Digital adaptions of the scores for Cage Variations I, II and III

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ABSTRACT

Western Australian new music ensemble Decibel have devised a software-based tool for creating realisations of the score for John Cage’s Variations I and II. In these works Cage had used multiple transparent plastic sheets with various forms of graphical notation, that were capable of independent positioning in respect to one another, to create specifications for the multiple unique instantiation of these works. The digital versions allow for real-time generation of the specifications of each work, quasi-infinite exploration of diverse realisations of the works and transcription of the data created using Cage’s methodologies into proportionally notated scrolling graphical scores.

1. INTRODUCTION

John Cage’s eight Variations (1958-67) occupy a unique position in the composer’s output. By the late 1950s, Cage had made significant progress in exploring the use of indeterminate sound sources (such as radio and LP recordings1), a range of chance procedures for generating notation2 and indeterminacy of notation3. His attention now turned towards the indeterminacy and “flexibility” of formal structure itself: “a way to further the diversity and flexibility of his compositions by removing the fixity of the score itself” [28].

The eight Variations were the principal vehicles for the exploration of this idea, constituting nearly a quarter of his compositional output during this period. Following the completion of Variations VIII, the most open of the works in every respect, Cage returned, for the most part, to more traditional compositional outcomes marked by his explorations of the “recomposition” of pre-existing works4.

Over the ten years from 1958 to 1967, Cage revisited to the Variations series as a means of expanding his investigation not only of nonlinear interaction with the score but also of instrumentation, sonic materials, the performance space and the environment. The works chart an evolution from the “personal” sound-world of the performer and the score, to a vision potentially embracing the totality of sound on a global scale. Table 1 gives a summary of the evolution of Cage’s approach to the score, sound sources and the performance space in the Variations series.

<table>
<thead>
<tr>
<th>Score specification</th>
<th>sound sources</th>
<th>performance space</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (1958)</td>
<td>quasi-determinate</td>
<td>instruments</td>
</tr>
<tr>
<td>II (1961)</td>
<td></td>
<td>sound producing means</td>
</tr>
<tr>
<td>III (1963)</td>
<td>indeterminate score</td>
<td>actions</td>
</tr>
<tr>
<td>IV (1963)</td>
<td>topographical map</td>
<td>sound producing means</td>
</tr>
<tr>
<td>V (1965)</td>
<td>astronomical chart1</td>
<td>electronic sound systems</td>
</tr>
<tr>
<td>VI (1966)</td>
<td>sound system component diagram</td>
<td></td>
</tr>
<tr>
<td>VIII (1967)</td>
<td>“silence” (ambient sounds)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: A summary of Variations I to VIII.

Although Decibel created digital versions of Variations I-VI, this paper focuses upon the digital realisation of Variations I, II and III, works that employ multiple transparent plastic sheets inscribed with either points lines or circles, for the purpose of creating a unique score for a performer to read5.

1 An early example is Credo in US (1942)[34].
2 These included the use the I Ching as a source of aleatoricism in Music of Changes (1953) [25 pp. 78-88]. “found systems” such as “folded paper templates” in Music for Carillon No. 1 (1952) [29 p. 92] and the “paper improvisation technique” in Music for Piano (1952-6) [29 p. 94]. Cage’s use of Astronomical maps as “found systems” dates from Music for Carillon No. 4 (1961) [29 p. 211] and was incorporated in Variations V (1965).
3 Cage’s exploration of indeterminate notation began in Music for Piano (1952) and culminated in 1958 with the mammoth opus Consort for Piano and Orchestra, [29 p. 109], [33 p. 132].
4 Examples are recomposition of pitches of Satie’s Scores (1918) in Cheap Imitation (1969) [4], “subtraction” of material from anthems and congregational music Apartment House 1776 (1970) and “rubbing” of Satie Chorales in Song Book (song 85) [27].
5 The instructions read “as though there were a drawing of the controls available and – on transparency – transcription from astronomical atlas which (if it were superimposed) would give suggestions for use of controls”[12].
6 Variations IV-VI generate specifications for the placement of sounds in the space, for electronic controller variables and for the assembly of electronic components in the space respectively.
There is relatively strong documentation of the evolving non-digital performance practice of the Variations as performed by David Tudor (Variations II-1961 [30], [31], [22]), John Cage (Variations II-1963 [23]), John Cage, Merce Cunningham et al (Variations 1-1965) [26], [19], David Miller (Variations I and II-2003 [24]), and João Vanni (France, Wand, and Tanaka Variations Ill-2008 [1]).

Traditionally, the realisation of Variations I and II in particular has necessitated time-consuming manual measurement and collation of multiple coordinates. In 2006 digital versions of Variations II were created independently by Nicholas Knouf and Pierpaolo Leo (Variations II-2006 [20], [23]). Both of these adaptations were “installation”-based, in that they generated both the score and a sonicisation of the score for viewers to manipulate in an art gallery, rather than scored materials for live performance.

The impetus behind Decibel’s realisation of these works has been principally performative: to create practical tools for the realisation of these works that retain both the idiosyncrasy and the precision of the Cage’s specification.

2. VARIATIONS I AND II

In Variations I and II, Cage’s materials generate what might best be described as a blueprint for the creation of a determinate score. (Miller describes them as “toolkits” [23 p. 21].) Although Cage states that the score resulting from the application of “rules” of this work may be “simply observed” by the performer, there are significant challenges involved in actualising Variations I or II in this way (as will be discussed below).

At first glance these works appear to be a deconstruction of traditional score, with only the five stave lines and the noteheads remaining and left to float freely in two dimensions. The lines and points are in fact used by the performer to generate a unique score, in which the distance of each point from each line determines one of five musical parameters: frequency, duration, amplitude, timbre and point of occurrence.

James Pritchett identifies the “BV” notation from Cage’s “Concert for Piano” (1958), illustrated in Figure 1 as the origin of this approach [29]. The connections between the “paper imperfection technique” works such as Music for Piano (1952-6), in which points representing events were spatially located on the page at knots in the surface of the paper and to and the “folded paper templates” of Music for Coriolis No. 1 (1952), in which points were notated at intersections between creases in folded paper, are also significant. In Variations I the notation is, more mobile, as the lines and points are printed on transparent sheets, however the “fixes the number and structure of events” is still fixed (289 p. 136).

Earle Brown’s concept of proportional notation [18], developed some years earlier, is taken it to its logical endpoint: here everything is measured. The ability to “read” the score in any orientation also draws on Brown’s December 1952 (1954) which may be read in any direction (Left to Right, Top to Bottom, Right to Left, Bottom to Top).

The precisely defined multi-parametrical nature of Variations I also suggests the influence of the integral serial methods of the European Avant Garde, which had dominated Cage’s “chart” compositions [29 p. 78-90]. But most importantly, in these works Cage demarcates a new end point for the act of composition, leaving not only the interpretation, but also the final realisation of the works to the performer.

The materials for Variations I comprise six square transparencies: the first printed with points and the other five printed with lines. Square 1 consists of 27 points of four sizes corresponding to the number of sounds they represent as illustrated in Table 2.

Each of the five additional squares is printed with five lines corresponding to the five parameters shown in Table 3. The performer may freely choose which parameter to apply to each line.

#### Table 2: The contents of Variations I square 1

<table>
<thead>
<tr>
<th>Square</th>
<th>Points</th>
<th>No. of Sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very Small</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Small to Larger</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Greater size</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Largest</td>
<td>4+</td>
</tr>
</tbody>
</table>

#### Table 3: Variations I Squares 2-6, showing the parameters to be assigned to each line

<table>
<thead>
<tr>
<th>Squares 2-6</th>
<th>5 Lines</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>frequency</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>overtone structure</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>amplitude</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>duration</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>occurrence</td>
<td></td>
</tr>
</tbody>
</table>
A reading of the work is created by measuring the distance from each point to each of the five lines to generate a composite of parameters that define each event with the following attributes: number of sounds (1-4+), frequency, duration, amplitude, timbre and point of occurrence. These attributes are relative with the continuum upon which the parameter is measured defined by the performer. For example: the point of occurrence of each event is relative to the total duration of the work (which is not defined by Cage). Figure 2 illustrates the measurement process required to define one event [16].

This procedure results in a mixture of determinate, permutable and indeterminate variables in Variations I. The number and position of the points and lines is fixed and there is a finite number of possible combinations and orientations of the transparencies, however the range of the continuum upon which each parameter is plotted is indeterminate. Table 4 illustrates the determinate, permutable and indeterminate factors involved in the generation of an instantiation of the work.

<table>
<thead>
<tr>
<th>Determine</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points/Sounds</td>
<td>27</td>
</tr>
<tr>
<td>Lines/Parameters</td>
<td>5</td>
</tr>
<tr>
<td>Min. no. of parameters</td>
<td>135 (27x5)</td>
</tr>
<tr>
<td>Permutations</td>
<td></td>
</tr>
<tr>
<td>Orientation of Points</td>
<td>8</td>
</tr>
<tr>
<td>Function of Lines</td>
<td>55 (120)</td>
</tr>
<tr>
<td>Orientation of Lined Squares</td>
<td>8</td>
</tr>
<tr>
<td>No. of Lined Squares</td>
<td>5</td>
</tr>
<tr>
<td>Max. No. of Permutations</td>
<td>38400</td>
</tr>
</tbody>
</table>

Variations II uses a similar system of dots and points, with some small but significant differences. There are six transparencies each with a single line and five transparencies each with a single point. The sixth line determines the structure of the musical event, whether it is a single sound, an aggregate or a constellation of sounds, the function that had been determined by the size of the points in Variations I.

The orientation of the lines and points is therefore completely open, meaning that there are an infinite set of potential configurations of the score. A performance consists of any combination of configurations and therefore in theory Variations II may describe any possible musical work [24 p. 42]. In this sense it “represents the most flexible composition tool that Cage ever invented” [29 p.136].

Performance of Variations I and II has traditionally involved one of three methods: “simply observing” [5] the resulting score, annotating an instantiation of the score [5][21] or transcribing the detailed measurements of an instantiation into a “performance score” [24 p. 22]. Figure 3 shows violinist Patricia Kopatchinskaja’s annotation of the score of Variations I [21].
The principal issue associated with “simply observing” or annotating the score, as can be observed in Figure 3, is that the notation on Cage’s transparencies is two-dimensional as opposed to traditional one-dimensional linear musical notation. To preserve the order of note occurrence, the transparencies must be read “two-dimensionally” in arcs emanating from the line that determines “point of occurrence” as shown in Figure 4. The distances to the other four lines and calculation of their parametrical value must occur simultaneously.

Although David Tudor’s realisation of Variations I relied on “careful definition of measurement scales and a precise performance score” [30 p. 2], James Pritchett shows that Tudor’s version of Variations II reduced Cage’s prescribed measurements to binary values: simple and complex. Figure 5 shows Tudor’s transcription of two events from the work. Tudor’s score overcomes the issue of reading multiple axes (the 50 events he used were aligned in rows), however its transformation of the multi-parametrical notation into single- or double-bordered squares with intersecting lines and circled or plain points is nearly as enigmatic looking as the original.

Duration is represented proportionally by the length of the rectangle. The vertical position of the rectangle indicates its frequency, thickness indicates volume and shade indicates timbre. The number of sounds in each event is specified by a number attached to each rectangle. A portion of such a realisation is shown in Figure 6. The notation draws on conventions established in works by Cage and his colleagues Earle Brown and Christian Wolff, as illustrated in Figure 7.

3. THE SCORE-READER FOR VARIATIONS I AND II

The imperative of generating performance materials that are easily and intuitively read, led Decibel to a decision to transcribe the data created in Variations I and II into proportionally notated graphical scores. In Decibel’s realisations of Variations I and II the parametrical data derived from measuring perpendicular distances is evaluated and then used to generate a scrolling, proportionally notated screen-score. The score moves from right to left with the point of occurrence of each event, rendered as a horizontal rectangle, indicated by its point of contact with a vertical line or “play-head” on the left of the screen. In this way the score moves “towards” the performer from the right in the same direction as a traditional paper score.

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This transcription enables a faster reading for performers using familiar symbols. In addition, the graphics appear ahead of the 'playhead', giving them time to consider their approach to the graphics. The score can be read by a single performer or multiple performers on their own.

This transcription enables a faster reading for the performers. The versions of the score can be generated for a group of performers networked to a master computer.

A control panel (shown in Figure 8) allows for determination of total duration of the piece as well as the relative duration of the events. The range of the continuums of frequency, amplitude and timbre indicated by the score is interpreted by the performer(s) on their own instrument. The duration of the work effects the density of events on the score. For example a duration of 360 seconds will distribute the 27 events over six minutes.

4. VARIATIONS III

In Variations III, Cage moved to a significantly different score paradigm. Here the composer's focus was on actions rather than sounds. The score is created by distributing 40 circles (printed on individual transparencies) onto a surface and then removing all but the largest group of circles that are in direct contact with one another. According to Fitchett, Cage's aim was to "enable free and direct action in the performance - one would simply do things and count the actions and variables in performance" [29 p. 149].

The digital score for Variations III mimics this procedure: first randomly distributing circles on the screen, then calculating the distances between them and fading out all but the largest group of overlapping circles.

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![Diagram](image.png)

**Figure 8:** The Master control panel for DeChelf's realization of the Cage Variations.

The evaluation of the data to generate the scores of Variations I, II and III and a component of the score player were written in Java and embedded within the Max/MSP patch. The Java code for Variations I and II and the score player mechanism were written by Stuart James, and the Java code for Variations III was written by Aaron Wyatz.

There were several advantages for re-implementing these processes in Java. One of them was the ability to access the same memory space that Max/MSP is pointing to, namely Jitter matrices, by utilizing the Java Jitter API. This marrying of both Java and Jitter processing proved to be an efficient way of accumulating, storing, and sorting tables of values required for building note events in Variations I and II.

For example here we see values stored into a Jitter matrix that are generated recursively in an outer section of code:

```java
int z = 0;
for (z = 0; z < coords.length; z++) {
    g[z] = x;
    storage.setCell(g, 0, coords[d][0]);
}

out(x), "Finished";
```

And here we see the score player mechanism referencing a stored Jitter matrix of note values determining the note polyphony within a designated time frame:

```java
if(value < timescale)
    grouped++;
else if(value > timescale)
    break;
```

---

1. The actions could not include those that result in an instrument's performance. Cage's 1963 performance of Variations III included rearranging electrical cords, putting on his glasses, making a cigarette, writing a letter, and drinking a glass of water" [29 p. 149].
For this purpose there were advantages for implementation in a procedural language like Java by making use of recursive function calls. This proved to be significantly faster to process the way than using a scheduled message environment like Max. The calculations were made in the following way:

```java
for (int i = 0; i < circles.length; i++) {
    double horizontal的距离 = Math.abs(circles[i](x) -
        circles[j](x));
    double vertical的距离 = Math.abs(circles[i](y) -
        circles[j](y));

    if (circles[i].getGroup() == circles[j].getGroup()) {
        // code for handling the same group
    }
    else {
        // code for handling different groups
    }
}
```

This calculation proves the invariance of the two-dimensional layout of the score in the score. It would be possible for example to "twist" the circles along an arbitrary horizontal axis, while retaining the points of intersections with other circles, in order to create a linear horizontal score. However, whereas the materials of Variations I and II give rise to a linear series of events and are therefore most appropriately rendered as a linear score, Variations III specifically evokes the indeterminacy of the two-dimensional score itself. Cage states the performer to "start at any circle" and "move on to any other circle" only requiring the performer to "observe the number of circles which overlap it" [10]. This realization then, simply provides the means to (very slowly) re-construct the score until it is complete with the resulting graphic, while retaining the indeterminacy of that the Cage affords the performer in the original score.

6 CONCLUSION

Rendering these works digitally allows two dramatically opposed arguments often raised against realistic indeterminate works such as the Variations I, II, and III. On one hand, since the audience always hears the work as a linear fiction sequentially in time there is always the question that the indeterminacy is somehow "false" that the performer managed it beforehand. In addition, such works sometimes provoke in the audience the intuition that the performers are themselves "making it up" because there is no way to determine whether they are accurately reading the score.

The precision provided by the computer-generated performance of Variations II and III arguably lends legitimacy to the performance, because the score that is created in both "accurate" to a reasonable degree and easily read by the performer as well as the audience.

On the other hand, such works are sometimes criticized on the grounds that potential variations of other versions implies that the particular one that being performed might not be the best example of the work. The ability to almost substitutionally generate multiple versions of the work as demonstrated in Variations II provides the opportunity to choose interesting and promising instantiations of the work.

We have attempted to be as authentic as possible to the realizations, Cage, presented in those three works using technology to provide a platform that is precise and autonomous in its realization while still keeping open the human element of interaction with the score. As Miller expresses in regard to "Authenticity" in the performance of these works:

Cage's formal statements [...] should be taken as points of departure and at periodic return in the course of developing representations. They are the documents that express, however essentially of times, the worker's potential and possibilities [25, p. 61].
REFERENCES


COMPUTING WITH CHORD SPACES
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ABSTRACT

The number of solutions involved in many algorithmic composition problems is too large to be tractable without simplification. Given this, it is critical that composition algorithms be able to move through different levels of abstraction while maintaining a well-organized solution space. In this paper we present the following contributions: (1) extended formalizations and proofs needed to implement the chord spaces defined by Tymoczko [11] and Callender et al. [2], (2) a generalized framework for moving between levels of abstraction using quotient spaces that can easily be integrated with existing algorithmic composition algorithms, and (3) an application of both to voice-leading assignment.

1. INTRODUCTION

A major problem in the area of algorithmic composition is the need for organized and easily traversable sets of solutions, also referred to as solution spaces, which are tractable in terms of both runtime and memory requirements. Many music-theoretic ideas are also not formalized to the degree necessary to ensure correct implementation of algorithms and accompanying data structures. In this paper we address both of these problems by presenting a general framework for organizing and traversing harmony-related solution spaces. Our work builds on that of Tymoczko [11] and Callender et al. [2], adding an additional layer of formalization necessary to create a generalized and extensible implementation. We then apply our framework to the task of voice-leading assignment, a common problem in music composition.

Consider the following situation: given a sequence of chords intended for a soprano, tenor, and baritone, rewrite the same chords for three tenors while factoring in additional constraints about each performer—perhaps one of the performers is a beginner, requiring smooth voice-leading. This paper presents a set of algorithms and supporting proofs to automate algorithmic composition and arranging tasks such as above. Our approach utilizes two important concepts: chord spaces [2, 11] and musical predicates.

A task such as outlined above will be referred to as a voice-leading assignment. Our goal is to construct a performable series of chords from incomplete information about those chords, such as the pitch classes involved in each. To assign a C-major triad to three voices, a specific C, E, and G must be chosen. This involves choosing octaves for each pitch class and determining which pitch should be assigned to each voice.

We use the term concrete chord to refer to chords with no room for additional interpretation and the term abstract chord when choices still exist. Voice-leading assignment is the process of turning abstract chords into concrete chords. This is also representative of a larger category of tasks in composition: moving between different levels of abstraction in music. Particularly for large problems, the solution spaces must be well-structured and efficient to traverse. Our approach to voice-leading assignment uses a type of quotient space called a chord space [2, 11]. Chord spaces are a way to organize chords in musically meaningful ways and provide a convenient, intermediate level of organization between abstract and concrete chords. For example, one such chord space groups chords based on pitch class content, providing a useful level of abstraction for voice-leading assignment. We use this space to turn a sequence of abstract chords represented in terms of pitch classes into a sequence of concrete chords. When finished, each pitch class in each chord is assigned an octave and a particular voice.

There are many other chord spaces that relate chords in different ways. These can also be used with our algorithm to perform variations on the voice-leading assignment task, allowing the algorithm a greater degree of control over what musical features are generated. By simply changing the chord space, our voice-leading assignment algorithm can be generalized to make choices about pitch classes and octaves.

Data-driven algorithms such as Markov chains have been used to learn voice-leading behavior from collections of examples [3, 12]. Markov chains suffer from state explosion when addressing low-level features in music while still capturing structure. Variable-length Markov models [1] and probabilistic suffix trees [10] attempt to address this problem, but are still prone to the same problem with the large alphabets involved in musical problems. Chord spaces [2, 11] can help with this, since they allow generative problems to be broken into multiple steps, each at a different level of abstraction.

Chord spaces, however, present a number of repre-