SOAL for music analysis

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SOAL FOR MUSIC ANALYSIS : A STUDY CASE WITH BERIO'S *SEQUENZA IV*

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ABSTRACT

This paper presents some functionalities of *SOAL* — *SonicObjectAnalysisLibrary*, a set of tools implemented in the *OpenMusic* ambient. We describe a study case, using *SOAL* for discovering some aspects of the harmonic syntax of Luciano Berio's *Sequenza IV* for piano. *SOAL* is a library of tools for music analysis, which is specially, although not exclusively, intended for the study of non-tonal and non-serial music. Thus Berio's music, namely this *Sequenza*, suits quite well for demonstrating *SOAL* capability in aiding music analysis. We first present the background concepts of *SOAL*, and how it works. Then we point towards some structural aspects of the Berio's piece, focusing the eclecticism of its harmonic syntax. After showing how *SOAL* was used in this context, we finally select and present some results which should contribute for a formal analysis of the piece.

1. *SOAL* FOR ANALYZING MUSIC

SOAL is intended to be useful for a range of analytic purposes, in situations where a 'top-bottom' approach is more or equally pertinent that a 'bottom-up' one. The root of *SOAL* background concept is the *sonic object*, here defined as the combination and interaction of musical 'primary' components (a collection of pitch-classes) with 'secondary' components — namely intensities, ranges, registering, densities, modalities of pitch statistical distribution, and global level effects (such as pedaling for the piano). The idea is to infer musical structures by comparing the relative sonic qualities of a sequence of such objects. This analytic paradigm is intended to complete, or to substitute in some cases, data obtained from more classical 'low-level' approaches, such as pitch-classes analytic methods.

SOAL tools are grouped into two main categories according to their scope. Each category has its corresponding folder in the standard *OpenMusic* library format. The first one addresses spatial sonic qualities, i.e. 'vertical' structuring, disregarding time distribution of events (Xenakis' *hors-temps* concept): these tools are displayed in the 'Achronic Analysis' folder. The second category concerns temporal qualities, i.e. 'horizontal', *en-temps* structuring of sonic objects: these are the 'Diachronic Folder' tools. Complementary folders include functions oriented to piano music analysis, and generic utilities.

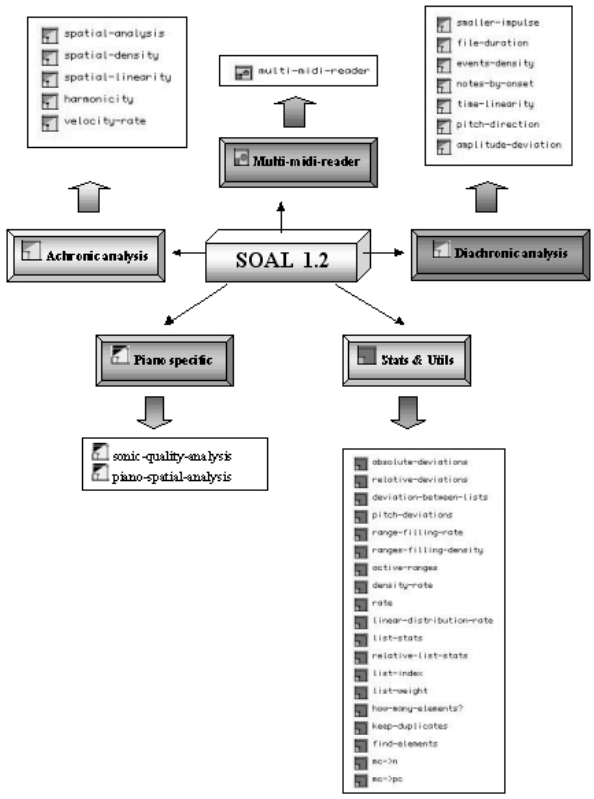

Figure 1: *SOAL* folders & functions diagram

To work with *SOAL*, the user has first to encode in MIDI format the musical entities (*sonic objects*) he wants to analyze. Once connected, each *SOAL* tool returns, among a set of miscellaneous data, a main numeric value which gives the *relative complexity weight* of the input file, for the specific secondary component addressed by the function (see fig. 2 a snapshot of *SOAL*).

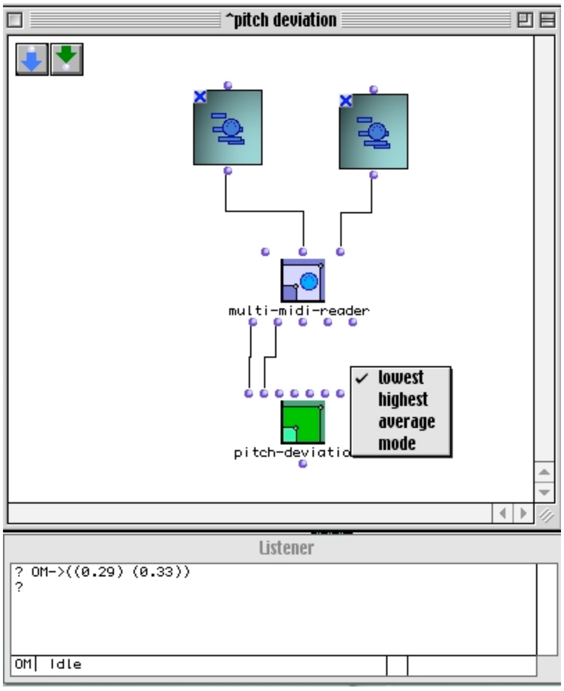

Figure 2: A typical *SOAL* patch, where two MIDI files (above) are simultaneously analyzed by the *pitch-deviation* function. The *multi-midi-reader* extracts all relevant MIDI data for analysis. The dialog box configurates some parameters for computer analysis. The list that appears in the 'Listener' window includes the resulting analyses for both input files.

The maximum value for the 'complexity weight' corresponds to the configuration of pitches, intensities, durations, etc, that would produce as 'complex' a sonority as possible. In all algorithms, this maximum complexity is the paradigm the input object is compared to. Thus all results are calibrated on a vector from (0.00), which means 'maximum simplicity', to (1.00), which means 'maximum complexity'. When an algorithm returns a complexity weight of (1.00), for instance, it means that the input file is as 'complex' as the maximum complexity paradigm. The specific meaning of 'simplicity' and 'complexity' varies according to the nature of the musical vector (a *SOAL* function). They may in some cases be described as vectors of poorness/richness, weakness/strongness, emptiness/ fullness, and the like. A chromatic cluster, for instance, would receive the value (1.00) on the achronic density vector, if analyzed by *SOAL Spatial-Density* function.

The 'relative complexity' paradigm allows comparing and processing together heterogeneous musical components, to correlate them e.g. using standard statistic algorithms (correlations, polynomial regressions…), and to compare different objects in different and no-coherent musical contexts. The settlement of an unique paradigm of relativity is where we believe *SOAL* contributes in a original and musically useful way for non-tonal music analysis, as absolute data about 'apples and oranges' hardly would be able to be compared and correlated for an understanding of musical structuring [1].

2. ON BERIO'S *SEQUENZA IV* HARMONIC SYNTAX

As most of pieces of the cycle, the Berio's *Sequenza* for piano has become a landmark of 20th century literature for this instrument. The composer said once that 'the control of harmonic trajectory and density is a common aspect of all Sequenzas', as is the intent 'to melodically precise and transform a mainly harmonic discourse' [2]. *Sequenza* IV reveals a rather systematical application of these structural ideas, as all the materials are derived from the opening vertical chords, which are progressively 'horizontalized', creating a 'continuum of figurations' from dense chords to thin 'arpeggiating and eventually melodic fragments which interact in a syntactic flux between structurally opposite and intermediate constituents' [3].

The chords heard at the first moment of the piece, are in fact a number of instances of the two main sonic categories which will constitute the core of the musical kinesis. The first category (we label A) is a 'bi-triadic' vertical structure, built upon two superposed major, minor, augmented or diminished triads. The objects of this category tend to feature a resonant, if not consonant, sound design. Some of them may have an added 7th and/or 9th, which reforce this resonant (harmonic) trend. On an opposite way, the second (B) category objects are rather based upon chromatic relations, with a large amount of seconds and fourths, which make them undoubtedly inharmonic, 'anti-resonant', almost 'noisy' (see fig. 3 some samples of both categories of chords).

Figure 3: Some A- and B-category chords. Above the staff: our labeling (2d integer informs the chord's number of pitches); inside: bar number.

3. *SOAL* 'S SET OF FUNCTIONS FOR *SEQUENZA*'S CHORDS

Our purpose, for this communication, is to roughly describe the sonic qualities of these chords, through *SOAL* evaluations, comparing A to B categories. For

1 For more details on *SOAL* concepts and functionalities, please report to its documentation [1].

this task, after having MIDI encoded some selected chords[2], we have made use of the following *SOAL* functions.

3.1. Pitch Sonic Quality (Q)

This tool, especially designed for piano music, weights the input file according to the relative timbral complexity of each of its own pitches. Acoustic properties of the piano were modelized to produce a *Q* global weight, where absolute pitches' spectrum pattern, relative intensities, and pedaling, are take into account.

3.2. Velocity Rate (V)

Weights the object according to the dynamic marking. The complexity weight on this vector is obtained by dividing the chord's MIDI velocity value (s) (which corresponds to the score dynamic marking) by the maximum velocity value (127) which corresponds to the theoretically loudest possible sound (usually symbolically marked with *fff* or more).

3.3. Relative Range Vector (A)

'Range' (ambitus) means a pitch space defined by two boundary pitches. *Relative range* compares the input object's pitch range to the music's or instrument's whole range. The complexity weight on this vector is obtained by dividing the interval between the input object's lowest and highest pitches by the whole pitch range. The vector goes from 'narrow' (0.0) to 'wide' (1.0).

3.4. Registering

For piano music, we have defined seven registers according to some global timbral differences caused by physical or mechanical variations, such as the number of strings per note (producing a correlated detuning or 'chorus' effect), the strings' material – they can be wound or unwound, the presence of dampers or not, the average stretching rate of the tuning, etc. The registers are shown Table 1. [3]

Reg. Label	Bound.
- 3	A0-A#1
- 2	B1-G2
- 1	G#2-E3
0	F3-F5
+ 1	F#5-D6
+ 2	D#6-D7
+ 3	D#7-C8

Table 1: The piano's 'register' partition according to acoustic criteria, as preset in *SOAL Piano-Spatial-Analysis* tool.

Instead of the *SOAL* standard *complexity weight* value, we have but retained, for this demonstration, a complementary function that extracts the number of notes per register (NNR column in the next tables).

3.5. Relative Linearity Vector (L)

Measures how equidistant are distributed the pitches. The interval between the contiguous pitches is compared to a paradigmatic interval (PI in the next tables), which corresponds to the interval that would be necessary for pitches to be exactly equidistant (chromatically approximated). The higher the weight, the less linear the pitch distribution, and, consequently, the more 'complex' the sonic quality.

3.6. Relative Harmonicity Vector (H)

Evaluates the closeness of the object's vertical pitch distribution to a paradigmatic harmonic spectrum-like structure, deduced from a fundamental – which can be provided by the input file, by a *SOAL ad-hoc* algorithm, or manually forced by the user – and constructed inside a given spectrum bandwidth.

4. A DESCRIPTION OF CHORDS SONIC QUALITIES FROM *SOAL* EVALUATIONS

4.1. A-category chords

SO	Q	V	A	NNR	L	PI	H
A1/6	0.05	0.19	0.32	(0 0 0 3 3 0 0)	0.3	560	0.6
A2/6	0.04	0.19	0.18	(0 0 0 5 1 0 0)	0.07	320	0.46
A3/7	0.04	0.19	0.2	(0 0 0 6 1 0 0)	0.13	283	0.4
A4/8	0.07	0.19	0.29	(0 0 1 7 0 0 0)	0.07	357	0.76
A5/7	0.11	0.39	0.33	(0 0 0 5 2 0 0)	0.16	483	0.83
A6/8	0.05	0.09	0.45	(0 1 2 3 2 0 0)	0.1	557	0.73

Table 2: A sample of A-category chords sonic structure analysis, according to the above mentioned *SOAL* functions. Legend: SO - Sonic Object label - Q: Pitch Sonic Quality - V: Velocity Rate - A: Relative Range - NNR: number of notes per register; the list is formatted from the lowest piano register (first value) to the highest one (7th value); the integers represent the absolute number of notes in the corresponding register – L: Relative Linearity – PI: Paradigmatic Interval (an integer in midicents) – H: Relative Harmonicity. See main text for more details.

As shown in the NNR column, all A-chords, except the last one, are condensed inside the piano's central region (registers –1 to +1, see Table 1 above). This composer's choice causes relatively narrow ranges (small *range* weights in A column). Associated with generally very soft dynamics (V column), the global sonic aspect of A-chords is of some relatively 'poor' timbral richness (see Q column).

A triadic superposition principle would lead to rather linear distributions of pitches, producing low *SOAL*

[2] For details about selection criteria, see [4]. The following is a very short description of the main tools used for this project. Please refer to *SOAL* documentation [1] for more details.

[3] The corresponding *SOAL* tools allow the user to define all registering configurations. However, the configuration used here is available, as a preset, in the special *Piano-Spatial-Analysis* function.

spatial-*linearity* weights. This effectively happens (see L column). Most of PI values round a minor or major third interval. *SOAL* gives a less linear quality (that is, a higher *spatial-linearity* weight) to the first chord, exactly because this principle is broken by the insertion of a 9th between F4 and G5, generating a wider paradigm (see PI column), and consequently, a lower match between it and most of the actual intervals, that remain thirds. It can be also observed that the algorithm analyses correctly the fair linearity of the last chord (L = 0.10), although it is rather built upon augmented fourths and perfect fifths than thirds.

The bi-triadism system, associated to a generally linear distribution of inner intervals, is expected to give a complex harmonic quality, as perfect harmonicity, by definition, depends on a unique fundamental and a logarithmic distribution of intervals. Thus, A-chords tend to sound quite inharmonic, giving relatively high *harmonicity* weights (cf. H column values). This quality increases for the last selected objects. Besides downward register expansion (see NNR), this is due to the elimination of pure triadic relations in the left-hand chords. Compare A3/7 with A4/8 in fig.3. We suggest that the highly inharmonic quality of A5/7 and A6/8 allows them to better mix with the generally dissonant context in which they are submersed (please check p. 8 and 12 of the Universal score). The contextual sonic integration appears to be also the reason of the uncommon wide range and the noteworthy *pppp* dynamic marking of A6/8 (see V, A and NNR values), since it merges into a very large register span and very low intensity context (see again the score, p. 12).

4.2. B-category chords

SO	Q	V	A	NNR	L	PI	H
B2/8	0.11	0.19	0.36	(0 2 2 4 0 0 0)	0.09	443	0.6
B4/9	0.05	0.19	0.34	(0 0 0 5 3 1 0)	0.29	375	0.78
B5/7	0.06	0.19	0.22	(0 0 0 7 0 0 0)	0.19	317	0.45
B7/9	0.06	0.19	0.18	(0 0 0 9 0 0 0)	0.25	200	0.49
B11/6	0.04	0.19	0.24	(0 0 0 5 1 0 0)	0.18	420	0.54
B12/6	0.08	0.28	0.29	(0 0 0 5 1 0 0)	0.05	500	0.44
B15/12	0.1	0.36	0.4	(0 0 1 6 4 1 0)	0.15	318	0.75
B17/8	0.1	0.82	0.36	(0 0 0 4 1 3 0)	0.11	429	0.64
B19/5	0.18	0.28	0.31	(1 0 2 2 0 0 0)	0.25	675	0.52
B23/6	0.33	0.82	0.3	(0 0 2 4 0 0 0)	0.3	520	0.45

Table 3: Some B-category chords sonic structure analysis according to the above mentioned *SOAL* functions. Same legend as Table 2.

There is a larger amount of structural diversity in B chords, resulting in Q and V lists' larger spans. However, NNR column demonstrates that Berio carries on avoiding the utmost registers. As a matter of fact, most chords tend to reproduce A category vertical span, having their range restricted to the central region, a small number of them expanding to +2 register (B4/9, B15/12 and B17/8). As for A-chords, this results in similar *relative-range* weights (A column).

One must notice two lower registered objects, namely B2/8, which contain pitches in the –2 register, and, more impressively, B19/5, the only *Sequenza*'s chord to reach –3 register, having A1 as bass tone. Moreover, it is to be mentioned the remarkably narrow objects B5/7 and B7/9. The later is especially noteworthy for its cluster-like figure, an extremely high density concentrating nine pitches into a 10th, with a PI value of 200, the Major second.

The B12/6 distribution pattern shows an almost perfect linear construction of superposed fourth (PI = 500), accurately quantified by the very low linearity weight (L = 0.05). Other chords of this category, as B2/8 and B11/6 in our selection, are built upon this interval, thus actualizing a structural opposition with the triadic system of A-category chords.

5. FURTHER RESULTS AND RESEARCHS

These entries are but a few examples of the data *SOAL* can provide and its musical implications. Our full project addresses the way the composer controls the evolution of its harmonic syntax, by means of the evaluation of the successive chords' relative complexity of sonic qualities. The complete results of this work are to be published elsewhere [4]. Among the information *SOAL* helped to discover in this piece, we should like to mention:

(a) the positive correlation between *range* and *harmonicity* chords' qualities ; the wider the chord, the less harmonic. This relation is not trivial, as it is generally admitted that a harmonic distribution need more vertical span than a not harmonic one;
(b) some 'cadential' formulas based upon the progressive decreasing of *harmonicity* weights;
(c) a cyclic macro-structuring, ABA-type, through two sonic vectors: intensities (*SOAL velocity rates*) and pitch spectral distribution (*harmonicities).* The qualities globally increase then decrease along the piece. Meanwhile, the peak of both curves is not coincident; this structural dephasing may be said to be a factor of the generally observed 'fluidity' of *Sequenza*'s form;
(d) at the same time, *SOAL* evaluation of registering revealed a parallel formal bi-partition of the piece.

We are also working on the sequence of resonant subjacent chords, a crucial dimension of the sound design and harmonic syntax of this *Sequenza* that does not seem to have been frequently discussed in related literature.

SOAL library is currently used in other on-going analytic projects concerning Crumb's *Makrokosmos*, Lachenmann's *Echo-Andante*, Messiaen's *Catalogue d'Oiseaux* and Debussy's *Trois Nocturnes*. [4]

[4] All these projects are suported by the CNPq – Brazilian Council for Research. M. Onofre and A. Rolim colaborate as granted under-graduate students.

6. REFERENCES

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