IMAGINARY LANDSCAPE No. 4: STUDY AND ANNOTATION OF THE SCORE

Andrea Valle
CIRMA-Università di Torino
andrea.valle@unito.it

Amedeo Casella
Università di Torino
am3d3o.casella@gmail.com

ABSTRACT

This paper presents a study of the score of John Cage's *Imaginary Landscape No. 4* for 12 radios and 24 players. After introducing the work and its history, the paper shows the relation between the formal operations at its origin and the final score. An annotation format is then introduced, and the resulting annotated version of the score is discussed. The latter may be used as an analytical tool, as a performing aid for human players, and as source data for an automated realization of the work. Finally, a complete graphic score is presented, obtained from data processing and displaying.

1. INTRODUCTION

Imaginary Landscape No. 4 [1] (hence on: *IL4*) is the fourth instalment of Cage's *Imaginary Landscapes* series. Written in 1951 –almost 10 years after the *No. 3* (1942)– it still shares a typical feature common to all the previous pieces, the experimental attitude towards electronic technology. In the case of *IL4*, this feature is apparent, as the piece is scored for 12 radios, each to be played by 2 performers, one controlling the frequency, the other the volume and the "tone" (see later). The piece was conducted by Cage himself at the premiere [1, p.157]. The score does not mention the need for a director, but the ratio for his/her presence is to be found in the involvement of a remarkable number of performers (24) and in the synchronisation difficulties due to the notation of time (see later). The historical relevance of *IL4* is twofold.

On one side, it explores the mediascape by radically replacing, still in a live-performed piece, acoustic sources with electronic devices. Moreover, it deals only with everyday appliances (common radios), thus proposing an *ante litteram* "lo-fi" approach to live electronic music, to be pioneered extensively by Cage in other pieces (e.g. *Cartridge music*, 1960), and then largely developed by David Tudor, Cage's close collaborator. This experimental media attitude has led to consider *IL4* as a pivotal work in relation to music exploitation of radio and (electromagnetic) noise [2, 3, 4]. It has been considered as a forerunner of random content access available from internet streaming [5]. Following recent trends in the computer music agenda, it has been noted that radios are treated like "multi-user" instruments [6, 7]. After Weinberg [8], the work has also been considered as a pioneering experience in networked music [9, 10, 11, 12] [2].

On the other side, *IL4* is also important in the context of Cage's production. It follows the seminal *Music of Changes* (1951). The latter piece, for solo piano, marks the beginning of the collaboration with David Tudor [13, p.178], and had a great influence among avantgarde European composers after its Darmstadt premiere in 1956 [14, p.111]. Following the inspiration of Zen Buddhism [13], in *Music of Changes* Cage experimented for the first time with *I Ching* – the Chinese divination book- as a composition method, with the aim of detaching himself from composition ("I wrote the music for radios feeling sure that no one would be able to discern my taste in that" [1, p.63]). In relation to the issue of abandoning subjectivity, Cage has stated not to be totally satisfied with *Music of Changes*, while reporting to having reached its goal with his following work, that is, *IL4* [1]. Indeed, the two works, even if sonically so different, share the same composition process, as they belong from a group of pieces based on the same set of procedures, first devised for *Music of Changes*, that have been defined as "Chart systems" [13]. Concerning *IL4*, it must also be noted that, even if the presence of 12 radios might suggest "an extremely raucous effect" [13, p.90], the widespread use of silence, together with Cage's request to use the AM tuning (where much less signal was broadcast), resulted in a very quiet piece, coherently with the aesthetic assumptions at the basis also of *Music of Changes* [3].

[1] John Cage, *Imaginary Landscape No. 4*, Edition Peters, no. 6718. The handwritten title on the score by Cage is "Imaginary Landscape No. 4 or March No. 2". Dedicated to Morton Feldman, its composition is dated by Cage between April 4th and 27th, 1951.

[2] The two last claims are highly debatable, as both multi-user instruments and networked performances focus by definition on interaction, respectively among the users and the instrument, and among the nodes in a network. There is no possible interaction among performers and/or radios in *IL4*, as the piece is strictly determined in its performance.

[3] AM tuning poses a series of relevant issues for actual performances. In *IL4*' score, written events concerning tuning may indeed result in absence of signal. Moreover, AM transmission is continuously declining, while also the much more popular analog FM is already going to be dismissed in some countries (e.g. Norway, from 2017, [15]). In this paper, we will not deal with performing issues. In any case, a quick survey on WWW reveals that many versions of the piece are in FM and do not take into account the tone parameter. A thorough discussion of another radio piece by Cage, *Radio Music* (1956), dealing with aspects that are relevant also for *IL4* is [16].

2. COMPOSITION

Cage described in detail the composition process of *Imaginary Landscape* in [17], while providing a more general context in [1], the two sources both dealing with *Music of Changes* and *IL4*. Following the so-called "micro-macrocosmic" rhythmic structure [13, p.14], he devised a time organisation based on a square number of measure (144), so that "the large lengths have the same relation within the whole that the small lengths have within a unit of it" [17, p.57]. Given this pre-organised time-canvas, the events in the score result from a double, linked mapping (Figure 1). The first mapping associates three tossed coins with lines, where [17]:

- 3 heads: broken, with circle;
- 2 tails + 1 head: straight;
- 2 heads + 1 tail: broken;
- 3 tails: straight, with a circle;

By iterating six times the tossing process, Cage was thus able to build various hexagrams, that is, figures made up of 6 horizontal lines that are labelled and used by *I Ching* as the basis for divination. Hexagrams as prescribed by *I Ching* are 64 (see Figure 1, bottom right, for the whole set). The presence of the "circle" in the above definitions indicates that a second hexagram is to be generated, in which "circled" line have to be swapped, that is, broken lines with circle in the first hexagram become straight in the second, and vice versa, as shown in Figure 1 (see "mobile").

The second mapping associates hexagrams to music parameters. To do so, Cage prepared many "charts", where each chart is a 64-element hash table linking a hexagram with a certain value for the selected parameter. The whole procedure is only partially described in available published sources and literature. Charts for frequencies, dynamics, tone and durations are event-related, as they are used to calculate the parameters for each event. There are eight charts for each of the parameters, because eight is the maximum number of overlapping radio parts that Cage arbitrarily decided to be possible (thus, each of the 8 possible radio parts has its set of charts). Of these 8 charts, four are "mobile" while other four are "fixed", in accordance with single or double hexagram to be used. Values in mobile charts have to be replaced once used [4] , while values in fixed charts can be used many times:

> mobile means an element passes into history once used, giving place to a new one; immobile means an element, though used, remains to be used again [17, p.58]

The type of chart (mobile or fixed) "is determined by the first toss at a large unit structural point [see later on tempi], an odd number bringing about a change, an even number maintaining the previous status" [17, p.58]. Many charts are in use simultaneously, as they refer to different voices. For each voice, charts related to sound events, half of the values (32) correspond to silence; the other 32 values are

[4] The replacement procedure is not documented in details, as far as we know. It could be observed that such a replacement weakens the idea of mapping itself.

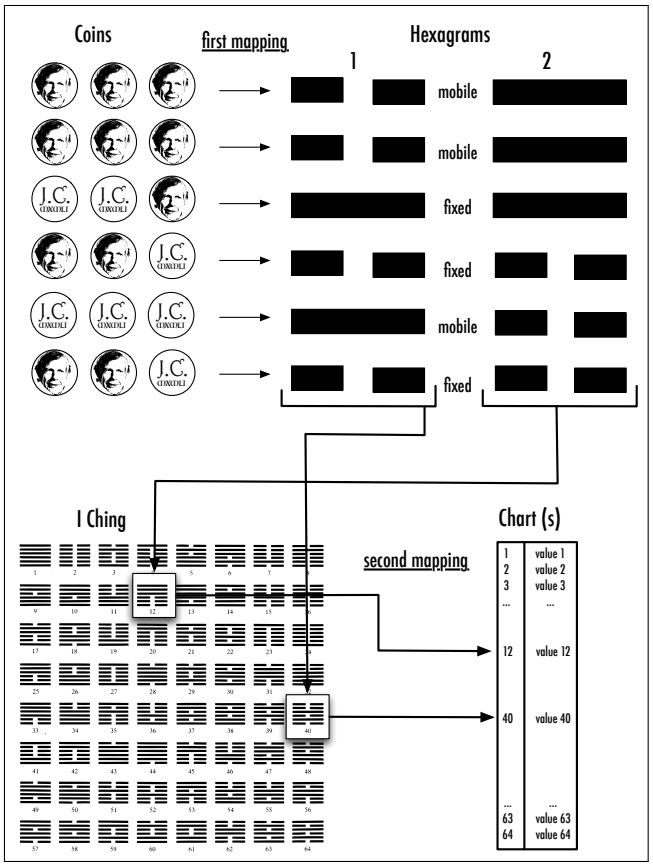


Figure 1. Schematization of the composition process.

combinations of radio frequencies. In the dynamics chart, only 16 values prescribe a new dynamics, while the other 48 values require to maintain the previous dynamics. Charts for durations specify their values by rational numbers expressed as a fraction (or as the sum of fractions) corresponding to the base time unit chosen by Cage, the whole note. Two more charts are in use, that are composition- rather than event-related, that is, they apply to all the events. They are both of fixed type. The chart for tempi "has thirty-two elements, the blanks maintaining the previous tempo" [17, p.58]. The chart includes also "accelerando" and "ritardando" indications. A new tempo is retrieved at a "structural point", which is calculated following the pattern 2-1-3, where each integer indicates four measures of 4/4. As each page always contains four measures, the pattern applies directly to the number of pages, that is, tempo changes each 2, then 1, then 3 pages. Finally, the chart for "superimposition" indicates how many events there will be in a certain portion of the structural space. Superimposition acts like an event filter. First Cage calculates all the eight layers, then applies the superimposition parameter that may result in filtering out some of the events. This process yields an even sparser sonic texture, so that after the premiere the piece was criticised "because it was so soft", as Cage remembered [1, p.63].

The composition process is schematized in Figure 1. To sum up, tossed coin sequences select the associated *I Ching* hexagrams. Then, hexagrams are associated to parameter values. Following his anti-subjective attitude, Cage is in-

deed quite strict in applying the procedures that he devised, so that the piece (as many others by Cage) might be considered as a pure example of algorithmic composition but, also, as a form of Parameter Mapping Sonification [18].

3. NOTATION

Music of Changes marked a radical depart for Cage. In the piece, time is no more thought of as metrical, that is, referring to a specific metric grid that, even if made flexible by various notation procedures, still acts as a discrete time quantization. Rather, Cage introduced "time notation", where the graphic space of notation is linearly proportional to time (see [19, chap.3]). The score is thus a plot of events in time [5]. Thus, while notating *IL4*, Cage began writing the values on standard paper by means of a ruler. Later, he decided to write the piece using "traditional" notation, as he had planned the piece to be performed by 24 players, who would otherwise find difficult to read the score, both because of their reading habits related to traditional notation, and for the lack of a beat to help them progress over time (as it happens with beat counting in metric notation). At a first look, *IL4*'s score seems to be notated in an ordinary way (Figure 3). The score defines a staff for each radio, which is given a five-line staff, where note heads represent MHF frequencies, expressed using the shortened numerical values common on standard radios' dials at time (55-160) [6]. Figure 2 shows a RCA Golden Throat: KPFA's John Whiting, one of the performers at second and third performance, reports that in the occasion of the premiere 12 of these radios were in use ("Cage saw them in a shop window and, persuasive as ever, got the manager to lend him 12 for the premiere" [22]). In the score, the frequency range is slightly out of the dial range on both sides, extending it from 50 to 165 (reading the staff as G-clef, the boundaries are represented respectively as D under the staff and A above the staff). Pitches are clearly a rough approximations of frequencies, as furthermore Cage does not use accidentals for sake of simplicity (e.g. the same pitch represents a range of frequencies).

Frequencies are indicated numerically on top of the note heads, and standard glissando lines represent continuous transitions between adjacent values. The volume is indicated on the bottom of each staff (as traditionally with dynamics), on a scale in the range $[1, 15]$, where 1 indicate silence and 2 is not in use [7]. The volume range is indeed arbitrarily applied to each radio, with no absolute meaning in terms of dynamics [8]. Finally, a dotted line under the notes indicates tone as "a change to high-frequency overtones", that is, it asks to switch off a discrete low pass filter commonly used on radios to avoid high frequencies in the noisy AM tuning [9].

Figure 2. RCA's "Golden Throat".

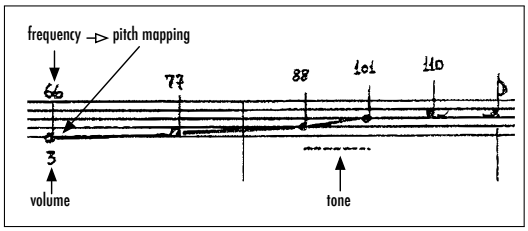


Figure 3. Notation symbols for frequency, volume, tone.

But a more careful inspection shows how *IL4*'s notation, at least in relation to time, results from two, partially contradictory, constraints. On one side, Cage's purpose was to use amounts of musical durations that are not representable by the conventional notation, as they are placed in a chronometric, "smooth" extension. On the other hand, Cage tried to obtain a score that was readable by musicians accustomed to the so-called common practice notation (CPN) [10]. The duration charts specify event durations by means of fractions of the whole (i.e. of a 4/4 measure). By concatenating fractions, durations are added progressively without taking account quantization by measure. CPN mensural notation can be said to be "subtractive": the measure is the time unit, and its duration is distributed among events so that at the end the former is filled. In contrast, Cage's rhythmic organisation could be defined as "additive", as it adds up durations without referring to the measure framework. These two ways of conceptualizing durations are mutually esclusive. In *IL4* each measure is thus deprived from its original, subtractive meaning in order to simply represent a certain amount of time, as in a time graph. Graphically, all the measures have the same length, and each page (made up of four measures) thus represents the same amount of time. In *IL4* durations are thus expressed with the CPN notation symbols, but:

[5] Valkenburg [20] has emphasized the influence of the "smoothness" of magnetic tape manipulation on this conceptualization of time. This was already observed by Cage himself, as the composer noted that time notation "is directly analogous to the practice of cutting magnetic tapes" [17, p.29], see also [19].

[6] That is, 540–1610 kHz in ITU region 2 (the Americas), see for USA [21]. The same range is used in *Radio Music* [16].

[7] Cage uses 1 to indicate the lowest position of the volume knob, avoiding 0 to specifically remark that radios should not be turned off by pushing the knob to its minimum, as in analog radios this would have resulted in an audible click.

[8] In the preface of the score, Cage proposes to use adhesive tape to mark the steps to provide a visual clue for the performers.

[9] This means that Cage assumes the lowpass filter standard setting as "on". It is interesting to note that the RCA "Golden Throat" model said to be used at premiere is *not* provided with such a filter (see schematics in [23]).

[10] Significantly, in the score of *Imaginary Landscape No. 5* –that does not involve live performers as it is a set of instructions for assembling tape fragments from long-playing records– Cage has decidedly opted for graph paper.

- their durations, as expressed by symbols (e.g. white vs. black note), is simply approximated, and its real value is expressed by indicating on top of the note head the associate fraction of the whole. In fact, note durations in a measure, if calculated in relation to their CPN value, rarely sums up to a whole note. But it must also be noted that fractions are *not* always notated, while sometimes they are placed on top of rests that fill entirely the measure. In this sense, this (not always consistent) notation seems a residual of the composition practice;
- their attacks depend on their actual placement in the space that stands for chronometric time (the placement of the symbols in the space depends on the sum of the durations of previous symbols). This is evident if considering the use of "X crotchets" (a term introduced by Cage in the preface of the score). Even if such symbol is provided with a traditional duration (a crotchet), Cage states that it simply "indicates the point of stopping sound and does not have any duration value": that is, the relevant element is only the placement of the symbol in space, to be used as a termination mark. Interestingly, rest symbols are placed in the middle of the time segment that they occupy (the beginning of a rest being indicated by the X crotchet). Moreover, if a note has to start exactly at the beginning of the measure, its visual placement faithfully respects the constraint and the note is thus placed *across* the bar (this is evident in the last note of Figure 3).

The situation is summed up in Figure 5. The first two measure of the score are shown in Figure 4.

In short, the 4/4 metric organisation is superimposed to time notation, and it is intended to provide a common time framework by means of the measures, and an approximate indication of the durations that it contains. In this way, the score is written in a more practically readable format without losing the original information, as contemporary events are aligned vertically by construction. In any case, the use of time notation does not imply that the ratio between time and notation space is fixed for the whole score, as it also depends on tempi. The latter are specified in beats per minute, with the quarter as a unit, in the upper left corner of the page (Figure 5), and they change following the 2-1-3 pattern, as already discussed. Such a mixed notation, while relevant to musical performance, partially hides to the analysis the overall organisation of the piece. Hence the idea of annotating the score.

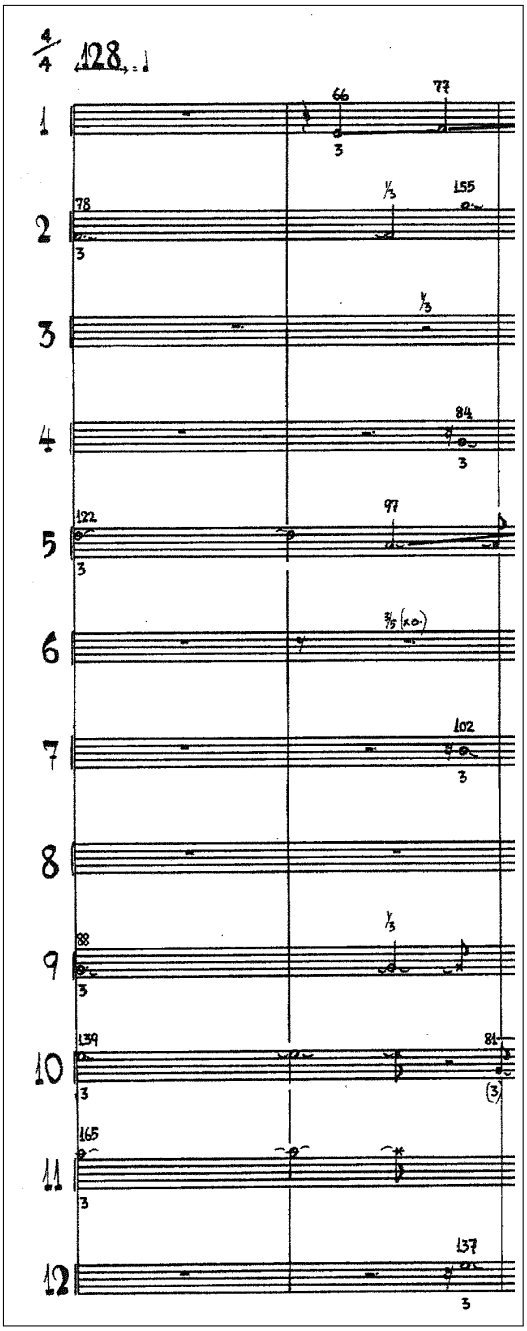


Figure 4. *IL4*, first two measure of the score.

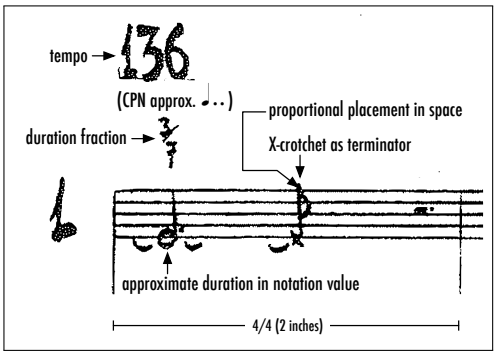


Figure 5. Duration notation.

4. RECONSTRUCTING THE RULED PAPER

As we saw, the actual score is notated in a partially "traditional" format, and in the score's preface Cage says the it resulted from an approximate conversion, a "rough tracing of the original" diagram (one could speculate to be written onto graph paper as in *Imaginary Landscape No. 5*), where quarter = $\frac{1}{2}$ inch. In the preface of the score, Cage also emphasizes that the same source diagram was drawn by means of an "inaccurate" ruler, so that "notation may

be said to be, to say the least, approximate". These statements by Cage seem to indicate a very loose relation between the actual score and the data at its origin. In order to verify these statements and to better understand the organisation of events in *IL4*, we pursued a reverse engineering approach to the score. We inspected the printed score (a reproduction of Cage's handwritten one), by carefully measuring the notated musical signs (i.e.notes and rests as placed in the graphical space). By assuming the ratio between duration and space provided by Cage (quarter = $\frac{1}{2}$ inch) it has been possible to measure all the durations as expressed in space widths. This task was performed with the goal of verifying our reconstruction of the notation procedure and to identify eventual inconsistencies between note placements (apart from their CPN value) and declared fractions. We found the graphical score quite accurate, as we were not able to individuate any error. Considering Figure 5, it can be observed that the CPN note symbol has a graphical extension of slightly less than half the measure, as defined by the ratio $\frac{3}{7} \approx 0.43$. Curiously, its approximate duration notated by Cage in CPN –dotted half note– is by far different ($\frac{3}{4} = 0.75$) [11] .

Thus, if considering note placement, the score is not "graphic" at all, if by graphic score we define a score that provides the user a set of indications, that are approximated within a certain range of values. Goodman [24] has proposed the couple "autographic" vs. "allographic" as a way to define the relation between a notation and its content (for music notation see [19]). An allographic notation depends on a formalized content, and the organization of the latter allows to define a symmetrical organization of the former. An autographic notation does not rely on such a well-defined organization. Its content is thus a variously extended set of performing possibilities. While many experiences in music graphic notations, in particular from the '60s and the '70s are frankly autographic (e.g. the collection published by Cage himself, [25]), *IL4*'s notation is indeed allographic, as it is defined by a clear bijection between mapped data and graphic signs, not only by construction (as explicitly declared by Cage) but also in terms of how it is actually implemented in the score, as our measurements have verified. This allographic regime allowed us to annotate the score.

5. AN ANNOTATION FORMAT

It can be said that the score is organized into events that can intuitively belong to two types: sound events and silences. We devised an annotation format that was intended to be abstract (that is, not hardware or software dependant), and easy to write and to read. The annotation process has been done by hand, and we needed a quick solution to annotate while measuring. XML encoding is rather verbose, and, while human-readable, it is typically generated by machines (or through GUI applications). To sum up, our encoding is intended as a minimal ASCII encoding that is still human-readable, partially redundant so that it allows fast error checking, that can be easily parsed without recurring to e.g. XML tools and converted into other formats if needed (e.g. the same XML). A sound event is described by the following parameters:

- `*:` beginning of the event
- `ID:` event unique identifier
- `@:` field separator
- overall duration of the event
- `@:` field separator
- dynamics value
- duration of the dynamics value
- dynamics type: `h` (hold) or `g` (glissando) [repeat for each value]
- `@:` field separator
- frequency value
- duration of the frequency value
- frequency type: `h` (hold) or `g` (glissando) [repeat for each value]
- `@:` field separator
- tone: `[0,1]`, where 1 indicates presence in the score
- duration of the tone value [repeat for each value]
- `#:` end of the event

A silence is described by the following ones:

- `*:` beginning of the event both sound and silence
- `ID:` event unique identifier
- `@:` field separator
- overall duration of the event
- `#:` end of the event

Event IDs are progressive, and apply both to sounds and silences, regardless of the type. This allows to easily retrieve each event of the score (through the ID) and to locate it (as the ID is progressive). Figure 6 shows the resulting annotation for the event of Figure 3. In Figure 6, the annotation spans over three columns for sake of readability, and has to be read by progressive columns, from top left to right bottom.

The final annotation of *IL4*' score consists of twelve ASCII files, one for each voice.

```
*                                g                1/4
1                                77               h
@                                2/4              @
2/4 + 2/4 + 1/4 + 1/4 + 1/4      g                0
@                                88               5/4
3                                1/4              1
7/4                              g                1/4
h                                101              0
@                                1/4              1/4
66                               h                #
2/4                              110
```

Figure 6. Annotation of a score event.

6. DATA PROCESSING AND PLOTTING

The annotated score provides a formalized data source, compliant with Cage's composition system, that can be further processed. As an example, it may be used in case of automated performance [12] . On an analytical side, our aim was to inspect visually the overall structure of the piece. A software application has been written in SuperCollider [26], as the SuperCollider language provides a rich variety of data structures, with associated visualization utilities

[11] A much better CPN approximation would have been a double dotted quarter note ($\frac{4+2+1}{16} = 0.4375$), as reported in Figure 5.

[12] A first, incomplete automated performance of the *IL4* has been implemented by the authors and Pietro Pasquiero by controlling via Arduino digital potentiometers that replaced frequency and volume standard potentiometers in radio kits, on February 1st, 2013 in Torino. See also [16] for an automated implementation of Cage's *Radio Music*.

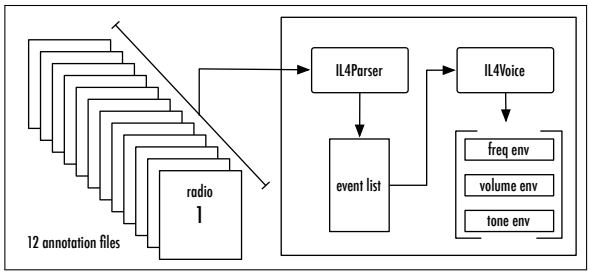


Figure 7. Software pipeline for visualization.

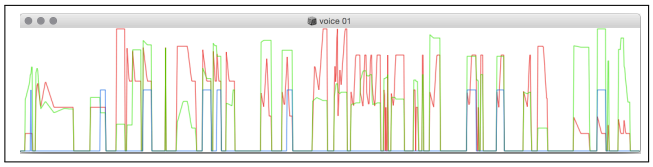


Figure 8. Synchronised envelope visualization for radio 1, whole duration.

that helped debugging. The information flow for the SuperCollider application is shown in Figure 7. Annotation files for voices are read by an instance of the IL4Parser class that outputs an event list for each radio part. The event list (that contains in a structured form all the annotated data) is passed to an instance of the IL4Voice class, that creates three envelopes (frequency, volume, tone) for the selected voice. In SuperCollider, envelopes are represented by the `Env` class, that codifies an envelope in form of a breakpoint table. While tone data are discrete (0 or 1), in order to take account of continuous transitions (glissando in frequency and volume), we used linear interpolation (as directly provided by the `Env` class). This assumption on linearity seemed reasonable because the performers do not rely on audible cues, but move the knobs only by referring to visual clues. Figure 8 shows an overlapping visualization in SuperCollider of the three envelopes for frequency (green), volume (red) and tone (blue) in the whole radio 1 part.

As discussed, even if using time notation, Cage refers to metronomic tempo as a time modulation. Because of this, absolute duration scales variably in relation to graphic width. To take into account this aspect, we have created an envelope for tempi (Figure 9, values in abscissa represent measures). Tempi have been interpolated (again, linearly) to account for accelerando/decelerando. In this case values are necessarily approximate as they depend on qualitative values to be decided during the performance (actually, this is the only "undetermined" –even if typically musical– indication provided in the score).

Envelopes for each voice represent time-stamped data regardless of time modulation prescribed by changing tempi. Thus, in order to obtain the time-modulated data, we resampled the envelopes taking into account changing ratios provided by the tempi envelope. By applying the tempi envelope, we also determined an overall absolute duration of the piece, in our case 04:37:370. The final frequency, volume and tone envelopes allow for a visual description of the score as a time graph. Figure 10 shows a representation of radio 1 part. Automated plotting has been generated by exporting data from SuperCollider into a textual format and importing them into the Python-based Nodebox package [13] . In Figure 10, on top, frequencies are reported when there is a change between adjacent frequencies greater than an (adjustable) threshold.

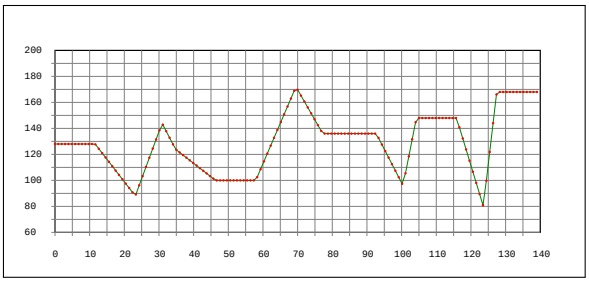


Figure 9. Envelope for tempi.

Page 8 shows a complete plotting of *Imaginary Landscape no. 4*, that is, including all radios with their control parameters over time. Plotting has been simplified with respect to Figure 10 so to avoid visual cluttering. The resulting graphic score allows to immediately appreciate the non uniform distribution of events among voices, even if the score is the result of chance operations. Radio 1 is the most dense parrt, followed by radio 2 and 8. Also, the use of the tone filter is very sparse (it is absent from 5 voices). By adjusting visual parameters, it is possible to reach the desired level of details, to fit analytical and/or performing requirements.

7. CONCLUSIONS

The accurate study of *IL4* reveals how Cage, in his first quest for anti-subjectivity, reached a -so to say- radical algorithmic approach to composition. The score clearly shows such a rigour, even if the composer himself seems to dismiss it in its preface. *IL4* is also an interesting example of how notation, as a technological means, necessarily acts as a mediator among various, sometimes contradictory, instances. The annotation of the score provides an additional analytic tool both for direct inspection and for information display, that can be directly used for performance, be it human-based or automatic.

8. ACKNOWLEDGEMENTS

We thank Francesco Richiardi for his advices on vintage radio tunings and constructions.

9. REFERENCES

[1] R. Kostelanetz, *Conversing with Cage*. New York–London: Routledge, 1987.

[2] A. Dunne, *Hertzian Tales. Electronic Products, Aesthetic Experience, and Critical Design*. Cambridge, Mass.: MIT Press, 2008.

[13] `https://www.nodebox.net/code/index.php/Home`.

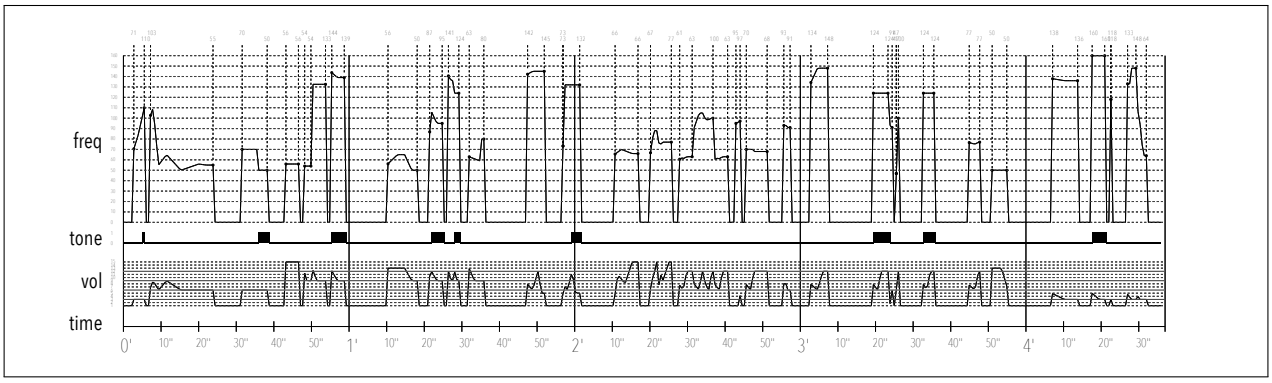


Figure 10. Visualization of *IL4*, radio 1.

[3] D. Kahn, *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts*. Berkeley, CA: University of California Press, 2013.

[4] S. H. Daniel Cermak-Sassenrath, Ayaka Okutsu, "Electromagnetic Landscape. In-between Signal, Noise and Environment," in *Proceeding of the 21st ISEA*, (Vancouver), ISEA, 2015.

[5] J. Freeman, "N.A.G.: Network Auralization for Gnutella," in *Proceedings of the ACM Multimedia*, MULTIMEDIA '04, (New York), pp. 180–181, ACM, 2004.

[6] S. Jordà, "Multi-user instruments: Models, examples and promises," in *Proceedings of NIME 2005*, (Singapore City), pp. 23–26, National University of Singapore, 2005.

[7] S. W. Lee and G. Essl, "Live coding the mobile music instrument," in *Proceedings of NIME 2013*, (Daejeon, Republic of Korea), pp. 493–498, Graduate School of Culture Technology, 2013.

[8] G. Weinberg, "Interconnected Musical Networks: Toward a Theoretical Framework," *Computer Music Journal*, vol. 29, no. 2, pp. 23–39, 2005.

[9] P. Rebelo and A. B. Renaud, "The frequencyliator: Distributing structures for networked laptop improvisation," in *Proceedings of NIME 2006*, (Paris), pp. 53–56, IRCAM, 2006.

[10] P. Mathews, N. Morris, J. W. Murphy, A. Kapur, and D. A. Carnegie, "Tangle: a flexible framework for performance with advanced robotic musical instruments," in *Proceedings of NIME 2014*, (London), pp. 187–190, 2014.

[11] M. Akkermann, "Computer Network Music. Approximation to a far-scattered history," in *Proceedings of the 2014 EMS Conference*, (Berlin), EMS, 2014.

[12] L. Gabrielli and S. Squartini, *Wireless Networked Music Performance*. Singapore: Springer, 2016.

[13] J. Pritchett, *The Music of John Cage*. Cambridge and New York and Melbourne: Cambridge UP, 1993.

[14] A. Trudu, *La "Scuola" di Darmstadt*. Milano: UNICOPLI-Ricordi, 1992.

[15] M. Dumiak, "Norway Pioneers the Digital Radio Future, Abandoning FM. http://spectrum.ieee.org/telecom/wireless/norway-pioneers-the-digital-radio-future-abandoning-fm," 2015.

[16] L. Vickery, "Adapting John Cage's Radio Music for digital performance," in *Proceedings of ACMC 2012*, pp. 69–77, Griffith University, Brisbane: ACMC, 2012.

[17] J. Cage, *Silence*. Middletown, CT: Wesleyan UP, 1961.

[18] F. Grond and J. Berger, *The Sonification Handbook*, ch. Parameter Mapping Sonification, pp. 363–397. Berlin: Logos, 2011.

[19] A. Valle, *La notazione musicale contemporanea. Aspetti semiotici ed estetici*. Torino: De Sono-EDT, 2002.

[20] J. Valkenburg, "From Bars to Inches (to Seconds): Timekeeping in the Music of John Cage," *Dutch Journal of Music Theory*, vol. volume 15, no. 1, pp. 68–75, 2010.

[21] U.S. Department of Commerce. National Telecommunications and Information Administration Office of Spectrum Management, "United States Frequency Allocations. The Radio Spectrum," 2003.

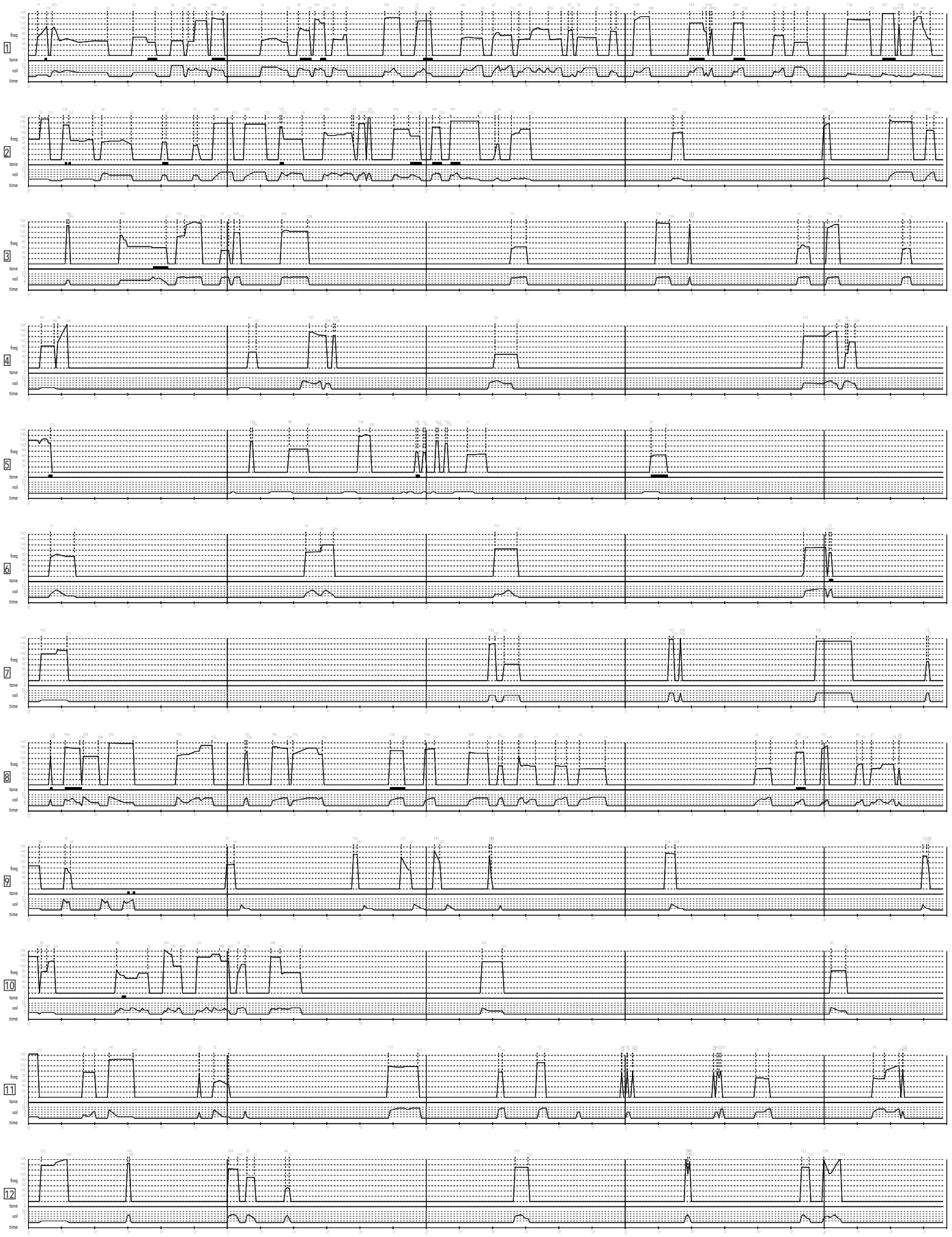
[22] J. Whiting, "My KPFA - A Historical Footnote. Random Radio."

[23] J. Rider, *Perpetual trouble shooter's manual*, vol. XVIII. New York: John Rider F. Publisher, 1949.

[24] N. Goodman, *Languages of Art*. Indianapolis: The Bobbs-Merrill Co., 1968.

[25] J. Cage and A. Knowles, eds., *Notations*. New York: Something Else Press, 1969.

[26] S. Wilson, D. Cottle, and N. Collins, eds., *The SuperCollider Book*. Cambridge, Mass.: The MIT Press, 2011.


1
2
3
4
5
6
7
8
9
10
11
12
freq
tone
vol
time