete inventory of the sources of all the musical settings for each of the five librettos under investigation. This is not the place to explain all the requirements to locate, identify, and retrieve the poetic and musical sources of some 180 operas. Despite the substantial information available in reference works such as *The New Grove* [23], Sartori [24], RISM,[12] or Corago,[13] members of the Didone team have found many other sources not identified there [13].

11 For a detailed discussion of the application of the system to each of the librettos studied, I invite you to watch the seminars delivered by José María Domínguez and myself available on the Didone project's website: https://didone.eu/index.php/seminars/ (accessed August 12, 2021).

12 https://rism.info (accessed August 12, 2021).

13 http://corago.unibo.it (accessed August 12, 2021).

The next step is the provision of digital copies of the sources identified as most relevant to our project. This task was initially approached in partnership with several European libraries, such as the library of the Conservatoire royal de Bruxelles, the Österreichische Nationalbibliothek (Vienna), the Bibliothèque Nationale de France (Paris), the Conservatorio S. Pietro a Majella (Naples), or the Biblioteca da Ajuda (Lisbon), yet it was severely affected by the COVID-19 lockdown. To overcome this difficulty, two of our researchers (Anzani and Aráez) are currently visiting the libraries in person to make digital photographs of the musical manuscripts and poetic imprints.

b Encoding

The process of engraving and producing encoded versions of the arias faces all the challenges of making a music edition plus the additional demands of computational analysis.

The first issue in our case was to define the editorial criteria that would work for a repertoire covering some six decades and written by dozens of composers – further copied by several different hands – who used slightly different notational conventions. It soon became clear that with such a massive corpus it was not practical to follow the conventions of critical editing. Our aim is not to reconstruct the ideal version of each aria as conceived by its composer – if that were possible in this repertoire – but to obtain a clean digital copy from the most reliable source, usually the one most likely connected with the premiere of the opera. This required as a preliminary step the identification of the *codex optimus* for each opera, ideally the composer's autograph if preserved.

However, some adjustments were necessary to ensure consistency among our engraved arias, adjustments that deviate our copies from the conventions of critical, performative, or diplomatic editions. The purpose was to minimize false computational variants and to standardize the corpus. One important example is the notation of the voltas in *da capo* and *dal segno* arias, another the normalization of dynamics and articulations, and a third the interpretation of time signatures to convey a sensible hypermetric structure.

The Instituto Complutense de Ciencias Musicales (ICCMU), the research center at the Universidad Complutense de Madrid hosting the Didone project, has three decades of experience in publishing music editions of large scores, mostly opera and *zarzuela*, as well as symphonic and chamber music.[14] Since all the ICCMU editions have been engraved using Finale music software since version 1.0,[15] we took advantage of our team's expertise and decided to use that software from the beginning. Finale allows us to automatically export the corpus as MusicXML files, but it is also important that in the future our editions can be used for both digital and paper publication, as well as to extract parts for their eventual performance by orchestras and singers.

During the early phases of the project, we explored the potential advantages of other encoding formats, particularly MEI and **kern. We identified several differences and a few minor challenges in the transfer between the diverse formats, and in the end, we were able to confirm that MusicXML was the most satisfactory format for our needs [19]. This is probably due to the fact that our corpus completely responds to common notational practice and has very few unconventional requirements, as would be the case with medieval or Renaissance music.

Beyond the basic export from Finale, MusicXML has two additional advantages. On the one hand, MusicXML files can be opened with common-use music software such as Musescore, which we use for harmonic annotation.[16] On the other hand, we can benefit from the power of the music21 library to extract meaningful information from our aria files in order to apply computational analysis.[17]

c Annotation

At the start of the project, we were not aware of any effective solution that can automatically extract harmonic information from encoded symbolic music such as our corpus. We tried some applications, but they were not reliable enough, especially at junctures with double functionality or omitted roots in the chords. Since we are convinced that harmony is a major feature for music semantics, and specifically for the expression of emo-

14 https://iccmu.es/divulgacion-y-publicaciones/partituras/ (accessed August 12, 2021).

15 https://www.finalemusic.com/ (accessed August 12, 2021).

16 https://musescore.org/ (accessed August 12, 2021).

17 Our former team member Paula Muñoz Lago even contributed an improvement in version 6.5 of music21 related to lyrics processing; see https://music21-mit.blogspot.com/2020/12/music21-v65-released.html (accessed August 12, 2021).

tions, we faced the necessity of finding or developing a system to annotate and analyze the harmonic structure of our arias.

On this matter, we contacted members of the Digital and Cognitive Musicology Lab (DCML), directed by Martin Rohrmeier, at the *École Polytechnique Fédérale de Lausanne.* They had already been working on a harmonic annotation standard syntax [17], together with Python tools – including the library ms3[18] [8] – for the extraction of such annotations. Since MusicXML files vary depending on the engraving software, the DCML uses Musescore 3 to introduce and store the annotations to be extracted. Ana Llorens has been working with the DCML team for the last eighteen months to improve the standard, as well as to initiate some other shared projects. Apart from the obvious benefit to our analysis, the manual annotation of the harmony of several thousands of arias will result in a corpus of encoded music that could be used in the future for machine learning and the eventual development of more precise automatic systems of harmonic annotation.

3.5 The Database

To determine when and where the operas were premiered, or who performed them for the first time, our team of historical musicologists have had to design and build a large relational database to store all the potentially relevant data for our analytical enterprise and all the connections therein. While our guiding unit is the opera production – with its venue, date, occasion, composer, singers, librettist, etc. –, we enrich our data in a process of specification to the level of the aria, providing information on the singer's voice type and compass, key, time signature, source, variants, dramatic position, passion, etc. This approach is different from that of other databases, such as Corago, which we took as an initial model. In this way, we can combine the musical and textual information extracted computationally from the MusicXML files with the contextual and historical data in which that information emerged.

3.6 A Large-Scale Method of Analysis

The ultimate purpose of the Didone project is to identify musical features associated with the expression of emotions. To that aim, we aspire to design a model of analysis that can be applied to thousands of arias. The massive number of works to be analyzed necessarily excludes the inspection of individual details and puts the focus on parameters that can be compared on the large scale. Our music theorist Ana Llorens has defined eleven parameters by which data can be extracted from the encoded corpus, either automatically or from the manual annotations. Those are: 1) key, 2) scoring, 3) tempo, 4) melodic configuration, 5) harmony, 6) meter, 7) form, 8) rhythm, 9) texture/density (including syllabic density) and articulation, 10) dynamic structure, and 11) phrase structure.

For each of these parameters, specific metrics, or features – currently around 200 –, have been musicologically defined with a view to combine them in the analysis. Some of the features, such as those referring to key, harmony, or form, apply to the musical piece as a whole and thus can be compared without further standardization. Others, however, such as those related to melodic construction or texture/density, depend on the number of parts – or instruments – sounding in the aria. In fact, they even depend on the metric structure, the time signature of the piece, and the tempo if we consider the temporal dimension of music, this is to say, if we still want to treat music as annotated sound and not just as a symbolic entity.

That is the reason why we have defined various hierarchical levels from which to extract the data, namely the score level, the instrument level,[19] and the part level. The score-level metrics can be extracted from all arias in the corpus, whereas the instrument- and part-level metrics vary depending on the scoring or instrumentation. Therefore, several metrics are extracted only from those parts/instruments that are present in the whole corpus, such as the strings and the vocal part, whereas we aim at reflecting the influence of other instruments in other metrics extracted at the score level.

18 https://johentsch.github.io/ms3/build/html/quick.html (accessed August 12, 2021).

19 By "instrument" we refer to as many equal instruments as there are in the piece. For instance, two oboes would form a single instrument.

3.7 The Code

At this stage, we needed to extract the relevant data automatically, not just for the arias one by one, but also for groupings thereof, in order to be able to discern whether, for instance, some historical or geographical factors played a role in the way our corpus actually sounded or the way we think it sounded. Therefore, we are developing two kinds of software in the Didone project.

First, we are designing a library, musiF, which serves to extract the desired metrics for each of the arias separately. Once the data are extracted, a large data frame with several thousand rows and columns containing the data for each of the arias is created, processed, and, ultimately, analyzed. The musical/poetic metrics are placed alongside the passion(s) expressed through the aria text, according to the method explained before, as well as other metadata that will help us to interpret the data in a more historically and aesthetically informed manner.

Second, we are creating code to generate data reports, in the form of Excel spreadsheets, with the selected metrics at the aria level, but also to group the arias by a variety of historical, geographical, dramatic, and even purely musical factors. This has two main advantages: First, these reports, along the accompanying visualizations, were designed by our music theorist and can easily be interpreted by her peers, thus fostering interdisciplinary collaboration; and second, thanks to human interpretation, they allow for discrimination of stylistic, historical, or other factors that might play a role in the ways composers expressed specific texts through music, beyond the influence of the emotion of the character on the stage.

3.8 The Interpretive Phase

We are continuously developing this phase, as all perspectives of the Didone project converge here. Currently, we are experimenting with various statistical and machine learning methods to analyze the data. As a first step, our computer scientists (Daniel Ibáñez and Martín Serrano) and our senior statistician (Eduardo García-Portugués) perform some exploratory analyses (regression models, correspondence methods, decision trees, etc.) on data from a small portion of our corpus, some 500 arias. They try to determine whether there is a specific musical metric or, most plausibly, a combination of metrics that can act as good predictors for the positive vs. negative valence of the emotion(s) expressed in the aria, yet this seems too general a classification. Therefore, they have already started to focus on the six basic passions as defined by Descartes and their musical expressions, with some promising preliminary results.

In such an analysis, the music is treated ahistorically, that is, our algorithms process the data regardless of their date or geographical provenance. Yet, thanks to the data reports I mentioned before, Valentina Anzani and Ana Llorens have identified some traits specific to composers' vocal writing for the castrato Carestini in the 1740s [1], and Ana Llorens and myself have observed some metrical- and gender-related practices specific to the court Iberian productions of mid-eighteenth century [14].

Conclusion

I hope that this little promenade has illustrated the aims and procedures of the Didone project, and, more importantly, the need for interdisciplinary work in the Humanities. Choosing a complex cultural product as the main object of our investigation automatically implies going well beyond music. It requires an understanding of the poetic language, the dramaturgy, the social and political context, the contemporary codes and values, the production system, the technical resources, and the philosophical background of opera. In other words, we depart from a series of decisions grounded on historical evidence and influenced by cultural and philosophical considerations to search for answers through the application of music analysis, statistics, and algorithms to an encoded corpus of music.

The process has implied a transformation of our Musicological Toolbox. If the comprehensive study of opera necessarily calls for interdisciplinarity, massive analysis of operatic arias requires going one step further within the discipline of music itself, in an agreement between different branches of musical research. This could appear to be a simple task, but it has certainly required a substantial dose of patience, compromise, and empathy to understand and apply the procedures and requirements of colleagues from other branches. The best example is our system to engrave arias. We call it the Arias Factory, because it runs like an industrial

process involving a large part of the team. It is a process in which each member must perform specific tasks and register them in order to produce top-quality encoded versions.

We all have learned a great deal in the course: how to work together, how to fulfill our individual tasks, how the final results depend on the contributions of every member, how to leave aside our personal inclinations and needs in order to reach agreements and find solutions to each challenge. In short, we have started to define what we could call a Musicology Lab. I am using the plural because this procedure was not imposed top-down. Quite the opposite, it is the result of the input of all members, and their invaluable contributions have helped to define and polish measures and methods.

The transformation has taken place inside the group, and we have yet to expand its influence beyond our research environment. We need to demonstrate that three or more authors signing an article does not divide its value; quite the opposite, their contributions can multiply the quality of the work. We need to show that the work of a team, also in music research, can reach scientific summits that are unattainable to individual scholars. We also need to encourage financial support for new professional profiles in musicology beyond the traditional teacher-researcher. In short, we need to keep transforming the Musicological Toolbox.

As explained above, the main outcome of the Didone project will be to identify certain resources used by eighteenth-century operatic composers to express emotions. Beyond this, we foresee several collateral outputs that will hopefully benefit a wide musical and musicological community. One significant result will be the development of algorithms for corpus analysis of symbolic music that will be applicable to other corpora. Furthermore, a major fruit will be to make new editions of thousands of neglected arias accessible in digital format, which will expand the range of music available to both individual performers and operatic venues. These arias will also be distributed in MusicXML and (annotated) Musescore formats to allow other scholars to double test our analytical processes as well as to apply other methodologies to our corpus. We have already set the date to grant open access to this massive corpus: It will take place on 1 February 2024, exactly three centuries after the first *dramma per musica* by Pietro Metastasio, *Didone abandonatta*, was premiered in Naples with music by Domenico Natale Sarro. This will be our humble tribute to one of the most important figures in the history of opera.

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