SYMBOLIC MUSICAL RESYNTHESIS AS AN EKPHRASTIC COMPOSITIONAL PRACTICE USING COMPUTATIONAL METHODS

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Abstract

In my artistic work, I explore the affordances of computational methods from the discipline of artificial intelligence for music composition. Grounded in philosophical perspectives that revolve around the notions of trans- and post-humanism and cybernetics, I understand the mediating role of computers in music composition as having the potential to expand a composer's creative process by providing him with novel ways of exploring relationships between musical material and structure. Under this premise, music composition becomes a process that occurs through the assemblage between human actors and technological artifacts, and this association should result in new, interesting, and valuable artistic works. In this text, I will discuss a personal compositional practice that I understand as ekphrastic, based on the notion of symbolic resynthesis of musical symbolic information employing computational methods, as means for composing an original piece in response to the madrigal "Io Mi Son Giovinetta" by Claudio Monteverdi.

Keywords: *computer-assisted composition, symbolic resynthesis, constraint algorithms, Markov chains.*

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CULTURE CROSSROADS

Introduction

Transhumanism and extended cognition

Since the beginning of documented history, humans have desired to enhance instrumental and mental capacities, seeking to expand the boundaries of physical existence. The term *transhumanism*[1] was used for the first time by the English biologist and philosopher Julian Huxley in 1957 to inaugurate a current of thought that refuses to accept traditional human physical and cognitive limitations. The seed of transhumanism, however, can be traced back to thinkers such as Francis Bacon, Thomas Hobbes, John Locke, and Immanuel Kant, among others. While slowly overcoming the notion of *hubris*[2] during the Renaissance, after the Enlightenment, empirical science and critical reason were empowered over magical thinking, which contributed to developing the idea that people's living conditions could be significantly improved by developing scientific knowledge and technological advancements. After the Second World War, many thinkers found hope for overcoming the limits of human nature in scientific and technical progress, particularly those related to biomedical advancements that ultimately would yield human-enhanced cognitive and sensory capacities and extended lifespans[3].

The idea of extending human cognitive capacities via means of technology has been connected to the philosophy of transhumanism. One of the more relevant theories in this regard is *post-humanism*, a concept that has been extensively developed by Katherine Hayles[4]. Post-humanism, in essence, is strongly connected to the notion *intelligence*[5] as a property of the formal manipulation of symbols and

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[1] For a historical perspective on transhumanist thought, see Bostrom [2005].

[2] *Hubris,* according to *Encyclopedia Britannica*, is defined as an overweening presumption that leads a person to disregard the divinely fixed limits on human action in an ordered cosmos. The religious interpretation of the idea of a natural order given by God that couldn't be challenged was the dominant way of thought in the ancient world and in the Middle Ages.

[3] The idea of a human being whose physiological functions are enhanced artificially via biochemical or electronic modifications to the body was first proposed in 1960 by Manfred Clynes and Nathan S. Kline under the term *cyborg*, which combines the words *cybernetic* and *organism*. See Clynes & Kline [1960].

[4] N. K. Hayles [1999].

[5] The concept of intelligence has been largely debated. According to Wechsler [1939], it can be defined as "the capacity of a person to act purposefully, to think rationally, and to deal effectively with his environment." (p. 229). Wechsler believed that intelligence is composed of various specific and interrelated functions that can be individually measured. More recently, this claim has been refined proposing that intelligence involves several capacities such as abstraction, logic, understanding, self-awareness, learning, emotional knowledge, reasoning, planning, creativity, critical thinking, and problem-solving. From the post-humanist perspective, intelligence is seen mainly as the ability to perceive or infer patterns of information, as originally discussed by Alan Turing in his very influential paper "Computing Machinery and

patterns of information rather than embodied enactment in human life. Hayles defines *cognition* [2016] as a process of interpreting information in contexts that connect it with meaning and discusses the potential extension for this process using assemblages between human and *technical cognizers* that can progress to higher levels of cognition and, consequently, improve performance in extended areas of knowledge. Other theorists have also discussed the idea of an extended mind by means of technology. The cognitive scientist and philosopher Andy Clark, for example, has long advocated for a type of active e*xternal cognition*[1] distributed across humans and computers instead of internalized within the boundaries of *skin and skull*[2].

Computers and art creation

Digital computers are the most transcendental technological advancement of modern human history. Without a doubt, they represent the best example of a technical *cognizer,* as discussed by K. Hayles, or an extension of the human mind, as proposed by Andy Clark. From its initial form as large pieces of electric machinery that fitted a whole room in the 1950s until our current personal laptops, computational processing power has increased exponentially[3]. As digital computers began to spread and become more accessible, in addition to solving complex mathematical problems and many other functionalities that they facilitated, the question of whether they could be used for art creation started to arise. Writers such as Aldous Huxley and George Orwell speculated in their dystopian novels on automated technology for art generation. Particularly fascinating is the case of the *versificator* in Orwell's "1984"[4], an obscure machine responsible for generating cultural content, media, and entertainment, through an automated process without human intervention. In the book, this device is described mainly as a generator of popular songs and has an essential role as an instrument of social alienation.

Intelligence" [1950] where he basically claims that the question of whether or not machines can think will end up being irrelevant since computers will be able to mimic human behavior so well that it will be impossible to distinguish them from its creators.

[1] The notion of the *extended mind* was proposed initially by Clark & Chalmers [1998]. A. Clark has further developed this idea in his posterior writings such as Clark [2004], [2008] and [2017].

[2] A. Clark [2004], p. 5.

[3] According to a theorem known as Moore's law, computers duplicate their processing capacity every two years. Following Moore's law, authors such as H. Moravec [1988] and R. Kurzweil [2000] have predicted that computers will achieve the processing capacity of a human brain in the early 21st century and largely outperform human intelligence by the end of the century.

[4] G. Orwell (1949).

In 1956, a piece of music entirely created using a computer saw the light. The Illiac suite, composed and programmed by Lejaren Hiller and Leonard Isaacson, is considered to be the first composition written entirely using a computer program running on the ILLIAC computer at the University of Illinois. The piece consists of four movements that Hiller and Isaacson describe and entitle as *experiments*. In each, diverse algorithmic and stochastic processes are employed mainly to accept or reject randomly generated pitch and rhythmic sequences based on predefined rules[1]. Some of these algorithms were conceived as computational formalization from a counterpoint rules existing in a treatise written by Johann Joseph Fux, *Gradus ad Parnassum*, written in 1725. Hiller and Isaacson claimed that musical parameters such as pitch and duration were quantitative entities feasible for rational and mathematical analysis, and the process of music composition could be studied – at least *semi-quantitatively*[2] – as a series of choices from an essentially limitless pool of musical elements. Therefore, it should be possible to describe and formalize this process using computational methods.

By providing greater processing power, speed, and more sophisticated search methods to solve specific musical problems, computers have had an expansive effect on music composition. Along with the developments of modern affordable computers and a large number of programs that can process and generate music, more composers have accepted them as valid means for composing, even when this involves the least possible direct human intervention[3]. However, the broad public's reaction to this new type of art has usually been quite critical. Furthermore, recent psychological research has empirically shown evidence for the claim of a strong bias against computer-generated music that historically has persisted[4]. The causes of this bias are not totally understood, but Colton & Wiggins[5] suggest that one reason could be that creativity is one of the abilities that define us as an intelligent species. Societies see and defend creativity as an exclusively human capacity, and creative people and

[1] The technical description of the compositional methods used for the Illiac Suite are described in detail by Hiller and Isaacson in their paper "Musical Composition with a High-speed Digital Computer" (1958 in 2019).

[2] Ibid, p. 9.

[3] The various roles and possibilities of interaction between humans and computers for music creation have taken different levels of agency. In order to better delimitate the scope of this reflection, I will focus on the mediation of a computer in the process of generation of symbolic musical information in the form of a score. In this type of creative process, the degree of automation can vary, but it mainly functions as a dialectical flow between a computer and a human being, a composer (see Bown, 2021). I will refer to this as computer-assisted composition.

[4] Moffat & Kelly [2006].

[5] Colton & Wiggins [2012], p. 12.

their contributions to cultural development are highly valued[1]. In the same line, K. Essl has suggested that using computational means that yield automatizations in the creative processes is often seen as a *weakness of subjective autonomy*[2].

Artistic research using computational methods for music composition

In my artistic research project, I aim to divert the historical bias against computer-assisted composition from the idea of an alienating workflow and an artistically precarious outcome into a method that can widely expand the process of music composition. My primary production of artistic work is rooted in contemporary experimental score-based music composition, encompassing points of intersection between computer-assisted composition, electroacoustic music, algorithmic poetry, and generative visuals. Some of my primary artistic inquiries revolve around how the use of a computer can function as an extension of my compositional thinking, how computational processes offer the artist the opportunity to expand their creative process, and how human creativity can co-exist with computational methods or be a disturbing element as a *ghost in the machine*[3]. Composing, thus, becomes a technologically mediated action[4] where its outcome can only be conceived holistically as the sum of the roles of the actants. The creative agency of computational methods manifests as the possibility of exploring new relations within a complex and multidimensional network of musical structures, opening the door to expanding a piece's conceptual, material, and formal architecture. In the act of technologically mediated composition, humans and technological means associate in the process of affording one another new possibilities and blurring the limits between the creative responsibility of the two agents[5]. In the words of Latour, two entities with different

[1] The notion of *creativity* has been discussed by many authors. However, I find fascinating the model of creativity proposed by Margaret Boden in her book *The Creative Mind: Myths and Mechanism* [2003].

[2] K. Essl [2007], p. 108.

[3] The *dogma of the Ghost in the Machine* was proposed by the British philosopher Gilbert Ryle in his book *The Concept of Mind* [1949] as a criticism of René Descartes' mind-body dualism. In recent science fiction films and series, the title "Ghost in the Machine" has been used several times to tell a story of a human consciousness that is somehow transferred to a computer. See https://en.wikipedia.org/wiki/Ghost_in_the_Machine for a detailed summary of these titles.

[4] The notion of technological mediation was proposed by B. Latour [1994] as a derivation of Actor-Network Theory, aimed at understanding the role of techniques and technical means and their place in society.

[5] Other researchers have proposed a similar claim, such as H. Rutz [2021]. The issue of computational creative agency has also been a central issue for the project "Algorithms that matter" (2017–2020) https://almat.iem.at/ by David Pirro and H. Rutz (U. of Graz, Austria), and it is also an important topic for the research group ARIGA (U. of Graz, Austria) https://www.researchcatalogue.net/view/1318686/1318687

timing, different properties, and different ontologies fuse into a new *actant*[1]. As I understand it, this fusion yields an expanded creative potential for music composition.

Methodology

Musical ekphrasis

In the last few years, I have developed a growing interest in composing musical pieces that respond to preexisting compositions[2], an artistic approach that I understand as ekphrastic. The word *ekphrasis* originates in Ancient Greek. Most of the classic examples of ekphrasis were described in the works of classical poets or historians, such as Homer, Herodotus, and Thucydides. A widely discussed example of it is the description of the decorations in the Shield of Achilles in Homer's Iliad.[3] The modern usage[4] of the word "ekphrasis" essentially refers to a literary representation of a work of visual art. The notion of a *musical ekphrasis*[5] puts in question the conventional interpretation of ekphrasis as existing only when employing words; under this premise, ekphrasis can be reinterpreted in more general terms as an artistic practice that aims to bring other artworks to aesthetic presence. Ekphrasis, thus, comes to existence as a form of representing information from source models such as preexisting artistic works, regardless of their original medium.

My methodology for composing response pieces is oriented towards developing a compositional grammar that translates symbolic information from an existing work into a new musical representation as a form of musical ekphrasis. This process entails a highly formalistic approach where symbolic musical parameters existing in a piece are translated into numeric representations to allow their processing, analysis, and resynthesis employing computational methods. For this, I use a software

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[1] Latour [1994], p. 44.

[2] Other contemporary composers have also written pieces that respond to preexisting works. Examples are H. Zender's "Winterreise", H. Hellstenius' "Dichterliebe", Daniel Biro's "To remember and forget" in response to Schubert's quartet in G Major D. 997, and Luciano Berio, who wrote his piece "Ekphrasis" (1996) in response to one of his own compositions, "Continuo II" (1990).

[3] See Zanker's (1981) footnote no. 15, where he provides a detailed account of examples and sources for ekphrasis in the works of these classic authors.

[4] Recent authors have proposed that the meaning of the word *ekphrasis* has gone through a process of transformation from its classical in Ancient Greece, where it referred to the language used to make an audience imagine a scene, into its modern version, now exclusively referred to the description of works of art and aimed at causing some impact on the listener. For a deeper discussion on the issue of ekphrasis, see Davidson [1983], Heffernan [1991], Krieger [1967], and Webb [2013].

[5] The concept of musical ekphrasis has been discussed extensively by Goehr [2010] and Bruhn [2001].

platform consisting of diverse computer-assisted tools for music composition that I will discuss later. In order to describe my compositional processes better and explain the connection between those and the specific computational methods I employ, I have coined the terms *symbolic sonification*, *symbolic resynthesis,* and *parametrical remapping*. In this text, I will discuss the concept of symbolic resynthesis and its practical implementation for the composition of the piece "Isovell Che Segila Chentelare" for vocal octet.

Symbolic resynthesis

Resynthesis is defined as the *act of synthesizing something again: a second or subsequent synthesis, as the combination of components or elements to form a connected whole*[1]. As a compositional process, symbolic resynthesis mainly considers the problem of recreating something musically, given a descriptive model constructed from analyzing a source. In the case of composing a response piece, a source for a model for symbolic resynthesis will be some previously existing musical work. I employ mainly two computational methods to generate my symbolic resynthesis models. On the one hand, I use Markov chains to create generative systems informed by probabilistic descriptive models of elements existing in a given set of musical elements and generate new versions of the analyzed group. These elements can be musical pitches, durations, or dynamics. On the other hand, I am interested in constraint satisfaction programming as a method for generating musical structures based on observable rules or formalizations of a determined musical style or compositional practice. These two methods are considered to be encompassed within the spectrum of Artificial Intelligence techniques, according to a taxonomy devised by Fernández & Vico[2].

Computational methods

A Markov chain is a stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event. Markov chains are based on the analysis of consecutive events or *states:* the more successive states I consider for the analysis, the more similar the resynthesis will be to its source. The number of states analyzed for a Markov model is known as its *order*. For example, a Markov chain of order 0 predicts the fixed probability of an element on a set, while a Markov chain of order 3 will analyze the probability for three consecutive events to appear. Figure 1 shows an example of a Markov chain of

[1] Merriam-Webster. (n.d.). Resynthesis. In: Merriam-Webster.com dictionary. Retrieved December 27, 2022, from https://www.merriam-webster.com/dictionary/resynthesis

[2] According to Fernández & Vico [2013], Markov chains are a member of the family of *Machine Learning* techniques, and Constraint programming is considered a type of *knowledge or rule-based* system.

order 1. The nature of Markov chains can be defined as dual: on the one hand, they provide a descriptive analysis of the probabilities of a set of elements and, on the other hand, facilitate a simple generative process relying on this model. Recently, Markov chains have been used for extracting patterns in different symbolic musical domains and generating, for example, jazz improvisations or identification and recreation of the musical style of a composer[1].

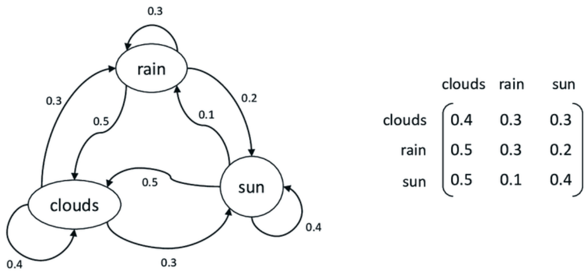

Figure 1. An example of a Markov chain of order 1 showing the probabilities of going from a weather condition to another. On the left, it is displayed as a state diagram. On the right, as a matrix with transition probabilities [Seyr & Muskulus 2019].

Another method that facilitates musical symbolic resynthesis deals with the determination of musical rules, such as harmonic, melodic, or rhythmic, and organizing musical elements by enforcing this rule or set of rules using *constraint algorithms*[2]. A constraint algorithm iteratively seeks for certain combinations of variables within a specified search space – consisting of musical information sets, such as pitches, durations, etc. – so that a specific rule or number of rules is satisfied, either entirely, using a deterministic solver, or at least partially, through a heuristic solver. The rules are usually expressed as logical statements and each candidate solution will be evaluated as *true* or *false*. Those evaluated as true are accepted and returned to the user, and those evaluated as false are rejected. In case of heuristic rules, each candidate solution is assigned a weight expressed as a numeric value. The higher the weight, the better the candidate solution fulfils the rule.

Figure 2 shows an example of how a simple constraint algorithm works. The domain – or search space – is a series of musical pitches, expressed as MIDI notes. Two deterministic rules are defined; the first one states that the first note should be 62, and the second rule states that each note should be higher than its predecessor. The result of passing an input through the search engine are several – as many as desired or as existing – sequences of values sorted according to the given rules.

[1] See Wang et al. [2016], Lui [2006] and Volchenkov & Dawin [2012].

[2] For an introduction on constraint algorithms in music composition, see Sandred [2017].

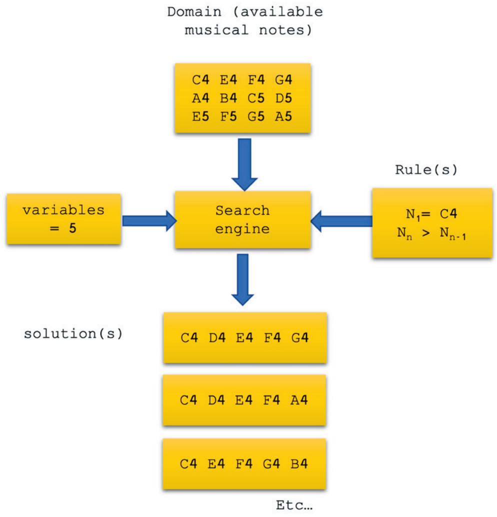

Figure 2. Example of a deterministic constraint satisfaction algorithm.

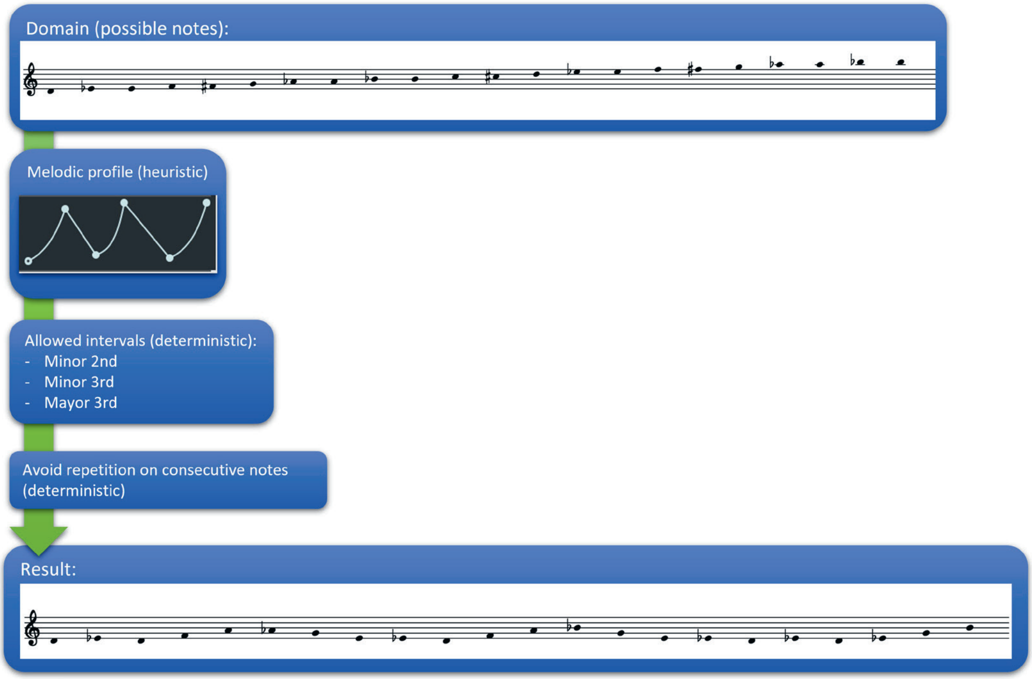

Figure 3. In this example, a given profile is applied as a heuristic rule, and two chained rules determine allowed intervals and repetitions[1].

[1] This type of rule chain was originally implemented by the composer Jacopo Baboni Schilingi. For further discussion on heuristic rules see Sandred [2017].

A more complex example of this is shown in Figure 3, where a set of musical notes is sorted heuristically according to a particular melodic profile, and a deterministic rule that will restrict the allowed melodic intervals that can occur between notes.

Compositional workflow

My platform for composing consists mainly of a large patch composed of several subpatches inside the computer program Max[1]. Max is open to external third-party objects and libraries, such as the "Bach"[2] package – composed of the libraries "Bach", "Cage" and "Dada" –, and "MOZ'lib"[3]. Bach is a free and open-source library that provides multiple tools for computer-aided composition to the Max environment. More importantly, Bach provides a well-developed music notation interface. MOZ'lib has as its primary purpose to reintroduce compositional techniques and research developed previously in LISP-based[4] computer-assisted composition programs such as PatchWork, Open Music, and PWGL into Max. It contains an implementation of PatchWorks for Max, a constraints-solving engine designed by Mikael Laursen[5], originally for the software PWGL and ported to Max by Örjan Sandred and Julien Vincenot. MOZ'lib also contains the library Cluster-Engine[6] developed by Örjan Sandred. Cluster-Engine allows to determining rules constraining simultaneously rhythm and pitch for polyphonic music, making possible for example to constrain the utilization of certain melodic or harmonic intervals depending on rhythmic figures or vice versa, among other possibilities involving the relation between musical parameters occurring in two or more simultaneous voices[7].

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[1] Max is a visual programming language for music and multimedia that allows the connection and combination of pre-designed building blocks called "objects" through cables through which different types of data flow, such as numbers, characters, text strings, lists, audio signals, among others. For more information visit https://cycling74.com/

[2] https://bachproject.net/

[3] https://github.com/JulienVincenot/MOZLib

[4] LISP is a family of programming languages that became widely used in Artificial Intelligence research. Due to its syntax and its employment of a characteristic datatype that facilitated the work with nested hierarchies similarly as they occur in a music score, it became very popular in the world of computer-assisted composition.

[5] M. Laurson [1996].

[6] Cluster-Engine was designed by Örjan Sandred originally for the PWGL environment and ported to Max MSP by Örjan Sandred and Julien Vincenot. For more information on Cluster-Engine, see Sandred [2009] and [2021].

[7] A more advanced implementation of Cluster-Engine inside MOZ'lib known as *Multi-domains* allows the determination of rules involving less conventional musical parameters such as articulation, dynamics or even lyrics.

Within my compositional workflow, the generation of musical material is not fully automated. Instead, it occurs in an *iterative*[1] fashion, where each module produces an output in the form of a musical phrase in a roll-type of notated score, and these phrases can be concatenated, joined, merged, and finally quantized into proportional notation. If the output of a module is non-satisfactory, some input parameters can be modified, yielding different outcomes.

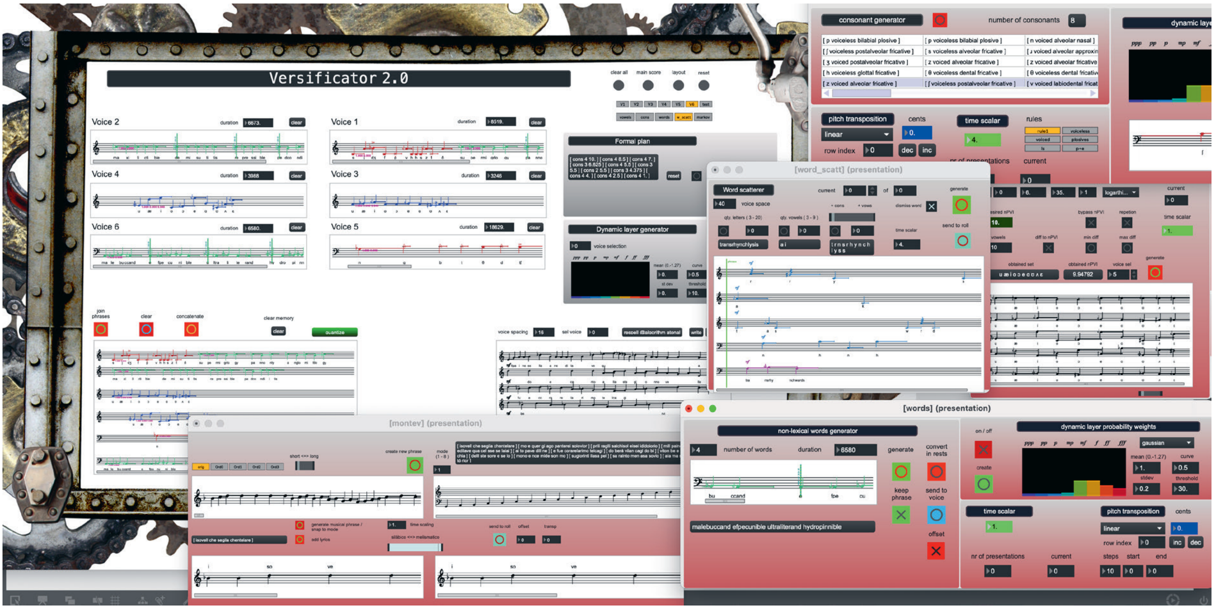

Figure 4. User interface for the Max patch employed to compose the piece "Isovell Che Segila Chentelare", consisting of a main screen and several subpatches.

Composition of the piece "Isovell Che Segila Chentelare"

This piece is a response to the madrigal "Io Mi Son Giovinnetta" by Claudio Monteverdi (1567–1643), with text by Giovanni Boccaccio (1313–1375), and the compositional idea has been driven by the notion of symbolic resynthesis at different levels of musical parameters and linguistic elements. I have defined two main approaches to resynthesizing the madrigal into an original response piece. Firstly, the use of Markov chains to generate an alternative version of the original Italian text as non-sense words or fragments of meaningful words. As explained earlier, it is possible to use different Markov orders for the process of resynthesis, which will yield more or less deviation from the source. In the case of a text, using a Markov order 0

[1] O. Bown [2021], p. 2.

will generate a completely random combination between letters and spaces, while a Markov chain of order 3 will analyze the probabilities for the occurrence of three consecutive letters, including spaces, therefore, yielding a result somewhat close to the original text and the original language. The vocalized text in the piece transits from lower to higher Markov orders, arriving at the end of the last phrase of the poem in its original form.

Table 1. Examples of alternative text snippets from the madrigal "Io mi son giovinetta" generated using Markov resynthesis in the piece "Isovell Che Segila Chentelare".

Resynthesis of the text from the madrigal *Io mi son giovinetta* (C. Monteverdi – G. Boccaccio) in the piece *Isovell Che Segila Chentelare* (J. Vassallo)				
Original text	**Markov order 0** (as an illustrative example, but not used for this piece)	**Markov order 1** (the first phrase gives the title for the piece)	**Markov order 2**	**Markov order 3**
Io mi son giovinetta E rido e canto alla stagion novella; Cantava la mia dolce pastorella; Quanto subitamente a quel canto il cor mio cantó; (etc…)	se nslirmfni n aereoaeriog ed oeiidellege e d l gomnluongraoic t (etc…)	isovell che segila chentelare mo e quer gi ago panterei soiovior prili raglli salchisol eisei addolorato (etc…)	se inettaggi rimaver mavella lagio el chi ridento che canche son giovin netto e che alla (etc…)	rido e canto sei begli occhi tuoi fiorisce ed ellin quel cor mio cantava la (etc…)

Secondly, an analytic deconstruction and posterior reconstruction of the concept of modality as a set of rules enforced by a constraint satisfaction engine that will drive the generation of polyphonic musical textures. The piece "Isovell Che Segila Chentelare" uses the idea of modality as a linear-combinatorial process constrained by rules regarding melodic movements and harmonic intervals between voices. The method for employing constraint satisfaction algorithms in the piece will be explained in detail later. But, first, it is important to understand some basic notions on how the concept of modality works in the music of Claudio Monteverdi and in a contemporary musical style, the *cool jazz*[1].

In a modal system, the melodic construction is conceived as a linear process. Any vertical combination of notes is accidental, except for some specific points, such as the cadences. This idea of linearity has long existed and developed in western music. Examples of this practice can be observed in most of the polyphonic works from the Parisian Gothic period until the Early Baroque, after which the tonal system emerged as a new form of harmonic and melodic organization. Monteverdi's madrigals are agreed to represent the old style of modal organization[2]. After the dissolution of

[1] The *cool jazz* is a genre that develops during the 1950s; chronologically, it follows the *bebop* and is contemporary with *hard bop*. For a deeper discussion on cool jazz and other jazz styles see Brendt [2002].

[2] McClary [1976].

tonality in the Early 20th century[1], the idea of linearity and independence of voices was mainly advocated by Schoenberg and the composers of the Second Viennese Second and posteriorly in the post-war period, by serial composers such as P. Boulez, K. Stockhausen, L. Nono, and others.

Jazz musicians specially developed the notion of modality and linearity for improvisation. Particularly interesting is the use of modality in the *cool jazz*, from the 1950s and on, by composers and performers such as Miles Davies, Dizzy Gillespie, John Coltrane, and Bill Evans, among others. Within the aesthetics of cool jazz, modality is used as a counterpunctual procedure, less strict in combinatorial possibilities between the voices. Each mode is defined by the intervallic structure of its corresponding scale. Ron Miller[2] proposes a categorization for the modes derived from major and melodic minor scales as being *darker* or *brighter*, depending on the position of the semitone within the intervallic structure, moving from the leftmost side of the tetrachords. The piece "Isovell Che Segila Chentelare" employs several modes organized according to Miller's categorization, appearing consecutively and moving from *darker* to *brighter*.

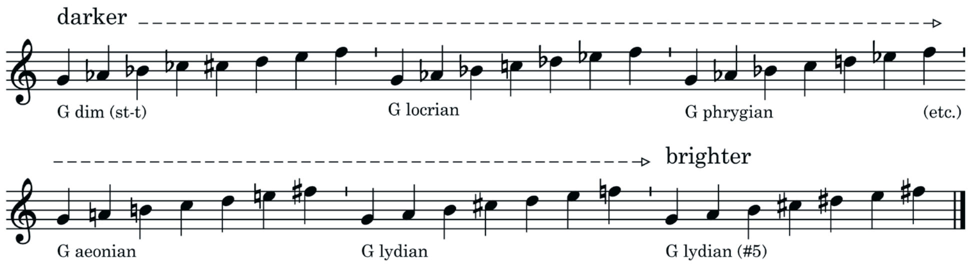

Figure 5. A modal transition from darkness to brightness, as described by Ron Miller, based on the succession of modes where the position of the semitone moves from right to left within the tetrachords.

Structurally, the piece "Isovell Che Segila Chentelare" is constructed as a succession of melodic phrases from the madrigal appearing in one of the voices in each SATB, and the rest of the voices forming a polyphonic texture. These original melodic fragments of the madrigal are labeled as *cantus* and are reconstituted in their modal structure according to a new choice of modes derived from Miller's categorization. For each *cantus* within a polyphonic texture, a different mode is used. Formally, the piece is divided into three sections. In each, the different duration proportions for simultaneously occurring voices in the polyphonic texture

[1] I take as a timepoint for the dissolution of tonality the composition of Schoenberg's 2nd string quartet, in 1908.

[2] R. Miller [1996].

resemble three types of medieval and renaissance textures: *cantus firmus* (a voice with longer-held rhythmic figures carries the cantus against a more rhythmic flow in the other voices), *discantus* (one voice has the cantus and a second voice draws a countermelody), and *contrapunctus floridus* (one voice carries the cantus and the rest of the voices draw ornamental and melismatic lines).

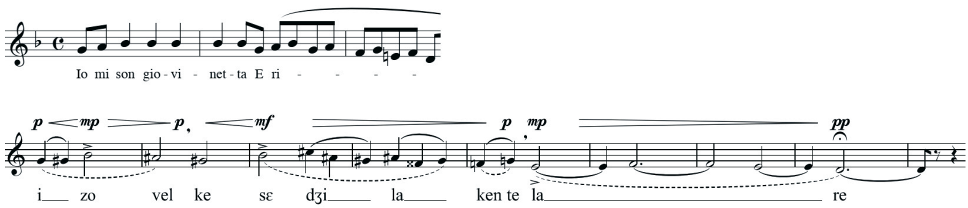

Figure 6. The upper line shows the original cantus of the madrigal, the second line shows a modal reconfiguration of it together with a rhythmic augmentation.

Rhythmically, the three textures are created by determining constraint rules that only allow specific rhythmic figures in the other voices than the *cantus*. Smaller values result in more ornamental and melismatic lines. The melismatic/syllabic quality of each voice, particularly for the *discantus* and *cantus firmus* textures, is determined by a constraint rule that checks the time scaling factor of each voice. The smaller the scaling value, the more melismatic; in other words, voices with smaller durations have few syllables and vice versa, and voices with longer durations have more syllables. Another rule is used that constrains certain voice onsets not to occur simultaneously, giving the texture more fluid linearity in particular when the voices are more ornamental. Harmonically, a constraint rule checks for certain types of resulting vertical intervallic combinations between voices on specific beats. For example, on beats 1 and 3 in a time measurement of 4/4, only harmonic intervals of minor/major third, perfect fourth/fifth, and octave can occur. Another rule prevents certain consecutive harmonic intervals between voices, such as parallel fifths and octaves. Melodically, a heuristic rule favors smaller melodic intervals for shorter rhythmic values.

It is possible to apply certain rules only to specific groups of voices. In the piece, the vocal octet has been conceived as a double choir composed of two SATB group, and the scope of the rules, in general, is restricted to each one of the two SATB groups. For example, one rule might apply to a pair of voices for generating canons to a variable interval (in general, a perfect 5th or +/− 7 semitones) or variable time interval (whole-note, half-note, or quarter-note).

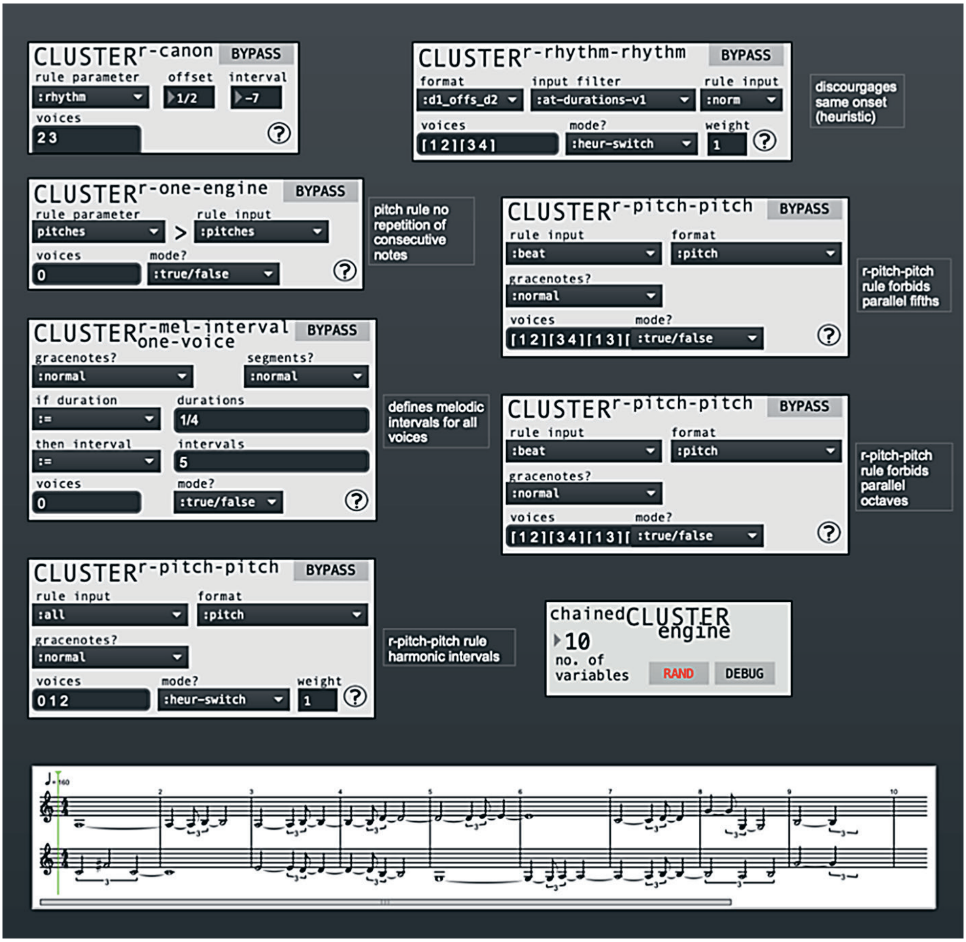

Figure 7. View of a set of chained rules that determine the generation of a musical phrase in two voices.

After the process of generation and evaluation of the outcome for each phrase, concatenation of phrases and sections, it is still necessary to export the final score into a professional music notation software and fine-tune several notation issues. Even though the notation interface offered by the "Bach" library is powerful and versatile, it is meant for something other than professional score editing and engraving. In addition, the piece must necessarily go through a phase of further compositional development *by hand* since some musical parameters still fall outside the scope of the process of symbolic resynthesis. This concerns mainly the election of tempi and vocal articulations, the addition of slurs and breathing points, and the development of a layer of dynamics for each voice.

Figure 8. Fragment of the piece "Isovell Che Segila Chentelare" for double-choir SATB.

Conclusion

In my current artistic practice, the possibility of using computer-assisted composition tools from the field of artificial intelligence provides me with greater flexibility to find solutions in a vast space of possibilities. In terms of musical symbolic information formalization and processing, computers have a central role in my compositional practice as *technical cognizers* that facilitate the exploration of new musical structural relations between a response piece and its preexisting source. Computational methods such as Markov chains and constraint algorithms can be powerful tools to carry out a process of symbolic resynthesis of musical information as a way of composing original response pieces. Historically, these methods have proven effective in the generation of interesting musical narrative.

In my compositional practice, these methods allow some flexibility to move between certain resemblance between an original response piece with its source or into more abstract generative processes that yield less recognizability. For this reason, they are well-suited for a type of artistic practice that aims to bring preexisting works of art into aesthetic presence in the form of response pieces, an approach that I understand as ekphrastic. In the current state of development of my workflow, however, these methods only allow me to work with the three central symbolic musical representations (pitch, rhythm and dynamics). Other musical parameters need to be still composed *outside* the system. I expect to develop my workflow further to include formalizations related to harmonic spectrum and timbre, to operate compositionally on them employing the aforementioned computational methods or others.

As a final remark, I consider that computational methods are effective tools for defining novel compositional strategies that facilitate an innovative exploration of musical possibilities, something that I see as an expansion of my compositional thinking.

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