A Systemic Model for Debussy's Prelude No.1

Liduino Pitombeira
Universidade Federal do Rio de Janeiro
pitombeira@musica.ufrj.br

Abstract: *This paper examines the analytical-compositional methodology called Systemic Modeling, proposed by Pitombeira as an intertextual tool that grasps deep parametric relationships within musical works. A discussion of the Theory of Compositional Systems and the Theory of Intertextuality, with examples, is provided in order to pave the way to the understanding of Systemic Modeling. Short examples of systemic modeling are given for clarification of its methodological phases. The entire Prélude No.1, by Claude Debussy, is modeled and a new piece is composed from this systemic model.*

Keywords*: Systemic Modeling. Compositional Systems. Parametric Generalization. Intertextuality. Claude Debussy.*

I. Introduction

A model, for the purpose of this article, is a representation of a musical structure on specific perspectives. Such perspectives, in terms of musical modeling, are directly related to the identification of parametric relationships amongst musical objects (pitches, chords, intervals, contours, etc.). We introduce in this article an analytical-compositional methodology called Systemic Modeling, shaped through the fusion of the Theory of Compositional Systems and the Theory of Intertextuality. Concomitantly, we propose the expansion of the concept of musical parameter, in order to observe a musical work on several levels of abstraction. As a case study, we propose the systemic modeling of Debussy's *Prélude No.1*, which will be modeled in terms of structure and voice-leading operations. Finally, a new work will be planned and composed using the systemic model of Debussy's piece as a starting point.

II. Systemic Modeling

This research started around 2010 as a means to understand the working principles and the coherence behind ten *Ponteios* by Camargo Guarnieri (1907-1993).[1] Through the application of different analytical tools (harmonic analysis, pitch-class set analysis, motivic analysis, reductive analysis, etc.) we have arrived at ten models presenting a series of general statements that explained the internal connections of those pieces with respect to specific parametric standpoints. These statements were organized into frameworks designated systemic models (or hypothetical compositional systems), as a reference to Systemic Modeling in engineering and computer sciences,

[1] Camargo Guarnieri was a Brazilian composer, pianist, and conductor, from São Paulo, who composed a vast catalogue of works inspired by Brazilian national elements. He wrote fifty *Ponteios* organized into five books. We studied the second book in 2010-11 and the first book in 2014-18.

for which "a model is a set of statements about some system under study" [21, p.27], or "an abstraction of a (real or language-based) system allowing predictions or inferences to be made" [13, p.370].

Systemic Modeling emerges as an epistemological convergence of the Theory of Compositional Systems and the Theory of Intertextuality. Therefore, before we discuss in detail the methodological aspects of Systemic Modeling, it is necessary to examine those two theories (i and iii). Additionally, we propose the expansion of the concept of musical parameter (ii). Such an expansion is fundamental since it will allow us to consider deeper representations of musical structures.

i. Compositional Systems

A compositional system is a set of relations amongst generic musical objects[2] in the scope of specific musical parameters. Compositional systems inherit their main formalization from Klir [9][3], for whom a system is a set of things and relations (Eq.1). Thus, a compositional system may be defined, for example, as a set of three things (τ_1, τ_2, τ_3) and two relations (ρ_1, ρ_2), as shown in (Eq.2), in which relation 1 (ρ_1) applied to τ_1 yields τ_2, and relation 2 (ρ_2) applied to τ_2 yields τ_3. If those things are three trichords (A, B, and C) and the relations are transpositions (T_1 and T_4), we may arrive in a very incipient compositional system such as the one showed in (Eq.3).

$$S = (\tau, \rho) \tag{1}$$

$$S_1 = ((\tau 1, \tau 2, \tau 3), (\rho 1, \rho 2)) | \rho 1(\tau 1) \rightarrow \tau 2 \wedge \rho 2(\tau 2) \rightarrow \tau 3 \tag{2}$$

$$S_1 = ((A, B, C), (T_1, T_4)) | T_1(A) \rightarrow B \wedge T_4(B) \rightarrow C \tag{3}$$

The process of assigning values to the generic objects of a system is called compositional planning (or design)[4] , which also includes: [1] the proposal of temporal articulations for these objects, and [2] the inclusion of additional parametric values (rhythm, dynamics, etc.) not considered in the system's declaration. Hence, let us assign the following value for trichord A, indicated in normal form[5] : $A = (125)$. We only need the value of A, since the other values will be determined by the relations (T_1 and T_4), i.e., $B = T1(125) = (236)$, and $C = T4(236) = (67A)$. Figure 1 shows a possible temporal articulation for the trichords, which will be distributed into three instruments (flute, oboe, and bassoon) as shown in the musical realization (Figure 2). One should notice that rhythm, dynamics, articulation, register, and timbre were freely applied to create the score.

A compositional system can be presented as [1] a set of declarations (the previous example), [2] a computational algorithm, or [3] a set of tables and diagrams. We may also think in a typology[6] consisting of three types of compositional systems: open, semi-open, and feedback (Figure 3). An open system works like a function that modifies inputs. A semi-open system has only output, which is generated by some kind of internal rule, deterministic or stochastic (the previous example is semi-open deterministic). A feedback system is found in chaotic implementations. We will provide below examples of open and feedback systems.

[2] The term object is inspired by Castrén [4]).

[3] This Theory of Compositional Systems, especially as it is defined in the master dissertation of Flávio Lima (2011)[14], written under my supervision, is also in debt to the General Systems Theory [1].

[4] For a comprehensive study of compositional design with pitch-classes see Morris [17].

[5] In this paper, normal forms are indicated inside parenthesis and prime forms are indicated inside brackets. Also, pitch classes 10 and 11 are represented by letters A and B, respectively.

[6] Our typology is loosely inspired by Durand [5].

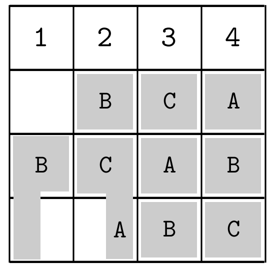


Figure 1: *A possible temporal articulation for the trichords of S_1.*

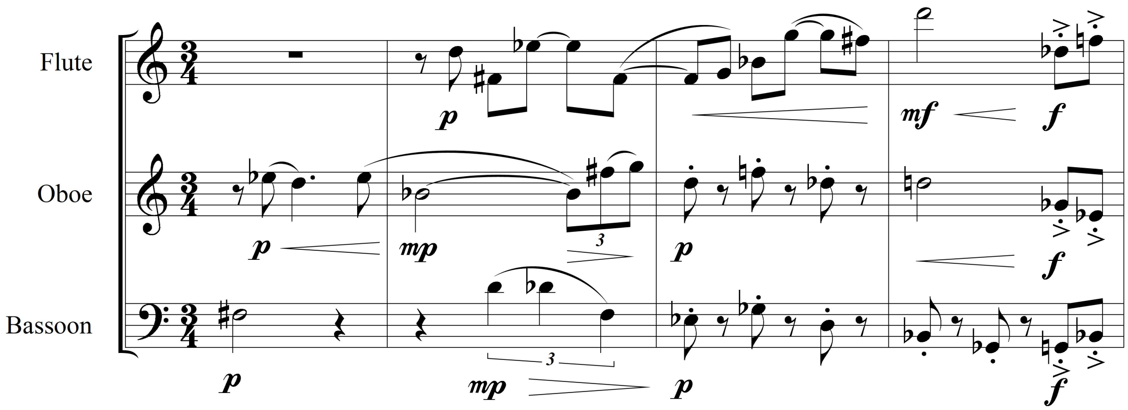


Figure 2: *A possible musical realization of the design shown in Figure 1. Trichords A = (125), B = (236), and C = (67A).*

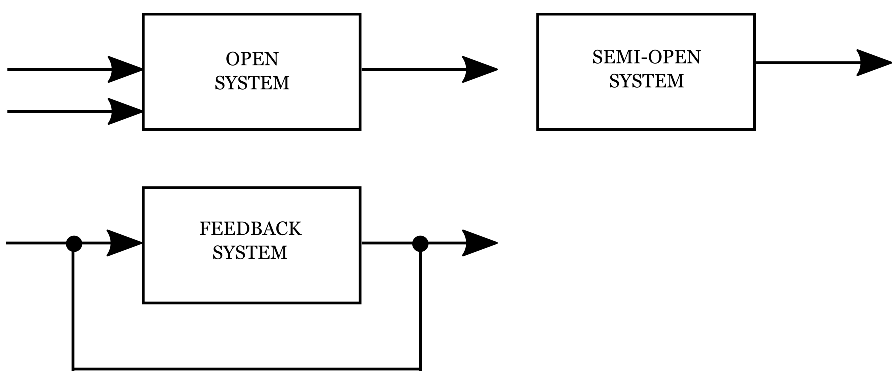


Figure 3: *Types of compositional systems.*

In order to exemplify an open compositional system let us consider the diagram of Figure 4, in which the open system S_2 receives the fragment A as input. This fragment is separated into two parametric components: pitch (B) and rhythm (C). Inputs k and w are functions defined by a composer during the compositional planning. Let us choose $k \to p = 2.p_0 - 60$, which means that the original pitch (p_0) multiplied by 2 and subtracted from 60 yields the new pitch p. Pitches, here, are measured in MIDI values, in which middle C equals 60. Therefore, the MIDI values in B (60 64 62 69 67), with the application of the rule for pitch (k), are transformed into the MIDI values in D (60 68 64 78 74). We may say that C maps onto D through operation k. Likewise, let us choose $w \to r = 2 + r_0$, i.e., each rhythmic value is added by two units. Each unit in this example equals a sixteenth note. Thus, the rhythmic values (or, more specifically, the durations) in C (6 2 7 1 8) map onto E (8 4 9 3 10) through operation w. The integration of D and E produce a new music fragment (F). Systems S_2, represented as a diagram in Figure 4, can be easily translated into a computational algorithm, as it is shown in Figure 5, using the application Octave with the MidiToolBox package [23].

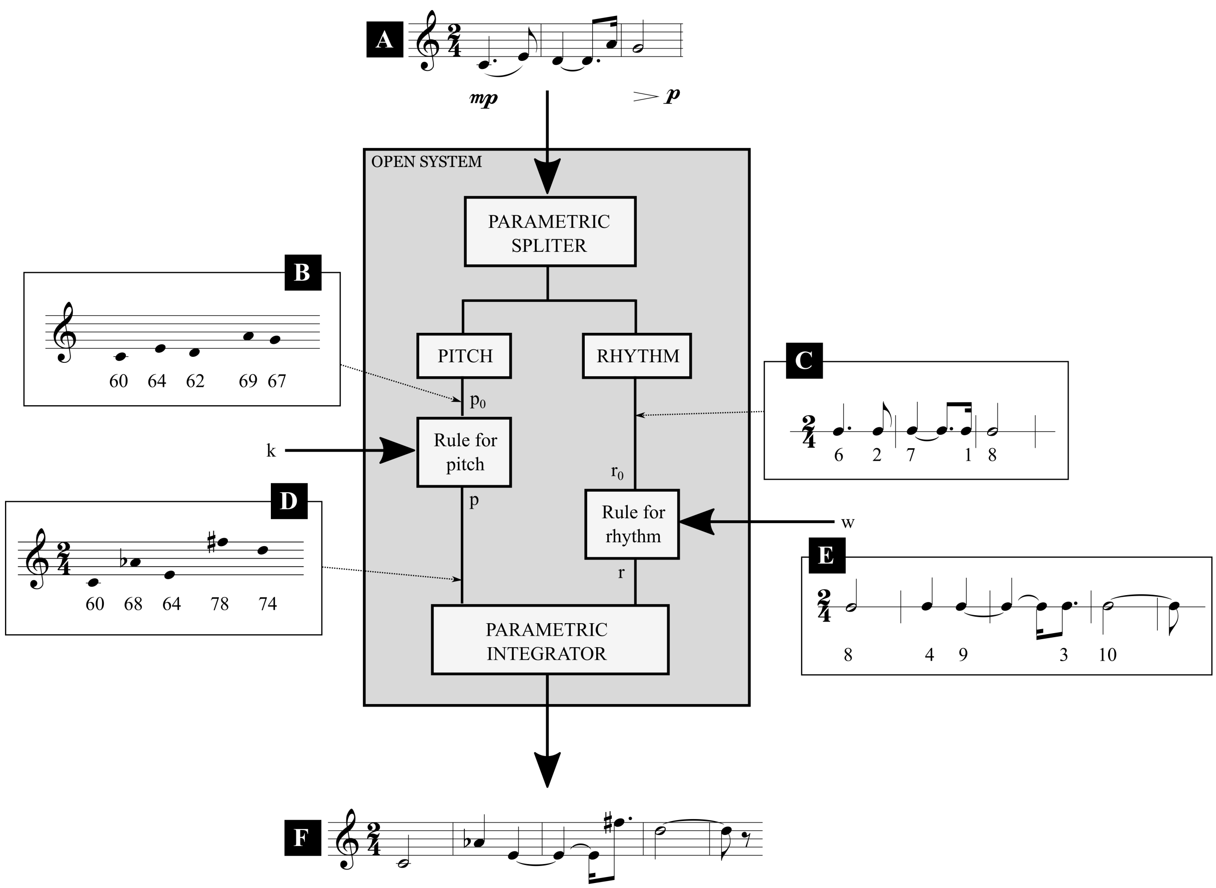


Figure 4: *An example of open system S2, in which A is the original line, B is pitch component of A, C is the rhythmic component of A, D and E are the result of operations on B and C, and F is the integration of D and E.*

```
midi2nm;
pitch = nm(:,4)'; % select only pitches and convert to row format
duration = nm(:, 2)'; % select only durations and convert to row format

newpitch = pitch*2-60; % modify pitches
newdur = duration + 0.5; % modify durations

lines = length (nm) % number of lines

Onset_ = [0]; % iniatilize the new onsets based on the new durations

for z=1:lines-1
    newvalue = Onset_(z) + newdur(z);
    Onset_ = [Onset_ newvalue];
end

Track = repmat (1,1,lines); %make a matrix for tracks with only 1s
Vel = repmat (60,1,lines); %make a matrix for velocities with only 60s

% Send the results to a new midifile

Matrizmidi_1 = Onset_';
Matrizmidi_2 = newdur';
Matrizmidi_3 = Track';
Matrizmidi_4 = newpitch';
Matrizmidi_5 = Vel';
Matrizmidi_6 = Matrizmidi_1*.5;
Matrizmidi_7 = Matrizmidi_2*.5;

Matrizmidi = [Matrizmidi_1 Matrizmidi_2 Matrizmidi_3 Matrizmidi_4 Matrizmidi_5
              Matrizmidi_6 Matrizmidi_7];

nm2midi(Matrizmidi, 'newpiece.mid');
```

Figure 5: *A simple computational rendition of S_2 using Octave and MidiToolBox.*

As an example of feedback systems we can propose the one-dimensional chaotic system called logistic map, formally defined as $x_{n+1} = k.x_n.(1 - x_n)$.[7] If k assumes a value around 4, the system becomes chaotic producing values apparently aleatoric. Figure 6 shows a very simple implementation of system S_3 as a computational algorithm written in Octave. This algorithm assigns the results of the logistic map to pitches and durations following rules that constrain the pitch space into two octaves and quantize the durations as multiples of sixteenth notes. The first six measures of a musical fragment generated with system S_3, for k equals 4 and the initial value of x equals 0.01, is shown in Figure 7. We have added articulations, tempo, and dynamics.

The systems aforementioned were created from scratch. Thus, they are original systems. As we will see later, a compositional system can also be derived from another piece, another work of art, or even from anything else that can be understood as a set of objects and relations. Before we proceed to the Theory of Intertextuality—the other theory that gave rise to Systemic Modeling—we will propose an expansion of the concept of musical parameter.

[7] A comprehensive study on chaotic systems of various dimensions applied to music can be found in Bidlack ([2]). Additional applications of one- and two-dimension chaotic systems can also be found in Pitombeira and Barbosa [18] and [19].

```
% pitch and duration matrices as well as k and value are initialized

k=4;
value=0.01;
pitches = [];
durations = [];

%calculations for durations and pitches

for n=1:100
  value=value*k*(1-value);
  pitch = mod(round(value*100),24)+60; %pitches are restricted to two octaves
  duration = ((mod(pitch,4)+1)*0.25); % durations are quantized to 16th notes
  pitches = [pitches pitch];
  durations = [durations duration];
end

music = [pitches' durations']


lines = length (music) % number of lines

Onset_ = [0]; % iniatilize the new onsets based on the new durations

for z=1:lines-1
    newvalue = Onset_(z) + durations(z);
    Onset_ = [Onset_ newvalue];
end

Track = repmat (1,1,lines); %make a matrix for tracks with only 1s
Vel = repmat (60,1,lines); %make a matrix for velocities with only 60s

% Send the results to a new midifile

Matrizmidi_1 = Onset_';
Matrizmidi_2 = durations';
Matrizmidi_3 = Track';
Matrizmidi_4 = pitches';
Matrizmidi_5 = Vel';
Matrizmidi_6 = Matrizmidi_1*.5;
Matrizmidi_7 = Matrizmidi_2*.5;

Matrizmidi = [Matrizmidi_1 Matrizmidi_2 Matrizmidi_3 Matrizmidi_4 Matrizmidi_5
              Matrizmidi_6 Matrizmidi_7];

nm2midi(Matrizmidi, 'newpiecechaos.mid');
```

Figure 6: *A simple implementation of S_3 in Octave .*

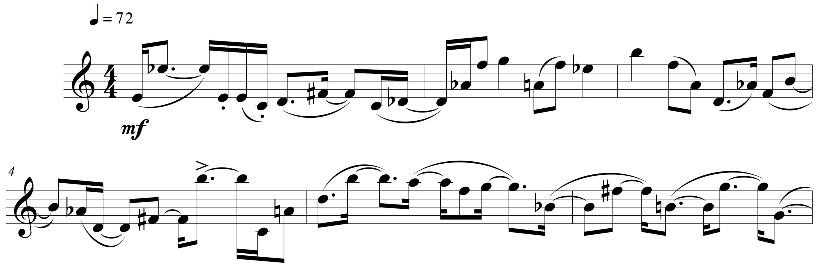


Figure 7: *A fragment generated with S_3.*

ii. The expanded concept of parameter

Musical parameters are formal descriptions of particular layers of a musical structure. Traditionally, parameters have acoustic counterparts. For example, the pitch parameter is isomorphically related to the frequency of a sound[8] , the dynamic parameter is related to the intensity of a sound, and so on. It is possible to organize parameters in terms of three internal categories (Table 1): dimension, type, and value. Thus, the pitch parameter can be observed in a musical score as an absolute entity (a note), horizontally (melodic line) and vertically (chords). A melodic line is built upon the concatenation of intervals, which can be measured considering four types: ordered pitch intervals, unordered pitch intervals, ordered pitch-class intervals, and unordered pitch-class intervals, i.e., interval classes. Moreover, melodic segments can be labeled in terms of normal and prime forms. Chords can be labeled as harmonic functions as well as normal and prime forms.

Table 1: *Categories of parameters*

Parameter	Dimension	Type	Value
Pitch	Neutral	Pitch	64 (MIDI)
		Pitch-class	4
	Horizontal	Ordered Pitch interval	19
		Unordered Pitch interval	19
		Ordered Pitch-class interval	7
		Interval class	5
	Vertical and Horizontal	Normal form	(1379)
		Set class (prime form)	[0268]
	Vertical	Harmonic function	Ger6+
Rhythm	Durational	Duration	♪
	Positional	Attack-point	3rd ♪, 3rd bar
Dynamics			mf

Furthermore, we can also classify parameters in terms of their level of salience as surface and abstract. Surface parameters are pitch (in absolute values, e.g., E4), rhythm (in durational and positional dimensions), dynamics, tempo, and articulation. Timbre represented as an encapsulated object can also be a surface parameter (for example: flute, oboe, sinewave, etc.). On the other hand, abstract parameters are related to surface parameters through some kind of non-bijective function, which means that there is no isomorphic relation between them. In other words, one can move from a surface parameter to an abstract parameter but not the other way. Consequently, there is loss of information in the mapping operation. Prime forms are good examples of abstract parameters. Let us take for example set class 0127 (shown in Figure 8). There is a function that maps each member of this class to its prime form. However, the prime form has no information about the original set (5670), which means that knowing its prime form means only to know its interval classes but not its actual pitch-classes. The same paradigm applies to contour, inversional axis, rhythmic partitions, degree of harmony endogeny, etc. When we say that a pitch segment is symmetrical around axis 0-6 we have no information about the actual pitches. As we will see later in this paper, this non-isomorphic property between surface and abstract parameters, including

[8]There is a bijective correspondence between pitches and their frequencies: $A_4 = 440Hz$, $B\flat4$ = 466.16Hz, and so on (for an equal tempered scale, with ratio $\sqrt[12]{2}$).

the loss of information, is a key concept for our modeling methodology.

Pitch-class set	{0 7 6 5}	Surface
Normal form	(5670)	
Prime form	[0127]	Abstract
Pitch contour	<0321>	
Durational contour	<2013>	
Inversional axis	0-6	

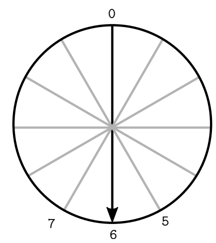


Figure 8: *Example of abstract parameters.*

iii. Intertextuality

As we have mentioned previously, the Theory of Intertextuality is also fundamental to the understanding of Systemic Modeling. The compositional use of intertextuality is not a 20th century innovation. The literature is replete with examples. The Theory of Intertextuality originated in the field of Literature. Julia Kristeva created the concept in a theoretical environment concomitantly connected with Bahktin's Dialogism and Saussurre's Semiotics. She said: "any text is constructed as a mosaic of quotations; any text is the absorption of another" [12]. Intertextuality in music has received profound investigations from Korsyn[9] [10], Straus [22], and Klein [8]. More recently, a master dissertation developed under my supervision in the Graduate Program in Music at Federal University of Rio de Janeiro as well as in the MusMat Research Group, proposed a new taxonomy for intertextual procedures in music [16]. In Mesquita's work, Systemic Modeling is a type of intertextuality that has an implicit presence and a subverted intentionality. In other words, it is an abstract intertextuality that focus on deep musical relationships, as we will examine in the next section.

iv. Systemic Modeling

Systemic Modeling aims at revealing a hypothetical compositional system (i.e., a systemic model) of a musical work. The modeled system is hypothetical since it does not necessarily express the composer's original intention. A model is achieved by focusing exclusively on relationships amongst musical parameters (surface and abstract), disregarding their particular values. Therefore, we will have a set of relationships and a set of generic objects. The borrowing of relationships (to be used in a new work) and the concomitant mention of particular parametric values from an original work is, therefore, an epistemological inheritance of both Theory of Intertextuality and Theory of Compositional Systems.

This methodology applied to music consists of three phases. The first phase is called parametric selection, which is basically achieved through a prospective analysis of a piece in order to determine the parameters that will be examined as well as the best analytical techniques to accomplish the task. The second phase is the analysis itself. It produces a structure called compositional profile, which consists of a set of objects and relationships. A systemic model is reached in the third

[9]Korsyn translates Bloom's revisionary ratios [3] to the musical domain; Straus proposes a series of eight intertextual tools for composition. Both procedures received practical applications in Flávio Lima's Master Dissertation [14].

phase—called parametric generalization—when the objects are removed from the scene and only the relationships amongst them remain.

The diagram in Figure 9 illustrates the methodological cycle of systemic modeling. In this example (a fragment from J. S. Bach's *Minuet in G major*), one starts by selecting the parameter to be examined. The pitch parameter was selected, exclusively in its horizontal dimension. Therefore, the excerpt is rewritten considering only the chosen parameter, i.e., only the pitches are examined. Then, an analysis takes place producing a compositional profile. For this analysis we considered the following criteria[10]:

1. There are three types of melodic movements or operations: [i] Conjunct (C), [ii] Leap (L), and [iii] Repetition (R). Each operation is labeled with a letter and number that indicates the number of occurrences of such operation. Operations can be combined generating an operation complex, for example L^1C^4.

2. A dashed line means that a pitch was just prolonged.

3. A full line with arrow indicates that a pitch moves onto another by means of some operation.

4. The circle means an overlap and it is used when a pitch is both the end and the start of an operational group.

Finally, the particular values are disregard and only the relationships remain. This is a possible systemic model or a hypothetical compositional system for Bach's fragment. Let us call it S_4.

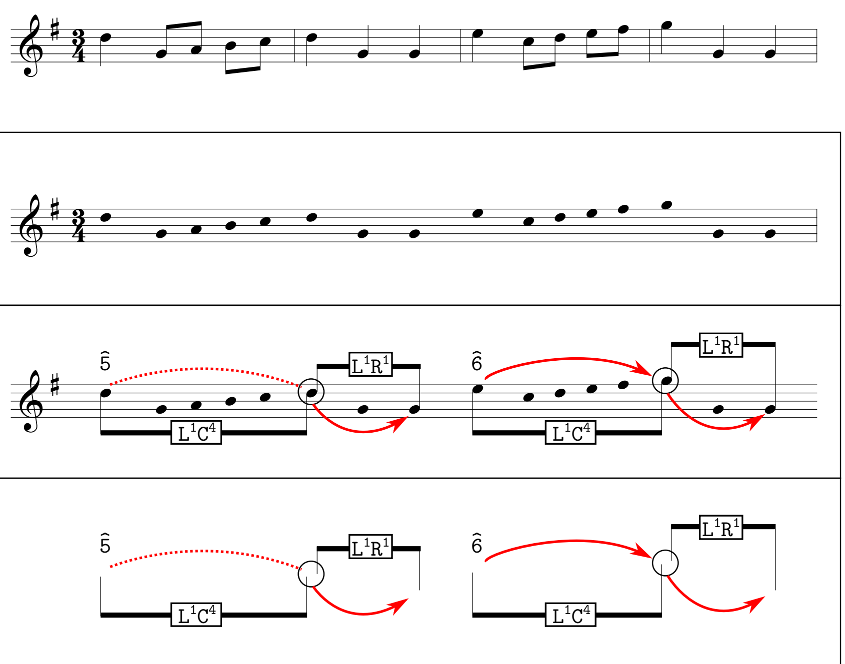


Figure 9: *The methodological cycle of systemic modeling. In the upper part we have the excerpt (J. S. Bach's Minuet in G major) that will be modeled with focus on the pitch parameter in its horizontal dimension. The systemic model appears in the parametric generalization line.*

[10]This analytical method is inspired by Kraft [11, pp.15–19]. A more interesting methodology for melodic analysis is found in Gentil-Nunes [7]. I have composed a piece for saxophone and piano (entitled *Linhas*) using this methodology.

From this model (system S_4) one can plan and compose a new fragment, which employs the same relationships of S_4 but different surface objects. We call this process Compositional Planing, which also has three phases. The first phase is called Particularization and consists of applying objects that satisfy the model relationships. Since our only starting point to compose the new fragment is the model, we have to define in advance the scale, i.e., the pitch space in which the piece will be designed. Messiaen's third Mode of Limited Transposition ($C, D, E\flat, E, G\flat, G, A\flat, B\flat, B$) will be the chosen scale. The fifth and sixth scale degrees of this mode in this transposition are respectively $G\flat$ and G. We can observe in Figure 10 that, once the systemic model does not specify direction of leap (L), the contour of the new fragment differs from Bach's contour.

The second phase of Compositional Planing is called Application. It is only necessary when the objects are abstract, i.e., when they are not surface parameters (an example will be given below).

The third phase is called Complementation and it consists of adding the parameters not declared in the system. The metric will be 5/8, the rhythmic structure and the articulations will be freely added. For the tempo we will choose quarter note equals 72, and the instrumentation will be solo clarinet.

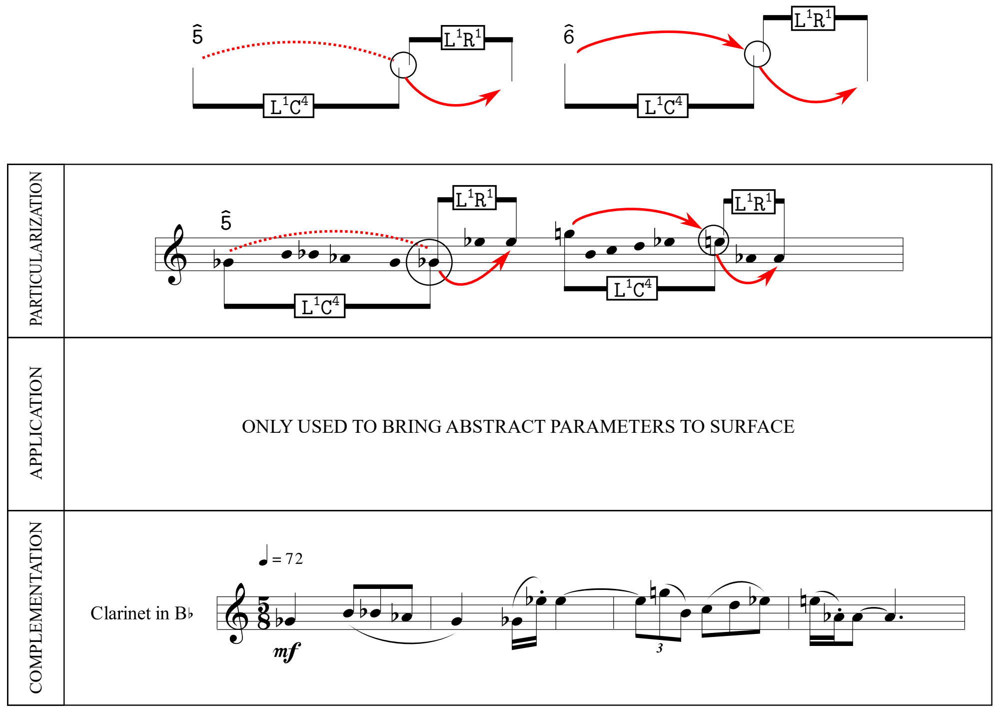
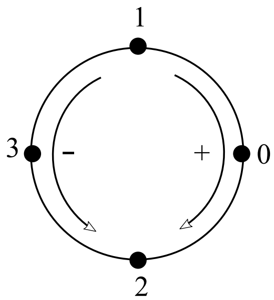


Figure 10: *Compositional planning of a new fragment from system S_4.*

The next example is from Webern's *Cello Sonata* (see Figure 13). Let us consider only the melodic contours of the first three measures of the cello part. Therefore, in the parametric selection phase, we disregard pitch, rhythm, dynamics, articulation, and timbre in order to focus only in the melodic contour. In the analytical phase, we find out that there are three segments of contours: <1023>, <2310>, and <0312>. We can search for relationships between the first contour and the others. The second contour is the inversion of the first contour.[11] To determine the relationship between first and last contours we have to define two operations: rotation (r) and subrotation (sr).

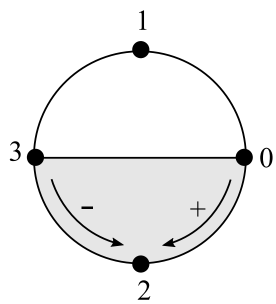
[11] The inversion of a contour C is calculated by the formula: $I(C_i) = (n-1) - C_i$, in which n is the cardinality of the contour and i varies from 1 to n. So, for the contour <1023>, with cardinality 4, C_1, i.e., the first contour point, is

If we locate contour points in a circle, the rotational operation, clockwise (r+) or counterclockwise (r-), is accomplished by starting a contour in different points.[12] For example, the contour <1023> has eight rotations, shown in Figure 11. Subrotation (sr+ and sr-) consists of freezing the first contour point and rotate the remaining points. Figure 12 shows the six subrotations of contour <1023>. Therefore, the relationship between C1 and C3 is a compound operation: rotation followed by subrotation. Figure 13 shows the systemic modeling of the first three measures of the cello part of Webern's *Cello Sonata*. The result is system S_5.



		r^+	r^-		
X	r_0^+	1 0 2 3	1 3 2 0	r_0^-	Y
R(Y)	r_1^+	0 2 3 1	3 2 0 1	r_1^-	R(X)
I(X)	r_2^+	2 3 1 0	2 0 1 3	r_2^-	I(Y)
RI(Y)	r_3^+	3 1 0 2	0 1 3 2	r_3^-	RI(X)

Figure 11: *Rotations of contour <1023>.*



sr_0^+	1 0 2 3	sr_0^-	1 0 3 2
sr_1^+	1 ...... 2 3 0	sr_1^-	1 ...... 3 2 0
sr_2^+	1 .... 3 0 2	sr_2^-	1 .... 2 0 3

Figure 12: *Subrotations of contour <1023>.*

From the systemic model shown in Figure 13, let us initiate a compositional plan. In the first phase—particularization—we reinsert objects to satisfy the model relationships. In fact, we just have to decide the first contour segment, since the others will be produced through model operations. We have chosen <0123> for the first contour segment (C1). Therefore, C2 equals <3210> and C3 equals <1302>. Those results have to be applied to surface parameters. Let us apply to the pitch parameter. This is shown in the results for the second phase—application (see Figure 14).

In the last phase—complementation—we introduce parameters not present in the systemic model. So, we have chosen tempo (72), metric (6/8), timbre (clarinet), and rhythm, articulations and dynamics shown in Figure 14.

1. Therefore, applying the formula, we will have $I(1) = (4-1) - 1 = 2$. For the second contour point we will have $I(0) = (4-1) - 0 = 3$, and so on. For a more comprehensive study on contour operations see [15], [17], and [20].

[12] Contour rotations are defined in a different fashion in [6]. One can observe that rotations produce also the canonic operations (original, inversion, retrograde, and inversion of the retrograde).

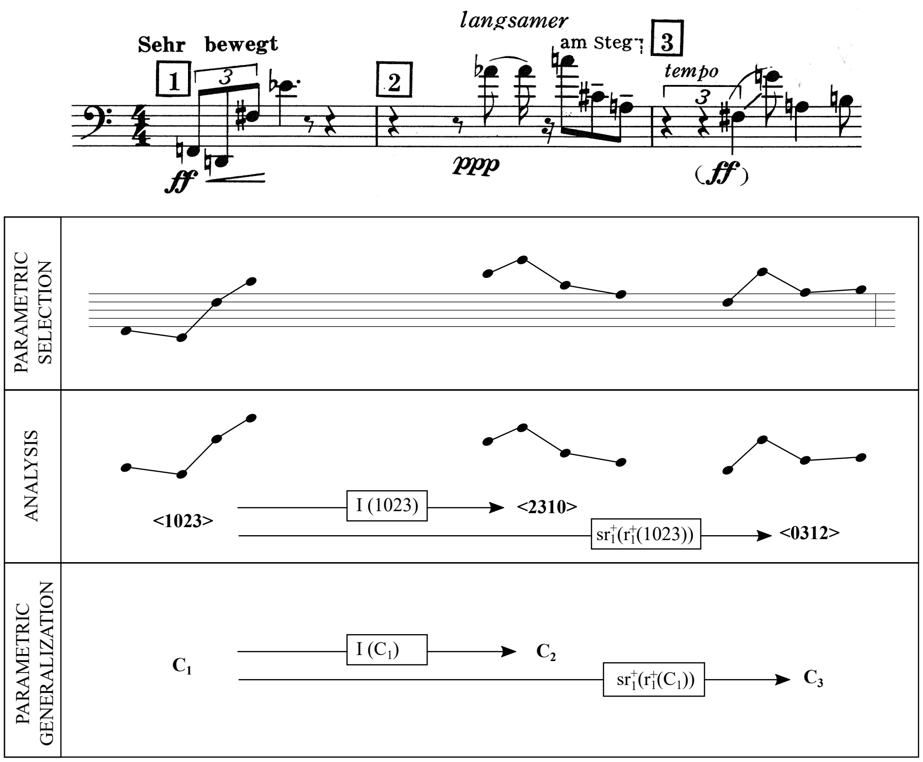


Figure 13: *S_5: systemic modeling of the first gestures of Webern's Cello Sonata.*

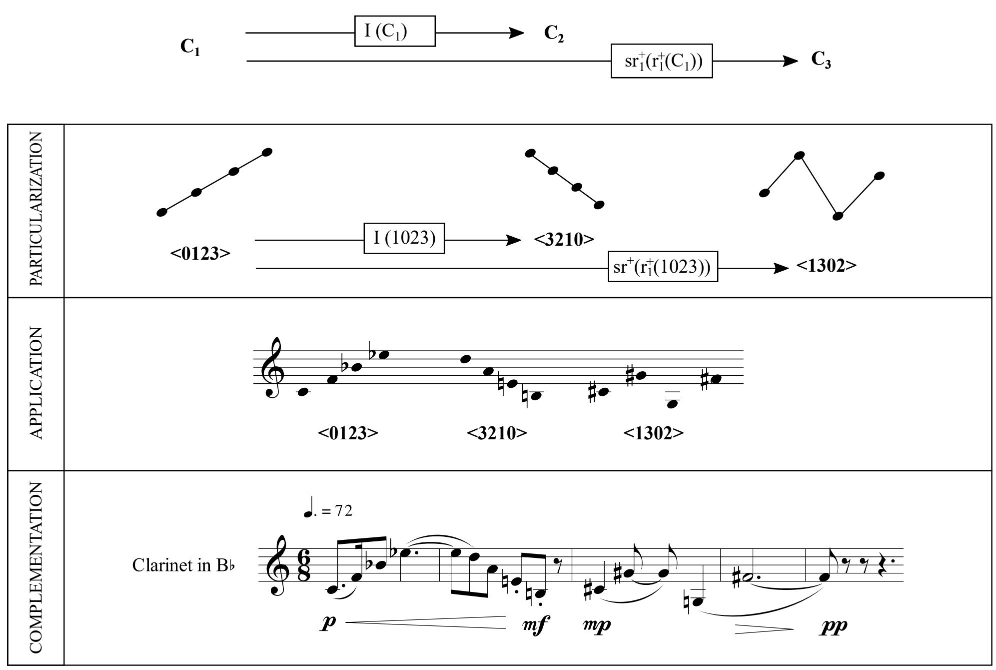


Figure 14: *Compositional planning of a new fragment from system S_5.*

III. Systemic Modeling of Debussy's *Prélude No.1*

Debussy's Prélude No.1, from the first book of Préludes, has loosely a form AA'BA"+ coda. Figure 15 shows section A (its first five measures). Through this figure we demonstrate our analytical strategy, which consists of focusing on the form as well as on the pitch parameter, in both its vertical and horizontal dimensions. Therefore, the passage, was divided into four melodic segments (a1, a1, a2, and a3) and 21 chords (labeled inside gray circles). The segment a3 is particularly idiomatic in terms of Debussy's aesthetical language since it is built with a voice-leading technique called *planning*. The melodic lines of segments a1 and a2 are built from a combination of chord notes (in the downbeats) with ornamental notes (passing and neighbor notes and an interpolation at the end of segment a2). The 21 chords of section A were modeled in terms of voice-leading operations and the relations amongst them, shown in Table 3, were translated into an algorithm in Python (show in Figure 16). Thus, the first chord (labeled X1), with cardinality 3, is transformed into the second one (X2), with cardinality 4, through the application of two operations: pitch-class A is split into 9 and B, and pitch-classes 2 and 5 move to pitch-classes 3 and 7 through parsimonious movement (+1 and +2, respectively). The same procedure goes for the remaining chords. The algorithm allows us, by changing only the first trichord, to build a new set of chords having the same relationships of the original piece. Such a possibility is of fundamental importance during the compositional planning of a new work. Through the application of the same analytical paradigm for the remaining sections we arrive at the following conclusions:

1. Section A' (mm.6-10) differs from section A only in the chords onset and register: chords are shifted by an eight note forward and filled up with repeated pitch-classes in different registers in a planning-like style; segment a3 is basically the same (except for a metric change to 4/4);
2. Section B (mm.11–24) is formed by five segments:
   (a) b1 and b1' (mm.11–14) are basically formed by the juxtaposition of a pedal note (same lowest note of the last chord of segment a3), an ascending planning, and a descending melodic line built exclusively on $B\flat$ pentatonic (b1) and $E\flat$ pentatonic (b1').
   (b) b2, b3, and b4 (right hand of the piano) are built on the chromatic scale, except for one pitch-class ($B\flat$). Segments b2 and b3 have a definite pitch centricity: the first pitch-class of b1 for the segment b2, and the first pitch-class of b1' for b3. The latter is formed by two statements of a motive in two measures, ending with the centric note. Chords in b3 are treated as a separate layer. Therefore, the melodic motive does not collaborate to chord formation in this section. This decision has the purpose of analytical simplification, since the chords are clearly triadic material, which would be interpreted otherwise if we had considered the notes of the melodic line. The last nine pitches of b4 are formed by arpeggios of chord X_1: $T_5I(X_1), T_7I(X_1)$, and $T_6I(X_1)$.
3. Section A" is formed by two segments a1', that differs from the original (a1) by an eight-note shift of the first pitch and by the use of *planning*.
4. Coda is built with four chords (the two last ones are the very first chord) against a bass alternation of two pitch-classes: the lowest note of the first chord and the lowest note of the last chord of section A.

The generalization of these analytical conclusions yields the systemic modeling for Debussy's Prélude, shown in Table 2.

Table 2: *One possible systemic modeling for Debussy's Prélude No.1*

Section	Measures	Segment	Comments
A	1	a1	Chord notes in the downbeat + nonchord tones
	2	a1	
	3–4.2.1	a2	Same as a1
	4.2.2–5	a3	Planning
A′	6	a1′	a1 shifted by an eight note forward and filled up with repeated pitch-classes in different registers
	7	a1′	
	8–9.2.1	a2′	Same as a1′
	9.2.2–10	a3	
B	11–12	b1	Juxtaposition of a pedal note (same lowest note of the last chord of segment a3), a planning, and a melodic line built exclusively on pentatonic scales.
	13–14	b1′	
	15–17	b2	b2, b3, and b4 are built on the chromatic scale, except for one pitch-class. Segments b2 and b3 have a definite pitch centricity: the first pitch-class of b1 for the segment b2, and the first pitch-class of b1′ for b3. The latter is formed by two statements of a motive in two measures, ending with the centric note. Chords in b3 are treated as a separate layer. Therefore, the melodic motive does not collaborate to chord formation in this section. The last nine pitches of b4 are formed by arpeggios of chord X_1: $T_5I(X_1), T_7I(X_1)$, and $T_6I(X_1)$.
	18–20	b3	
	21–24	b4	
A″	25	a1″	Shift of the first pitch and use of planning
	26	a1″	
Coda	27–31		Built with four chords (the two last ones are the very first chord) against a bass alternation of two pitch-classes: the lowest note of the first chord and the lowest note of the last chord of section A.

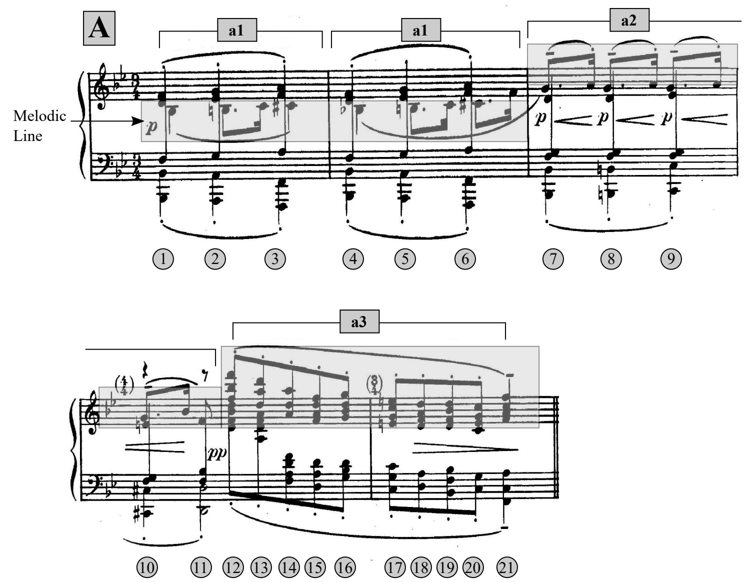


Figure 15: *Debussy's Prélude No.1, section A (mm.1–5) showing chords and melodic segments.*

Table 3: *Chords of section A of Debussy's Prélude No.1, and their relations.*

Measure	Beat	Chord	pcs			
1	1	**X1**	**A**		**2**	**5**
			-1	+1	+1	+2
	2	**X2**	**9**	**B**	**3**	**7**
			(-4)	+2	+2	+2
	3	**X3**	**5**	**1**	**5**	**9**
			—	—	—	—
2	1	**X4**	**A**		**2**	**5**
			-1	+1	+1	+2
	2	**X5**	**9**	**B**	**3**	**7**
			(-4)	+2	+2	+2
	3	**X6**	**5**	**1**	**5**	**9**
			+5	+1	+0	-2
3	1	**X7**	**A**	**2**	**5**	**7**
			+1	+0	+0	+0
	2	**X8**	**B**	**2**	**5**	**7**
			+1	+1	+0	+0
	3	**X9**	**0**	**3**	**5**	**7**
			+1	+1	+0	+0
4	1	**X10**	**1**	**4**	**5**	**7**
			+1	+1	+0	+3
	2	**X11**	**2**	**5**	**5**	**A**
			+0	+0	—	+0
		X12	**2**	**5**		**A**
			+0	+0		-1
	3	**X13**	**2**	**5**		**9**
			+0	+0		+0
		X14	**2**	**5**		**9**
			+0	+0		+0
	4	**X15**	**2**	**5**		**9**
			+0	+2		+1
		X16	**2**	**7**		**A**
			+2	+0		+2
5	1	**X17**	**4**	**7**		**0**
			+1	+2		+2
		X18	**5**	**9**		**2**
			+0	+1		+0
	2	**X19**	**5**	**A**		**2**
			-1	-3		-2
		X20	**4**	**7**		**0**
			+1	+2		+0
	3	**X21**	**5**	**9**		**0**

```
"""
Created on Tue Oct  9 21:18:17 2018
Debussy Prelude 1 -- model for chords
@author: Liduino Pitombeira
"""

Entrada = input('Enter with a trichord in the format xyz using a for 10 and b for 11:')
print('')

Gen=[]

# Convert Entrada to a list of integers base 12
for i in range(3):
    x = int(Entrada[i],12)
    Gen.append(x)

#Calculates the chords contents

#SECTIONS A A'
X1 = Gen
X2 = [(Gen[0]-1)%12,(Gen[0]+1)%12,(Gen[1]+1)%12, (Gen[2]+2)%12]
X3 = [(X2[2]+2)%12, (X2[1]+2)%12, (X2[2]+2)%12, (X2[3]+2)%12]
X4 = Gen
X5 = X2
X6 = X3
X7 = [(X6[0]+5)%12, (X6[1]+1)%12, (X6[2])%12, (X6[3]-2)%12]
X8 = [(X7[0]+1)%12, (X7[1])%12, (X7[2])%12, (X7[3])%12]
X9 = [(X8[0]+1)%12, (X8[1]+1)%12, (X8[2])%12, (X8[3])%12]
X10 = [(X9[0]+1)%12, (X9[1]+1)%12, (X9[2])%12, (X9[3])%12]
X11 = [(X10[0]+1)%12, (X10[1]+1)%12, (X10[2])%12, (X10[3]+3)%12]
X12 = [(X11[0])%12, (X11[1])%12, (X11[3])%12]
X13 = [(X12[0])%12, (X12[1])%12, (X12[2]-1)%12]
X14 = X13
X15 = X14
X16 = [(X15[0])%12, (X15[1]+2)%12, (X15[2]+1)%12]
X17 = [(X16[0]+2)%12, (X16[1])%12, (X16[2]+2)%12]
X18 = [(X17[0]+1)%12, (X17[1]+2)%12, (X17[2]+2)%12]
X19 = [(X18[0])%12, (X18[1]+1)%12, (X18[2])%12]
X20 = [(X19[0]-1)%12, (X19[1]-3)%12, (X19[2]-2)%12]
X21 = [(X20[0]+1)%12, (X20[1]+2)%12, (X20[2])%12]
```

Figure 16: *Algorithm for the chords of section A of Debussy's Prélude No.1.*

The systemic model for Debussy's *Prélude No.1* consists of a generalization of the analytical conclusions (show in Table 2). The chords' grammar is encapsulated into a Python algorithm (part of it is shown in Figure 16). If we generalize the pentatonic scales of subsection b1, Table 2 is already in the format of a generalized compositional system. From this system, we will describe the compositional planning of a new piece, in the next section of this article.

IV. Compositional Planning of *Le sphinx des Naxiens*

Based on the algorithm for Debussy's *Prélude No.1* (Figure 16), using a first chord (037) different from the original (A25), we have determined a new set of chords (Table 4) that will be the basis for a new piece: the first movement of *Trois Monuments*, for piano. This movement is entitled *Les sphinx des Naxiens*. The title is a reference to monuments of the Delphi Sanctuary, similarly how it was applied in Debussy's *Prélude No.*1, which is entitled *Danseuses de Delphes*, a fragment of sculpture from Apolo's temple in Delphi. The other two movements of *Trois Monuments* were also composed with the use of intertextuality. *Le pillier des Rhodiens* employed a type of stylistic intertextuality by the use a modal melody in a planning set, pedal points, and ostinatos. *Le trésor des Athéniens* is built by the juxtaposition of one-measure quotations (and developments) from all the twelve Préludes of the first Book.

The new piece has the same number of measures of Debussy's piece (31) but different time signatures (2/4 + 3/8 and two occurrences of 3/4 + 3/8). The first task was to distribute the chords of Table 4 through those 31 measures. After that we built the melodic segments following the rules declared in Table 2, with respect to the use of nonchord tones, *planning*, scalar material, centricity, and initial pitch-class. In Figure 17 one can see that the segment a1 uses chords X01, X02, and X03. The upper pitches form the melodic line for this segment (in green) to which is added the nonchord tone E (in red). Segment a3 (with a square frame) is built with the use of *planning*. In Figure 17, important observations taken from Debussy's systemic model (Table 2) are highlighted, in order to make it easy to compare the musical realization with the system itself. Information regarding other parameters not declared in the systemic model was freely determined during the compositional process.

Table 4: *Chords of Pitombeira's Le sphinx des Naxiens, generated by the Python algorithm of Debussy's Prélude No.1.*

Sections A and A'	Section B	Section A'' + Coda
X01= [0, 3, 7]	X22= [5, 9, 2]	X60= [0, 3, 7]
X02= [11, 1, 4, 9]	X23= [6, 11, 4]	X61= [1, 4, 9]
X03= [6, 3, 6, 11]	X24= [8, 0, 5]	X62= [2, 5, 10]
X04= [0, 3, 7]	X25= [10, 2, 7]	X63= [3, 6, 11]
X05= [11, 1, 4, 9]	X26= [11, 4, 9]	X64= [0, 3, 7]
X06= [6, 3, 6, 11]	X27= [1, 6, 11]	X65= [1, 4, 9]
X07= [11, 4, 6, 9]	X28= [3, 7, 0]	X66= [2, 5, 10]
X08= [0, 4, 6, 9]	X29= [4, 9, 2]	X67= [3, 6, 11]
X09= [1, 5, 6, 9]	X30= [4, 10, 2]	X68= [3, 6, 8, 11]
X10= [2, 6, 6, 9]	X31= [6, 0, 4]	X69= [3, 6, 8, 11]
X11= [3, 7, 6, 0]	X32= [8, 2, 5]	X70= [0, 3, 7]
X12= [3, 7, 0]	X33= [9, 3, 7]	X71= [0, 3, 7]
X13= [3, 7, 11]	X34= [11, 5, 9]	
X14= [3, 7, 11]	X35= [1, 7, 11]	
X15= [3, 7, 11]	X36= [3, 9, 1]	
X16= [3, 9, 0]	X37= [6, 0, 3]	
X17= [5, 9, 2]	X38= [8, 2, 6]	
X18= [6, 11, 4]	X39= [10, 3, 6]	
X19= [6, 0, 4]	X40= [0, 5, 8]	
X20= [5, 9, 2]	X41= [1, 6, 9]	
X21= [6, 11, 2]	X42= [1, 3, 7, 9, 11]	
	X43= [1, 3, 6, 9, 11]	
	X44= [1, 3, 7, 9, 11]	
	X45= [1, 3, 6, 9, 11]	
	X46= [1, 4, 10]	
	X47= [11, 3, 9]	
	X48= [10, 1, 7]	
	X49= [11, 3, 7]	
	X50= [9, 2, 7]	
	X51= [9, 1, 5]	
	X52= [7, 0, 5]	
	X53= [8, 11, 5]	
	X54= [6, 11, 4]	
	X55= [6, 9, 5]	
	X56= [6, 10, 2]	
	X57= [5, 10, 3]	
	X58= [5, 8, 2]	
	X59= [5, 9, 1]	

We have discussed in this paper the theoretical aspects of Systemic Modeling, including its genealogical connection with the Theory of Compositional Systems and the Theory of Intertextuality. Examples of compositional systems (open, semi-open, and feedback) were given for methodological clarification. We also have proposed an expansion of the concept of musical parameter in order to include abstract characteristics of a musical text. The cycles of Systemic Modeling and Compositional Planning were examined in detail with the aid of two hypothetical examples. Finally, we have modeled the first *Prélude* of Debussy with the purpose of composing a new piece from its systemic model. This methodology has been studied by the author of this paper since 2010. Presently, it has been the main topic of two research projects developed in the Graduate Program of Music of the Federal University of Rio de Janeiro, as well as in the MusMat Research Group[13]. Approximately 20 new pieces were produced from systemic models by Pitombeira and also by his Graduate and Undergraduate students.

[13] http://musmat.org

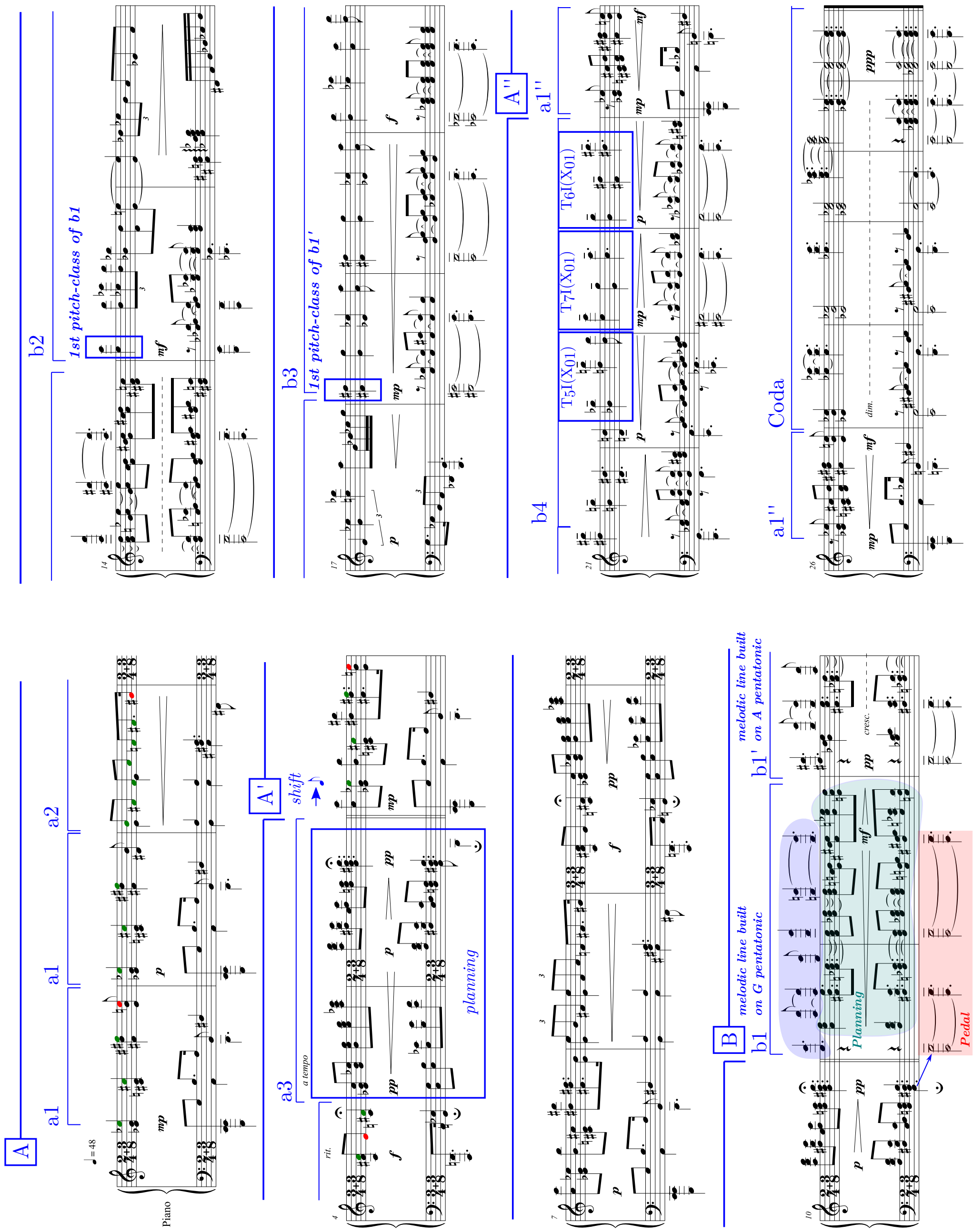


Figure 17: *Pitombeira's Le sphinx des Naxiens, first movement ofTrois Monuments.*

References

[1] Bertalanffy, L. 1968. *General Systems Theory*. New York: George Braziller.

[2] Bidlack,Rick. 1992. Chaotic Systems as Simple (But Complex) Compositional Algorithms. *Computer Music Journal*, V.16, N.3, 1992, pp. 33–47.

[3] Bloom, Harold. 2002. *The Anxiety of Influence:* a Theory of Poetry. New York: Oxford University Presso.

[4] Castrén, Marcus. 1999. Identifying Aspects of Similarity Between Musical Objects: A Pitch-Class Set-Theoretical Approach. *Systems Research in Arts*, V.1 (Musicology), George Lasker, Ed. pp. 6–9.

[5] Durand, Daniel. 1996. *La systémique*. Paris: Presses Universitaires de France.

[6] Friedmann, Michael L. 1985. A Methodology for the Discussion of Contour: Its Application to Schoenberg's "Music". *Journal of Music Theory*, V.29, N.2, pp.223-248.

[7] Gentil-Nunes, Pauxy. 2011. *Análise particional:* uma mediação entre composição musical e a teoria das partições. Doctoral Thesis, Universidade Federal do Estado do Rio de Janeiro.

[8] Klein, Michael L. 2005. *Intertextuality in Western Art Music*. Bloomington and Indianapolis: Indiana University Press.

[9] Klir, George. 2001. *Facets of Systems Science*. New York: Kluwer.

[10] Korsyn, Kevin. 1991. Toward a New Poetics of Musical Influence. *Music and Analysis*, V.1, N.12, pp. 3–72.

[11] Kraft, Leo. 1990. *Gradus:* an Integrated Approach to Harmony, Counterpoint, and Analysis. New York: W.W.Norton.

[12] Kristeva, Julia. 1980. *Desire in Language:* A Semiotic Approach to Literature and Art. New York: Columbia University Press.

[13] Kühne,Thomas. 2009. Matters of (Meta-) Modeling. *Journal on Software and Systems Modeling*, V.5, N.4, pp. 369–385.

[14] Lima, Flávio. 2011. *Desenvolvimento de Sistemas Composicionais a partir da Intertextualidade*. Master Dissertation, Universidade Federal da Paraíba.

[15] Marvin, Elizabeth West. 1988. *A Generalized Theory of Musical Contour:* Its Application to Melodic and Rhythmic Analysis of Non-Tonal Music and its Perceptual and Pedagogical Implications. PhD Dissertation, University of Rochester.

[16] Mesquita, Gabriel. 2018. *A Acústica da Influência:* uma recomposição da interextualidade na música. Master Dissertation, Universidade Federal do Rio de Janeiro.

[17] Morris, Robert. 1988. *Compositional Design with Pitch-Classes:* A Theory of Compositional Design. New Haven: Yale University Press.

[18] Pitombeira, Liduino; and Barbosa, Hildegard. 2009. Planejamento composicional a partir de sistemas caóticos. *Anais do XIX Congresso da ANPPOM*, Curitiba, 2009 pp. 485–488.

[19] Pitombeira, Liduino; and Barbosa, Hildegard. 2010. Geração de Parâmetros Composicionais a partir da Implementação Computacional de Sistemas Dinâmicos. *Anais do 8o. Congresso de Engenharia de Áudio 14a. Convenção Nacional da AES Brasil*, São Paulo, 2010, pp. 1–4.

[20] Sampaio, Marcos.2012. *A Teoria das Relações de Contornos Musicais:* Inconsistências, Soluções e Ferramentas. Doctoral Thesis, Universidade Federal da Bahia.

[21] Seidewitz,Ed. 2009. What Models Mean. *IEEE Software*, Sep/Oct 2003, pp. 26–32.

[22] Straus, Joseph N. 1990. *Remaking the Past:* Musical Modernism and the Influence of the Tonal Tradition. Cambridge, Massachusetts : Harvard University Press.

[23] Toiviainen, P., and Eerola, T. 2016. MIDI Toolbox 1.1. *URL: https://github.com/miditoolbox/1.1*