Decisions and Deviations:
Foregrounding Bodies in Algorithmic Composition

Critical Commentary on the Portfolio of Original Compositions

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Abstract

Rigid adherence to algorithms, from serial to AI, has often been criticised as 'fetishsistic', 'mechanical', and 'inhuman' by composers, scholars, and currently, the media. Upon observing a common sentiment in my own music, in my thesis, rather than rejecting the algorithm, I continued to embrace an autonomous approach to examine the issue more closely. I identified three kinds of tensions in the process.

The first tension is between the material and the work, where I note that my raw material (what I term the 'maquette'), though parametrically comprehensive, required additional intervention to become the final piece of work. This reveals a lack of musical intentionality in the maquette itself, which I had to resolve by situating the material in different musical contexts. Additionally, by further automating the process, I experienced a difficulty in accounting for specific instrumental idioms in the algorithm, indicating a further tension between automaticism and idiomaticism. At this point, my role as the composer was reduced to only fixing practical incompatibilities in the material, such as adjusting pitch register to match the instrument's range. However, I found that these decisions, despite appearing mundane, function as the composer's remaining agency for intuition, serving crucially as the bridge between the abstracted maquette and the bodily experience of performing it. I argue that these practical decisions—functioning not within but around the algorithm—are where the 'magic' happens in an autonomous process, making the difference between the maquette and the work. Consequently, in my music, I attempt to foreground these decisions as narrow opportunities for creativity using three approaches: open forms, text-based transformations, and the physicality of the instrument.

From the outset, the overarching argument that I make in this thesis is, paradoxically, against overarching arguments. I argue that adherence in algorithms is akin to the application of any general theory in composition. When the theory is used squarely in the practice, be it counterpoint or dodecaphony, the music loses its uniqueness, and the pieces that result are typically those that are decried the most by composers (including myself). I propose that what is most significant—and definitionally where any newness is most likely to be found—is in the particular, which to me, are the decisions that occur before and after the generative stage. In my last set of pieces, while the algorithm has remained the same, their originality rests not in what can be generalised about them, but precisely in what cannot. It is these intuitive decisions, difficult to explain without demonstrating in the practice, that I believe their uniqueness is defined.

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1. Introduction

This is a practice-led thesis on the topic of algorithmic composition. The majority of the research took place in the form of practice, by repeatedly attempting (and arguably failing) to write algorithmic music. Thus, the function of this critical commentary is not to argue a grand theoretical proposition. Instead, the text serves as an authentic description of my process of learning and practising. My music usually experiments with a theoretical construct, and the learning takes place through reflecting on the practice. Consequently, in this cycle of constant trial and error, I realise that there is tension between ideas that work in theory, and ideas that work in practice. More specifically, I found a discrepancy between my understanding of algorithmic music and my own experience of attempting it. In this gap, there is a strong, unresolved tension between the theory and practice, which refuses to function as one coherent unity, making it almost implausible to apply the theory directly into practice. This gap between theory and practice is a recurring theme throughout my thesis. As I will show in the writing, I kept trying to test theories in my compositions, and I have failed repeatedly. The pieces that I found success with are, counter-intuitively, the ones where I decided not to follow through with the theory. Even in the contextual research, I noticed that historically, there are *general* theories that describe musical practices, be it dodecaphony or Bach chorales, but in practice, the music is unlikely to fit squarely into those theories. Twelve-tone music *generally* follows a tone row, and the music comes from some form of reordering in its numerical series. But in practice, it is rare (but not impossible) to find examples that adhere strictly to this theory of generality. As I will show throughout this thesis, when the theory is used directly as the practice, the music loses its uniqueness, and the pieces that result are typically those that are decried the most by composers (including myself).

From the outset, the overarching argument that I make in this thesis is, paradoxically, against overarching arguments. I argue against their approach toward the general. I propose that what is most significant—and definitionally where any newness is most likely to be found—is in the particular. To me, these are the things that are specific to an individual piece of music, and in the context of algorithmic music they tend to happen before or after (but not during) the generative process. I will return to acknowledge this gap in the conclusion.

With that said, part of the reason this gap exists stems from my preconceived understanding of algorithmic composition in general. Before coming to Leeds to do a PhD, I studied at Trinity Laban Conservatoire with John Lely and Sam Hayden. I had never used algorithms at that point, at least not rigorously. My understanding of rigorous algorithmic

composition came from lectures that explained the numerical symmetry in Webern's *Variations for Piano,* Op.27 (1936) or working out Stravinsky's hexachord system from *A Sermon, a Narrative, and a Prayer* (1961) by hand, and I also recall a seminar where Lely shared the manuscripts of Michael Parsons' piano pieces to explain the method behind them. My impression was that these composers, in general, sought to compose autonomously by rules and numbers, which impressed me, but for the wrong reasons. I viewed these pieces as mathematical challenges, where the music is objectively governed by numerical relationships, with no personal expression involved. More bluntly, I found these pieces interesting in the same sense that I find sudokus engaging. To the younger me, composing with algorithms seemed to be exclusively a matter of problem solving. I thought that the numbers would work themselves out, thereby removing the involvement of the composer completely. As such, when I turned to algorithms in the first year of my PhD, I was aiming for the algorithm to write music by itself without requiring any involvement from me.

There are two consequences from subscribing to this mode of thought. Compositionally, I felt lost. Without wanting to be involved, my music was only a result of logical problem solving, and it turned out to be completely blank. As I describe in detail in Chapter 2, I was dissatisfied with the initial results and kept looking for ways to fix the issue without being personally involved. Hence, the constant cycle of trial and error. There is a catch-22 here: I was dissatisfied with the emptiness of the algorithm, but I could not act on it because I did not wish to be involved in the process, so I continued to be dissatisfied with the algorithm. Eventually, as I will outline below, after three years of experimentation, through receiving feedback from performers and tutors, I arrived at the realisation that I had misunderstood algorithmic music from the outset. I will expand on this realisation in the conclusion.

The second consequence is that academically, with the shallow readings of Webern, Stravinsky, and Parsons in mind, I unknowingly read the literature on algorithmic music from a skewed perspective. I read about the processes of Cage, Boulez, Xenakis, and currently, AI, on the premise that these pieces were also merely products of abstract, inexpressive, numerical relationships that aimed to remove the composer's involvement. The following commentary attempts to retrace my misconceptions to show how I arrived at my current thinking. By noting what I have learned along the way, I hope to shed light on the gaps between theory and practice. Ultimately, some decisions are simply intuitive and 'composerly', and it is often difficult to explain without experimenting with them in practice. It took three years for me to re-learn what it means to compose algorithmically, and I will try

to lay out my journey of self-realisation as fully as possible in this thesis. But before that, I shall unpack my misreading of algorithmic literature to illustrate the significance of this thesis in its broader context.

1.1 Context

Discourses surrounding Artificial Intelligence (AI) in music have become increasingly widespread ever since the emergence of generative software such as ChatGPT, DALLE-E, and MusicGen. The gist of these ongoing discussions can be reflected in the media's recent headlines: 'AI Composes Classical Music', 'What Happens When A.I. Enters the Concert Hall?', 'Is AI Music a Genuine Threat To Real Artists?', and 'If AI Starts Making Music on Its Own, What Happens to Musicians?'[1] These articles refer to AI algorithms as if they are all capable of writing music autonomously. To some, it is obvious that this is an exaggeration by the mainstream media to attract clicks and attention in its headlines. However, to others, particularly those who are inexperienced in algorithmic music, these writings can be misleading if such generalisations are not discerned carefully.

The problem can be exemplified in the media's portrayal of the Beethoven's Tenth Symphony project. On 9 October 2021, Beethoven's Tenth Symphony was premiered in Bonn in celebration for his 250th birthday. The following headlines were used: 'After more than two centuries, Beethoven's Tenth Symphony has been completed by an AI', 'Beethoven's Unfinished 10th Symphony Brought to Life by Artificial Intelligence', and 'Beethoven started composing his 10th Symphony in the 1820s. AI finished it in 2021'.[2] If one were to read these articles at face value, it would seem as if the AI were a digital composer who finished Beethoven's symphony autonomously without requiring any human intervention.

However, it would be a conjecture to interpret these titles too literally, as Miguel Civit *et al.* describe the actual process:

> The final work was based on some sketches by the original composer, the first two movements having been pieced together from those fragments by British musicologist and composer Barry Cooper in 1988. The last two movements were composed with some help from AI tools, but still required a lot of work by human composers.[3]

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[1] Georg Predota, 'AI Composes Classical Music', *Interlude*, 5 January 2023, <https://interlude.hk/ai-composes-classical-music-david-cope/> [accessed 5 July 2023]; Garrett Schumann, 'What Happens When A.I. Enters the Concert Hall', *The New York Times*, 10 Jun 2023. <https://www.nytimes.com/2023/06/10/arts/music/ai-classical-music.html> [accessed 5 July 2023]; Kelly Bishop, 'Is AI Music a Genuine Threat To Real Artists?', *Vice*, 16 February 2023, <https://www.vice.com/en/article/88qzpa/artificial-intelligence-music-industry-future> [accessed 5 July 2023]; Allison Parshall, 'If AI Starts Making Music on Its Own, What Happens to Musicians?', *Scientific American*, 27 March 2023, <https://www.scientificamerican.com/podcast/episode/if-ai-starts-making-music-on-its-own-what-happens-to-musicians/> [accessed 5 July 2023].

[2] Miguel Civit, *et al.*, 'A Systematic Review of Artificial Intelligence-based Music Generation: Scope, Applications, and Future Trends', *Expert Systems with Applications: An International Journal*, 209 (2022), 1–16 (1).

[3] Ibid.

With the context provided by Civit *et al.*, it is evident that these headlines were, in fact, exaggerating the extent of automaticism in the algorithm. The symphony was not literally 'completed by an AI'. The technology was not even used for the first half of the symphony. Instead, the AI was only used to produce fragments for the second half, which required composers and musicologists' interpretation to bring the final work to life. In that sense, these titles should be read as hyperbole that describe the use of algorithmic materials in a human-driven compositional process. It is not the AI that 'finished' Beethoven's symphony. It is the humans using the AI who did. Namely, they are a team consisting of Michael Schuld (executive producer), Matthias Röder (project manager), Ahmed Elgammal (machine learning specialist), Walter Werzowa (composer), and musicologists Mark Gotham and Robert Levin.[4]

This exaggerated tone of writing can be found in reports for all sorts of AI projects, regardless of genre and the type of algorithm. For instance, Dadabots' lo-fi black metal album, *Coditany of Timeness* (2017) has been described as 'created by an artificial intelligence' by Tom Dent-Spargo and Jon Cristian.[5] Cristian even denied the involvement of its creators, 'but the record', he writes, 'wasn't created by musicians'. Again, this is not entirely true because as Dadabots explain,

> [The process] was a lot of trial and error… we had been tweaking hyperparameters for months to get a speech model to make music… and [Zack] listened through the 10 hours of output audio, found sections that sounded like complete songs, and arranged them in an order.[6]

In contemporary music, it is not uncommon to find blogs and reviews written in the same way. Nils Schlechtriemen introduced the history of generative music with the subtitle 'Machines make music themselves' to refer to the algorithmic music 'from Karlheinz Stockhausen to Pierre Boulez, from Roger B. Dannenberg to David Cope, from acousmatist Roland Kayn to ambientologist Brian Eno'.[7] Jennifer Walshe's collaboration with Dadabots, *A Late Anthology of Early Music* (2020) is frequently met with reviews such as 'I feel pity for these machines being so utterly inept at capturing the essence of music, yet a respect for this

[4] 'AI Team', *Beethoven X: The AI Project*, 2021 <https://www.beethovenx-ai.com> [accessed 4 June 2024].
[5] Tom Dent-Spargo, 'Passing the Musical Turing Test', *The Robotics Law Journal*, 9 March 2018 <https://roboticslawjournal.com/analysis/passing-the-musical-turing-test-65327148> [accessed 10 November 2023]; Jon Cristian, 'This Frostbitten Black Metal Album was Created By an Artificial Intelligence', *The Outline*, 1 December 2017 <https://theoutline.com/post/2556/this-frostbitten-black-metal-album-was-created-by-an-artificial-intelligence> [accessed 10 November 2023].
[6] CJ Carr and Zack Zukowkski, 'FAQ', *Dadabots*, n.d. <https://dadabots.com/faq.php> [accessed 10 November 2023].
[7] Nils Schlechtriemen, 'Is Artifical Intelligence Altering Contemporary Music?', *HHV Magazine*, 28 June 2022 <https://www.hhv-mag.com/feature/popmusik-und-kuenstliche-intelligenz/> [accessed 10 November 2023]. In Chapter 3.4, I argue against Schlechtriemen's notion of 'machines make music themselves' using examples by some of the composers he mentions here.

so alien result'.[8] This is, again, a misunderstanding of the composer's involvement in the generative process. As Walshe explains the process behind *A Late Anthology*:

> I was working with over 800 training outputs which Dadabots very kindly generated for me by training their version of Sample-RNN on my voice. I was able to hear the network gradually and learn to iterate my voice, and I mapped that process onto the early history of Western music.[9]

It is, however, conspicuous that these misinterpretations are attributing the compositional process to the algorithms themselves, neglecting the composer's involvement completely.

It is undeniable that generative algorithms are becoming increasingly autonomous and easy to use. For example, AI tools such as AIVA and MusicGen can create music at a push of a button based on their user's settings before the generation process. Yet even within these easy-to-use autonomous programs, there are different decisions to be made by their human users: AIVA has individual parameters for its users to customise, while MusicGen asks for a more general text prompt. To me, the problem in the media's way of writing about AI is two-fold. First, when composers are said to have written music using an AI, the insinuation is that the AI is always capable of writing the music by itself, without requiring any intervention by the composer. I will explain over the course of this thesis that composers deviate from their algorithms more frequently than is usually acknowledged. And even if an autonomous algorithm was used, there would still be sophisticated layers of decisions to be made before and after the generative process. In other words, music is rarely written by AI. It is usually the case that the points of decisions would have shifted to pre- and post-generation only. As long as these decisions are still being made by humans, it would be the humans who are doing the composing, not the AI itself. As I will stress throughout my discussion of historical precedents (for this and through my own compositional work), this bears a striking resemblance to reports of how post-war music more generally, whether serial or chance derived, has been discussed. Although there may be (more-or-less) automatic processes involved, the composer's decision making before and after those processes remains key to the conception of the piece. To put it bluntly, I argue that it is the composerly decisions around the algorithm that make the 'magic' happen in algorithmic music.

It is, however, curious that when AI is used in compositions, the human agency in making these decisions becomes invisible, as if the music was written by the AI itself. The

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[8] Offler, 'A Late Anthology of Early Music, Vol 1: Ancient to Renaissance', *Rate Your Music*, 6 April 2023 <https://rateyourmusic.com/release/album/jennifer-walshe/a-late-anthology-of-early-music-vol-1-ancient-to-renaissance/> [accessed 10 November 2023]. Chapter 3.4 illustrates the commonality of this sentiment of results feeling 'alien' in algorithmic composition.

[9] Estela Oliva, 'Jennifer Walshe & Jon Leidecker, Thoughts on Collaboration', *CLOT Magazine*, 9 May 2023 <https://news.artnet.com/news/ai-experts-cultural-stagnation-2322743> [accessed 4 June 2023].

second layer of my problem with writings on AI is in this false opposition of viewing AI as a 'human counterpart', a 'threat', or some 'dehumanised procedure'. In my thesis, I argue that these 'hidden decisions', from pre- and post-generation, are equally important (if not more important) than the algorithm itself. These decisions can be extremely rich and diverse, and they enable a myriad of ways to write algorithmic music differently.

Since there is already plenty of existing literature that explains different algorithmic techniques on more general terms, such as Gerhard Nierhaus's *Algorithmic Composition* and *The Oxford Handbook of Algorithmic Music* edited by Roger Dean and Alex Mclean, this thesis will not be about algorithmic techniques in themselves.[10] Instead, the focus will be on identifying the specific points of tensions in different ways to use the algorithm, which I explore compositionally in the practice.

There are two reasons I am pursuing this topic. On a personal level, at the beginning of my PhD, as I noted above, I was one of those who would read these misleading headlines at face value without realising that they were exaggerations. I was new to algorithmic music and naively assumed that algorithmic composition meant sitting back and letting the algorithm write music itself. Eventually, it took a rocky three years of trial and error for me to develop a more critical sense of algorithmic composition. I hope to document my journey authentically through the thesis so that other composers or readers who are not yet familiar with algorithmic procedures can avoid the mistakes that I made along the way. This is to say that in all honesty, I confess at the outset that these are not the pieces in my output about which I, myself, have the greatest excitement. But these pieces are kept in the portfolio because they show exactly where I come from, and they reflect the modest journey of how I arrived at my musical thinking now. In the process of reflecting on each piece, I am able to identify my own dissatisfaction more clearly, which drives the improvement for future work.

On a broader level, by researching into the context of algorithmic music, I note that current issues on AI music are rooted in historical discourses between post-war avant-garde composers and their critics. I will address these discourses briefly below, and more fully in the rest of my writing. In this practice-led thesis, I try to address these issues through my music, and vice versa, my practice leads me to examine these issues more deeply. As such, in this critical commentary, one might be able to sense a progression which reflects my journey

[10] Gerhard Niehaus, *Algorithmic Composition: Paradigms of Automated Music Generation* (Vienna: Springer-Verlag, 2009); Roger T. Dean and Alex Mclean, eds., *The Oxford Handbook of Algorithmic Music* (New York, NY: Oxford University Press, 2018).

from naivety to more nuanced thinking around algorithms. Before I begin to discuss my portfolio of works, it would be useful to first establish what I mean by algorithmic music.

1.2 Definitions

To be sure, algorithmic methods in composition have existed long before the emergence of AI tools. Karlheinz Essl defines the term 'algorithm' as 'a predetermined set of instructions for solving a specific problem in a limited number of steps'.[11] It is worth stressing that this definition has two necessary components: 1) a predetermined set of instructions, and 2) a finite number of possible outcomes. Following this definition, the use of algorithms in composition can be traced back to at least 1025 in Guido d'Arrezo's solmisation system.[12] Guido's instruction was concise: each vowel is mapped to a pitch, so any given text would lead to a resulting melody. This 1-to-1 mapping system is clearly algorithmic.

Another example of early algorithmic music would be the puzzle canons from the Renaissance. The notation for these canons can take all sorts of forms. Some are graphic, such as the heart-shaped and circular notation of songs by Baude Cordier (*fl.*1400).[13] Some are presented as riddles, as seen in the 'Agnus Dei' of Guillaume Du Fay's *L'homme armé* (1474), which has the phrase 'Cancer eat plenus sed redeat medius' (the crab goes [forwards] in full but returns by half).[14] There are also puzzle canons that are partially notated, accompanied by symbols and instructions for singers to decipher, such as Johannes Ockeghem's *Missa Prolationum* (1465), a four-voice double canon where only two voices are presented in the notation.[15] These puzzle canons are also algorithmic because there are specific ways to decode the instructions and they typically only lead to a single outcome.[16]

Moreover, W. A. Mozart's *Musikalisches Würfelspiel* (Musical Dice Game) (1792) is also algorithmic but functions in a different way. Unlike puzzle canons, Mozart's score is

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[11] Karlheinz Essl, 'Algorithmic Composition', in *The Cambridge Companion on Electronic* Music, ed. by Nick Collins and Julio d'Escriván (Cambridge: Cambridge University Press, 2011), 107–25 (107).
[12] Nick Collins, 'Origins of Algorithmic Thinking in Music', in *The Oxford Handbook of Algorithmic Music,* ed. by Roger T. Dean and Alex Mclean (New York, NY: Oxford University Press, 2018), 67–79 (69).
[13] Fabrice Fitch, *Renaissance Polyphony* (Cambridge: Cambridge University Press, 2020), 2.
[14] Ibid., 347.
[15] Ibid., 212. A parallel example in contemporary music would be Klaus Lang's *ubi est mundus* (2019) where parts can be deciphered from the puzzle notation. Additionally, a decoded version of the full score is also available. A detailed description of the process is documented in Klaus Lang, 'Kompositorische Praxis als Handwerk an zwei Beispelen', unpublished article (2023), Used with permission from Lang.
[16] Notably, some puzzle cannons can lead to multiple solutions. Examples include Pierre Moulu's *Missa Alma Redemptoris Mater,* which can be sung with or without rests; Ockeghem's *Missa Cuiusvis toni,* which can be sung in four modes; and Bach's *Verschiedene Canones über die ersten acht Fundamental-Noten vorheriger Arie* (BWV 1087) where materials can be pieced together in different order and combinations.

conventionally notated, and he is the sole user of his algorithm.[17] It is also worth noting that Mozart's algorithm introduces an element of chance.[18] Mozart pre-composed eleven versions of each bar, whose selection he then determined by throwing two dice to produce a number between 2 to 12 (it is worth noting that the probability distribution is uneven in this mechanism—there is a 1/6 chance to roll a 7 but only 1/36 to roll 2 or 12).[19] Although the selection of material is left to chance, Zbikowski notes that Mozart's system has been set up to achieve the underlying syntax of a typical minuet.[20] For instance, there are significantly fewer options within the algorithm at cadential moments. Within the first sixteen bars, only one version of bar 8 exists, and there are only two versions bar 16. Therefore, regardless of the excerpt being selected, the harmonic structure will remain constant. The *Musikalisches Würfelspiel* serves as an example to show how decisions can be made at the pre-compositional stage to manipulate the algorithmic outcome.

1.3 Serial Algorithms

The twentieth century has seen a revival of interests in algorithmic music. To be sure, Arnold Schoenberg's serialism, while a formalised procedure, is not technically algorithmic according to Essl's definition. While there are a finite number of ways to arrange rows (12! = 479,001,600 possible combinations) and limited ways to transform them, Schoenberg is in intuitive control over how the predetermined series is used. For example, his *Variations for Orchestra,* op.31 (1926–28) follow the pitch series of his tone row and its retrograde, inversion, and retrograde inversion. However, here, Schoenberg has expressive freedom to manipulate parameters around pitch material, including orchestral timbre, rhythm, and texture. All of these elements were interpreted intuitively to craft musical expression out of dodecaphonic materials.[21] While the serial material itself is algorithmically generated (in the sense that there are theoretically a finite number of ways to create a tone row), Schoenberg's

[17] It is worth clarifying that numerous musical dice games were invented before Mozart's. The decision to discuss Mozart's version is because it is typical of how dice games work. For a historical overview of dice games, see: Stephen A. Hedges, 'Dice Music in the Eighteenth Century', *Music & Letters,* 59(1978), 180–187.
[18] A similar approach is used in Lejaren Hiller and John Cage's collaboration on a piece called *HPSCHD* (1969). The title refers to the harpsichord, as it is a computer-generated piece for harpsichord and tape. The piece uses an open form that consists of seven harpsichord solos and fifty-two tape parts. The solos were created using excerpts by Mozart, Beethoven, Chopin, Schumann, Gottschalk, Busoni, and Schoenberg, processed using a programme based on the *I Ching.* See: Stephen Husarik, 'John Cage and LeJaren Hiller: HPSCHD, 1969', *American Music,* 1(1983), 1–21.
[19] Fred K. Prieberg, *Musica ex machina: Über das Verhaltnis von Musik und Technik* (Berlin: Ullstein, 1960), 113–17.
[20] Lawrence M. Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (Oxford: Oxford University Press, 2002), 140–53.
[21] For Schoenberg's own commentary on how he used the pitch series freely in *Variations for Orchestra*, see: Arnold Schoenberg, 'Composition with Twelve Tones', in *Style and Idea* (New York, NY: Philosophical Library, 1950), 92–242 (118–131). This intuitive command of serial material is also noted in Boulez's infamous attack on Schoenberg in 'Schoenberg is Dead', which I will address in Chapter 2.4.1.

music is not algorithmic because of his liberal use of material which opens up innumerable possibilities in the algorithmic outcome.

With that said, in a roundabout manner, Schoenberg is still considered a putative pioneer of contemporary algorithmic music due to the way his music led to divided reactions among the next generation of composers, especially Pierre Boulez, John Cage, Luigi Nono, and Iannis Xenakis. These composers each held distinct perspectives on serialism and embarked on various algorithmic experiments with their own motivations. In my thesis, I will draw extensively from the works of these composers, and there are three reasons for choosing them. First, although their music existed before the age of AI, there is a deep pool of literature surrounding their musics which can provide the theoretical basis for my thesis. Second, as I will explain below, I found that these discussions on post-war algorithmic music are in fact, almost a mirror with the current issues on AI that I identified above. Third, the musics and writings from this period have always been influential on my own practice, even before I started my PhD. Therefore, I view these composers to be very close to my practice. For instance, during my undergraduate years, I initially had a more naive interpretation of Cage's *Silence*, as I remember reading this particular line in the essay on Experimental Music:

> One may give up the desire to control sound, clear his [*sic*] mind of music, and set about discovering means to let sounds be themselves rather than vehicles for man-made theories or expressions of human sentiments.[22]

In hindsight, this was only problematic because I read this with John Cage's *Music of Changes* (1951) in mind. While researching on the piece for my dissertation, I took his statement at face-value. I inadvertently misinterpreted that because he wanted to 'let sounds be themselves', and since he had 'given up the desire to control sound', he had removed himself from the creative process altogether. And since Cage no longer participated in the compositional process, I assumed that he must have stopped caring about the sounds he created. It seemed as if the algorithm was composing the music, not Cage.

However, after spending more time with Cage's work over the years, I now realise that this cannot plausibly be the case. Cage's words exaggerated his ambition to break free from pre-existing traditions by introducing an element of unpredictability in his music. Clearly, the algorithm itself did not compose the music; it was still Cage who did, but he operated on a different level. Instead of working with the individual notes on the page, Cage composed the algorithm, carefully, so that he could depend on the algorithm to make

[22] John Cage, 'Experimental Music', in *Silence: Lectures and Writings by John Cage* (Hanover, NH: Wesleyan University Press, 1961), 7–13 (10).

decisions for him. As Cage writes: 'the composer resembles the maker of a camera who allows someone else to take the picture'.[23] This does not mean Cage lost interest in the sounding outcome. Rather, he viewed the act of 'making the camera' as his compositional approach, intentionally limiting his involvement so that he can be surprised when the 'picture' has been taken.

This is precisely the same issue in the writings on the Beethoven AI. It is (all too) easy to misread these texts to assume that all algorithms are autonomous and that they are there to replace composers. As a result, the role of the humans in *how* the algorithm is used to create the piece is sometimes neglected. I will follow up with a more detailed discussion on Cage's process in Chapter 2.4.2.

To shed light on the richness and the relevance of the historical discourses from this period, Boulez held a different criticism on Cage's Experimental music. In 'Alea', Boulez criticised experimental music as being 'poisonous' to contemporary music due to its use of chance and indeterminate notation.[24] He writes:

> You see what it comes back to? Always a refusal to choose. The first idea [of chance] was purely mechanistic, automatic, fetishistic; the second [of open scores] is still fetishistic, but one escapes choice, not by numbers, but through the performer.[25]

This passage shows that even before the invention of computer algorithms, Boulez had a similar concern over the 'fetishistic' implications of autonomous algorithms.[26] Boulez accuses Cage of 'a refusal to choose' because his approach was 'mechanistic' and 'automatic'. However, as I will elaborate in Chapter 2.4.2 (and, reiterating in Chapter 3.3.5), there is certainly no absence of decisions in Cage's processes. Those processes simply entail a different set of decisions to be made at the pre-compositional stage. It is worth noting that at the time of writing 'Alea', Boulez had a limited understanding of how Cage's process in *Music of Changes* was similar to his own. Therefore, in fairness to Boulez, he seems to be self-critical of his own *Structures*, which also had issues with the fetishistic neglection of bodies. This will be addressed more explicitly in Chapter 3.3.3.

Additionally, it is not uncommon to find scholars and critics who write about Boulez's music under the same assumption. For example, in *Music in the Late Twentieth Century*, Richard Taruskin writes: 'all one had to do was introduce strict serial ordering into the four

[23] Ibid., 11.
[24] Pierre Boulez, 'Alea', in *Stocktakings from an Apprenticeship*, ed. by Paule Thévenin (Oxford: Clarendon Press, 1991), 27.
[25] Ibid., 28.
[26] Despite Boulez's criticism in 'Alea', Boulez later experimented with open form himself in his Third Piano Sonata, which I will discuss in detail in Chapter 4.1.

Messiaenic domains. And that is just what Boulez did in *Structures* for two pianos (1951)'.[27] Taruskin writes as if Boulez's *Structures* wrote itself, with notes automatically falling into place by adhering to the serial order. This implies, once again, a misunderstanding of the human agency within an autonomous algorithm, as if the composer simply sat back and let the numerical process do the composing instead.

Taruskin's misunderstanding of Boulez is most evident in a later chapter where he notes that Boulez's obsession with numbers, stemming from Du Fay's fourteenth-century isorhythms, 'rested on a Platonic faith in number as the ultimate and imperishable reality'.[28] Taruskin illustrates the problem by quoting the *Scholia enchiriadis*, 'notes pass quickly away… numbers, however, though stained by the corporeal touch of pitches and motions, remain'.[29] However, this interpretation does not accurately reflect Boulez's actual beliefs. Taruskin seems to have assumed that Boulez's interest in automatism meant that his priority was on the rigid procedure and avoided human intervention. As I will explain in Chapter 2.4.1, Boulez's music possesses a unique kind of expressivity, although the agencies for these kinds of expression are not always immediately apparent.

Moreover, in 'The Aging of the New Music', Theodor Adorno criticises the young composers of the time following the same assumption. To be sure, Martin Iddon notes that Boulez was likely 'off the hook' in Adorno's critique, as Adorno was only referring to Karel Goeyvaerts based on one, albeit very significant encounter with Goeyvaerts.[30] However, Adorno expanded on the issue with Goeyvaerts to include other young composers altogether, including the likes of Herbert Eimert and Karlheinz Stockhausen in his writing. Zagorski summarises Adorno's issue with the young composers' algorithmic attempts: 'they simply accepted their systems and did not direct their own subjective needs against the compositional tradition that history had bequeathed to them'.[31] Here, much like the way current media is writing about AI, Adorno has evidently subscribed to thinking that these composers simply sat back and watched the algorithms write music by themselves.

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[27] Richard Taruskin, *Music in the Late Twentieth Century* (New York: NY, Oxford University Press, 2009), 42.
[28] Ibid., 62.
[29] Ibid. Taruskin is also mistaken here to claim that Boulez's interest in numerical processes is rooted in the music of Du Fay. Boulez has called isorhythms 'a phenomenon of dissociation', and 'an actual procedure directly contrary to that which we observe in the history of Western Music'. In Chapter 3.3.1, I note a similar issue with isorhythms in my percussion piece *Recursion.* See Pierre Boulez, 'Stravinsky Remains', in *Stocktakings from an Apprenticeship,* ed. by Paule Thévenin (Oxford: Clarendon Press, 1991), 106–110 (109).
[30] Martin Iddon, *New Music at Darmstadt: Nono, Stockhausen, Cage,* and *Boulez* (New York, NY: Cambridge University Press, 2013), 129.
[31] Marcus Zagorski, '"Nach dem Weltuntergang": Adorno's Engagement with Postwar Music', *The Journal of Musicology* 22, 4 (2005), 680–701 (689).

However, the problem is, as Iddon explains, Adorno was ultimately mistaken to take Goeyvaerts' Sonata for Two Pianos (1950–51) as a typical example of multiple-serialism, because in reality, it is much more rigorous than the norm.[32] While there is not enough scope to fully unpack the controversies and reactions surrounding Adorno's critique here, the point is that, much like the discussion in Chapter 1.1, Adorno seems to have assumed all algorithms are fully automatic and therefore neglected the layers of human decisions involved in these algorithmic processes.[33]

The list goes on. For example, Luciano Berio once described the algorithmic music from the 1950s as 'writing music without being personally involved'.[34] Stockhausen's *Kontra-Punkte* (1952–53) has been described by Albert Rodemann as 'an abstract, dehumanised art'.[35] Ernst Thomas has made a similar remark that *Kontra-Pinkte* is 'a total objectivity and complete elimination of the subjective expressive will', where Stockhausen himself 'does not compose' but simply 'obeys the intellectually independent material'.[36] Furthermore, Armin Schibler, in a disagreement against Boulez, Goeyvaerts, and Stockhausen's admiration for late Webern, wrote that these composer's work with rows 'threatens to become an abstract process which supresses every declaration of humanity'.[37] Schibler even went as far as to conclude that these composers sought an 'elimination of the human element from art'.[38] These sorts of critique, I would argue, come from the same perspective as those paranoia headlines that speak of 'the threat of AI'.

Placing a focus on Cage, Boulez, Nono, and Xenakis, it is intriguing to observe how these composers disagreed with each other and tried to use algorithms differently. Conspicuously, not only did they disagree among themselves, they also frequently debated with musicologists and critics. For example, Adorno saw Boulez as the more 'humanised' composer of the group, but there are also writers who see Nono as being far more 'human' than Boulez. This is to say that the algorithmic music of this era comes with an intriguing history of different perspectives and opinions. The main body of my thesis draws on some of the most debated pieces to reveal both sides of the arguments. For example, why do some writers, such as Reginald Smith Brindle, claim that Nono's *Il canto sospeso* (1955–56) is a rigorously serial piece, while others, such as Jonathan Impett, call it 'intuitive'? There are

[32] Iddon, *New Music at Darmstadt,* 114.
[33] See ibid., 91–102.
[34] Reginald Smith Brindle, *The New Music: The Avant-Garde since 1945* (Oxford: Oxford University Press, 1987), 41.
[35] Iddon, *New Music at Darmstadt,* 99.
[36] Ibid., 98.
[37] Ibid., 97.
[38] Ibid.

similar debates on Boulez's *Le Marteau sans maître* (1954), as well as John Cage's *Music of Changes*, which will be unpacked in the following chapters.

1.4 Process Algorithms

Apart from serial music, another prominent strand of algorithmic music in the twentieth century would be process-based works, such as Steve Reich's *Clapping Music* (1972). In *Clapping Music*, written for two performers, the first performer repeats a twelve-quaver motif to create a rhythmic loop. Simultaneously, the second performer claps the same motif but shifts by one quaver beat on every repetition. Each loop is then repeated exactly twelve times, resulting in a gradual phasing process between the two performers. The piece concludes when the cycle is complete, which is when the performers come back in sync. *Clapping Music* fits neatly with Essl's definition of algorithmic, because once the process is set up, there can only be one way the piece can happen. The points of compositional decisions are then all within the pre-compositional stage. The implications of this will be discussed in Chapter 3.3.4.

Notably, these kinds of process-based algorithms have a remarkable degree of autonomy. As Reich describes, 'once the process has been set up it inexorably works itself out'.[39] This is because process-based works are generally structured to follow an extremely concise set of instructions, where the emphasis is placed on hearing the process without any room for deviation. This rigid adherence to the process means that these pieces have inherently fewer possible outcomes due to the fact that the process is in itself the music.

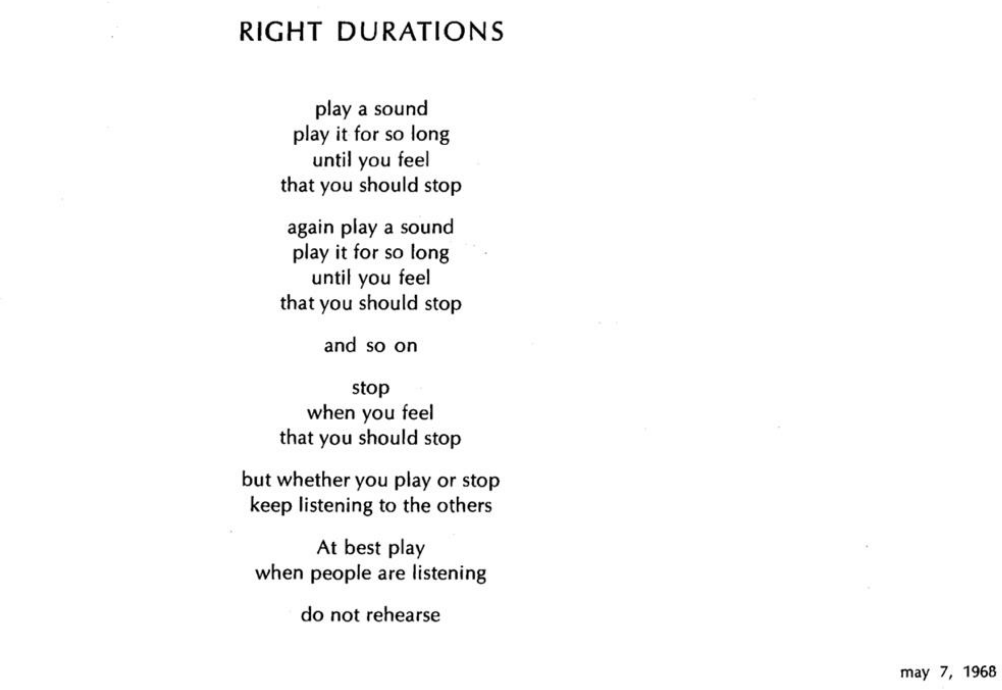
Apart from phasing, these process-based algorithms can also underpin spectral processes such as in James Tenney's *Critical Band* (1988). *Critical Band*, for any ten or more sustaining instruments, is based on a geometric expansion of the harmonic series. *Critical Band* begins by a sustained A in unison, then expands in contrary motion, in increments of the Pythagorean harmonic mean, which is calculated by dividing an interval into equal parts.[40] As such, following the initial fundamental ratio 1/1, the ascending sequence begins with pitches 129/128, then 65/64, where 129/128 is the harmonic mean of 65/64 (proportions 128:129:130). Consequently, 65/64 is taken as the next harmonic mean, to produce 33/32 with proportions 64:65:66. This process continues where 33/32 is used to find the next pitch of 17/16 (33:32:31), and so on to reach 9/8 (just-major second), then 5/4 (just-major third),

[39] Steve Reich, 'Early Works (1965–68)', in *Writings on Music, 1965–2000*, ed. by Paul Hillier (New York, NY: Oxford University Press, 2002), 20.
[40] Bob Gilmore, 'Changing the Metaphor: Ratio Models of Musical Pitch in the Work of Harry Partch, Ben Johnson, and James Tenney', *Perspectives of New Music*, 33 (1995), 458–503 (494).

by which the harmonic mean becomes constant and the remaining pitches form the proportion 10:11:12:13:14:15:16. The descending sequence uses the same concept but with slightly different proportions that end in the octave (2:1). The perceptual effect of this process is that the piece starts in unison, then splits into extremely small-interval cluster chords that are within the 'bandwidth' of a major second (which is a result of using high primes). The piece gradually unfolds into larger intervals where harmonic relationships become clearer towards the end of the piece, finishing on an A dominant seven chord.

Despite *Critical Band* also following a limited set of algorithmic instructions, it is worth noting that there is significantly more compositional agency here than in *Clapping Music.* In *Critical Band*, the duration of each note forms a rather arbitrary acceleration. Furthermore, even though the choice of pitch is calculated by a function of harmonic mean, it is ultimately up to Tenney which ratios to begin and end on. This is to say that there can be potentially very different ways to rewrite *Critical Band*, but there can only be one way to do *Clapping Music.*

To be sure, not all process-based music is algorithmic, such as Stockhausen's *Right Durations (Richtige Dauern)* from *Aus den sieben Tagen* (1968). The text score (figure 1) provides the instructions for a musical process that involves individuals playing and stopping at will. However, according to Essl's definition, *Right Durations* is not algorithmic because there are innumerable ways to realise this process, considering that there can be different instrumentation, pitch, duration, timbre, and more. While the instruction is fixed, there is not enough consistency in how the piece would sound every time, which is why it is technically not algorithmic.



RIGHT DURATIONS

play a sound
play it for so long
until you feel
that you should stop

again play a sound
play it for so long
until you feel
that you should stop

and so on

stop
when you feel
that you should stop

but whether you play or stop
keep listening to the others

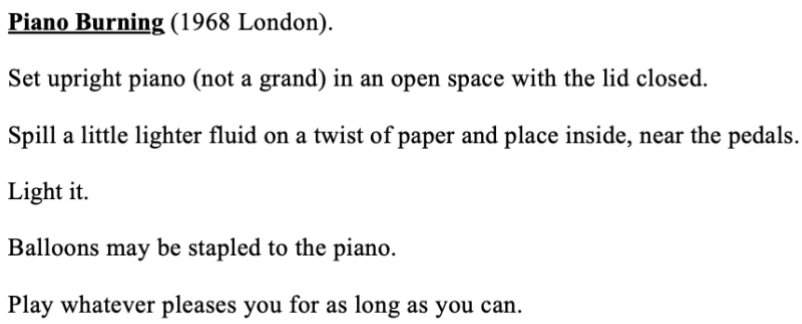
At best play
when people are listening

do not rehearse

may 7, 1968

Figure 1: Text score for *Right Durations*[41]

This distinction between algorithms and processes, however, is not always that clearly demarcated. For instance, Annea Lockwood's *Piano Burning* (1968) is a process piece that can be argued both ways. The score is shown in figure 2.



Piano Burning (1968 London).

Set upright piano (not a grand) in an open space with the lid closed.

Spill a little lighter fluid on a twist of paper and place inside, near the pedals.

Light it.

Balloons may be stapled to the piano.

Play whatever pleases you for as long as you can.

Figure 2: Text score for *Piano Burning*[42]

On the one hand, *Piano Burning* can be described as non-algorithmic. Since the piece takes place in a physical space, there are immeasurable ways in which the environment can change over the duration of the piano's burning. So, if the ambient environment is considered to be part of the performance, then it could be said that there are infinite ways that the burning process can unfold. But on the other hand, it could also be considered algorithmic because

[41] Karlheinz Stockhausen, 'Right Durations', in *Aus Den Sieben Tagen*, score (London: Universal Edition, 1968).
[42] Annea Lockwood, 'Piano Burning', *Annea Lockwood*, n.d. <https://www.annealockwood.com/compositions/piano-transplants/> [accessed 4 June 2024]

regardless of what happens over the fire, conceptually, the piece can only unfold in one way, which is the process of a piano literally burning to ashes.

Similarly, Brian Eno's *Music for Airports* (1978) is simultaneously algorithmic and non-algorithmic. Eno explains:

> *Music for Airports*, at least one of the pieces on there, is structurally very, very simple. There are sung notes, sung by three women and myself. One of the notes repeats every 23 1/2 seconds. It is in fact a long loop running around a series of tubular aluminum chairs in Conny Plank's studio. The next lowest loop repeats every 25 7/8 seconds or something like that. The third one every 29 15/16 seconds or something. What I mean is they all repeat in cycles that are called incommensurable – they are not likely to come back into sync again.[43]

As Eno neatly summarises it, the piece follows a rather simple generative process of loops that are set to indivisible ratios, so the loops are incredibly unlikely to be in sync again. It can be considered algorithmic because the piece is based on individual loops repeating themselves, so technically there is a finite number of ways this generative process of stacking tracks can unfold. But in practice, however, since the loops are never actually back in sync, the music is always only a part of the looping process. Although the algorithm unfolds following the same process every time, the result is almost guaranteed to be slightly different on each run. In that sense, *Music for Airports* can be said to be non-algorithmic, because the sonic outcome is everchanging.

Finally, it is worth making a passing mention of data sonification as a unique kind of algorithmic process. Carla Scaletti defines data sonification as 'data generated by a model, captured in an experiment, or otherwise gathered through observation, and mapping those data to one or more parameters of an audio signal or sound synthesis model'.[44] Sonification follows a strict mapping process of non-musical data. Once the mapping system has been set up, there can only be one way the process can unfold; therefore, it is algorithmic. Notably, Scaletti makes a distinction between sonification and data-driven music. She argues that both forms use the same generative techniques, but sonification's goal is to 'better understand, communicate, or reason about the original model, experiment, or system', while data-driven music's goal is to 'make an audience think by creating a flow of experience for them'.[45] Since Scaletti has already established sonification as non-music, and taking into account that sonification takes a predominantly electro-acoustic form, the discipline is beyond the scope of this thesis to discuss beyond its definition.

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[43] Brian Eno, 'Generative Music: A talk delivered in San Francisco, 8 June 1996', *In Motion*, 7 July 1996 <https://inmotionmagazine.com/eno1.html> [accessed 4 June 2024].
[44] Carla Scaletti, 'Sonification =/= Music', in *The Oxford Handbook of Algorithmic Music*, ed. by Roger T. Dean and Alex Mclean (New York, NY: Oxford University Press, 2018), 363–79 (365).
[45] Ibid., 378.

1.5 A Short Summary

As seen in the survey above, the term ‘algorithmic music’ encompasses a wide range of methods and forms. These generative procedures have long existed before the use of AI, and they can be based on processes including (but not limited to) mapping, chance, dodecaphony, phasing, sound spectra. These methods can be categorised as process-based and non-process based, though the distinction can sometimes be ambiguous. Algorithms can lead to one or multiple outcomes (but never infinite), and they can be notated in different forms ranging from staves to graphic to text. Some algorithms lead to a strictly predetermined score, while some are left for performers to decipher. To illustrate the relationship between these examples more clearly, the examples mentioned so far (including the ones mentioned in footnotes) are organised into table 1. There are four spaces on the table: algorithmic processes, algorithmic non-processes, non-algorithmic processes, and non-algorithmic non-processes. Within each space, the examples are listed in the order from most autonomous to least autonomous, though this order can only be interpreted loosely.

		Algorithmic	**Non-algorithmic**
Process	Very autonomous	Sonification Reich's *Clapping Music* Data-driven music Tenney's *Critical Band*	Eno's *Music for Airports* (also algorithmic) Lockwood's *Piano Burning* (also algorithmic) Stockhausen's *Richtige Dauern*
	Semi-autonomous		
Non-Process	Very autonomous	AIVA and MusicGen Guido's solmisation Ockeghem's *Missa Prolationum* Klaus Lang's *ubi est mundus* Du Fay's Crab Canon Moulu's *Missa Alma Redemptoris Mater* Ockeghem's *Missa Cuiusvis toni* Bach's *Fourteen Canons on Goldberg Variations* Cordier's circular notation of songs Multi-serialism (to be discussed) Mozart's *Musikalisches Würfelspiel* Walshe's *A Late Anthology of Early Music* Dadabot's *Coditany of Timeness*	
	Semi-autonomous	Beethoven's 10th Symphony	Schoenberg's *Variations for Orchestra*

Table 1: Algorithmic and process music

It is worth noting that there is not a great deal of AI-algorithmic music mentioned in the table above. This is because the thesis is not explicitly about music that uses AI. There are three reasons for this. The first is the limited accessibility of resources. At the time of writing, apart from several online blogposts and programme notes, there are relatively few resources available. Some notable examples of AI-algorithmic pieces that would be interesting to discuss include Jennifer Walshe's *MOREOVER* (2020), Tina Tallon's *Archipelago* (2020), and the 2019 re-released album *Unseen Worlds* (1991) by Laurie Spiegel.[46] In contrast, by setting the scope to include pieces from the last seventy years, there is a lot more established scholarship for me to base my research on. While it would be fascinating to discuss state-of-the-art autonomous algorithms, I am more curious about the general creative tensions that

[46] For more information on these pieces, see: Tina Tallon, 'Archipelago', *Tina Tallon*, n.d. <https://tinatallon.com/compositions/archipelago/> [accessed 4 June 2024]; Estela Oliva, 'Jennifer Walshe & Jon Leidecker'; and Laurie Spiegel, 'Unseen Worlds', *Bandcamp*, 18 January 2019 <https://lauriespiegel.bandcamp.com/album/unseen-worlds> [accessed 4 June 2024]

composers have had to face in their algorithms. I will explain these tensions in greater depth in what follows. By drawing from these earlier pieces from the 1950s and their surrounding discourses, I can address current issues on AI more critically from a historical perspective.

As an overview, this thesis is structured around the chronology of my research over three academic years. In Chapter 2, I describe my experience building a cognition-inspired algorithm in my first year, where I observed a tension between algorithmic material and the work. The third chapter discusses my second-year compositions where I built a new algorithm that was supposed to be more autonomous, treating material as the work, but I was faced with more physical challenges about idioms and bodies. Chapter 4 is where I explain my third-year compositions, all of which were written in response to the question of bodies raised in Chapter 3. Finally, after discussing all of the works in my portfolio, I finish with a conclusion to sum up my findings and to reflect on my journey of self-discovery through the experience of writing algorithmic music.

2. Cognitive Constraints on Compositional Systems

Before I developed an interest in algorithms, my original PhD plan was to study the application of music cognition theories to composition. The topic was inspired by James Tenney's *Meta+Hodos*, where he borrows from music psychology to describe contemporary music using what he calls 'temporal gestalts'.[47] Borrowing from gestalt principles in visual perception, Tenney's terms consider music in parameters such as 'proximity' and 'similarity', which he uses to create hierarchical groupings in units of segment, sequence, clang (Tenney's word for a sound-configuration, or a musical idea) and element.[48] These ideas are especially useful for describing music that is usually generalised as 'atonal' and 'ametric' in traditional music theory. Consequently, this new way to approach music sparked my interest in exploring this relationship between cognition and composition.

Compositionally, I was also inspired by Tenney's conception of a reciprocal relationship between his theory and practice. Tenney's research follows a feedback loop where he tests his experimental ideas in his music, and in turn, his music inspires him to develop the theories further.[49] Even though my approach has become more distant from Tenney, my practice-research aims to follow this methodology. This is reflected in the structure of my thesis, where there are pieces of reflection and theoretical research interwoven between commentaries of my music.

As such, my research began with a completely different focus, though the work is still adjacent to the theme of algorithmic music. Following the direction of my initial PhD plan, in my first year, I soon came across Fred Lerdahl's essay titled 'Cognitive Constraints on Compositional Systems (CCCS)'.[50] As the title suggests, Lerdahl seems to be advocating for a compositional approach that is informed by music cognition, so my first-year assessment became a practice-led investigation on his ideas. While Lerdahl's essay resonated with my research interest then, his ideas had caveats which I will address below. By the end of my first year, I wrote *Four Pieces with Cognitive Constraints* (2021), which form the first part of my portfolio. Even though these pieces were written with a different research focus in mind, they are still worth including in my thesis because they reflect the starting point of my algorithmic thinking. Consequently, my reflection on the challenges I faced in my first year

[47] James Tenney, *Meta + Hodos: A Phenomenology of Twentieth-Century Musical Materials and an Approach to the Study of Form* (Urbana, IL: University of Illinois Press, 1968), 3.
[48] Ibid., 23–24.
[49] Larry Polansky, 'Introduction', in *From Scratch: Writings in Music Theory*, ed. by Larry Polansky *et al*. (Urbana, IL: University of Illinois Press, 2019), xi.
[50] Fred Lerdahl, 'Cognitive Constraints on Compositional Systems', in *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition*, ed. by John A. Sloboda (Oxford: Oxford University Press, 1988), 231–59.

will lead directly into the third chapter. In other words, the following section will begin quite far from the issues of algorithmic music, but I will gradually reintroduce these themes as I reflect on my first year's work.

2.1 CCCS in Theory

Lerdahl's motivation for developing the CCCS stemmed from his dissatisfaction with serial pieces such as Pierre Boulez's *Le Marteau sans Maître*. Lerdahl argues, 'it is impossible to hear any serial structure in the piece'.[51] He directs the same criticism to the musics of Babbitt, Carter, Nono, Stockhausen, and Xenakis, which seems unfair to me as these composers have written drastically different musics over the course of their careers.[52] Conspicuously, this assumption that all serial music involves a dogmatic use of tone row echoes the aforementioned misconception in Adorno's 'The Aging of the New Music'. This highlights the commonality of the issue, and I will return to address it in the next chapter.

Notwithstanding Lerdahl's overgeneralised view of serialism, in his article, he confronts the apparent 'huge gap between compositional system and cognised result'. He emphasises, 'the issue is not whether serial pieces are good or bad… [t]he issue is why competent listeners do not hear tone rows when they hear serial pieces?'[53]

It is telling from Lerdahl's attack on Boulez that he has missed the point of serialism. Lerdahl claims that the CCCS attempts to 'bridge the gap' between serial methods and heard structure, but serial structures are often deliberately obfuscated so that they are unrecognisable, which is notably the case in *Le Marteau*. In the piece, Boulez deviated from the pre-determined material at certain moments of the piece (which is in itself determined by a serial process), so serial structures (i.e. tone rows) are not always present in the music.[54] In fact, *Le Marteau* is widely considered to be Boulez's return to musical expression as his use of multi-serial material was undertaken semi-intuitively. This is ironically not far from Lerdahl's aim with the CCCS.[55] To put it bluntly, the reason Lerdahl struggled to hear any serial organisation in the piece is because there is not one for him to hear in the first place, or

[51] Lerdahl, CCCS, 232.
[52] These composers wrote very different musics over the course of their careers. Throughout my thesis, I will draw on examples by Boulez, Nono, Stockhausen, and Xenakis to illustrate the richness and variety in serial procedures in their music. For the musics of Babbitt and Carter, see Emily Abrams Ansari, 'Serialism in Canada and the United States', in *The Cambridge Companion to Serialism*, ed. by Martin Iddon (New York, NY: Cambridge University Press, 2023), 225–40. This theme is explained more fully in Mark Delaere, 'Serialism in Western Europe', in *The Cambridge Companion to Serialism*, ed. by Martin Iddon (New York, NY: Cambridge University Press, 2023), 205–24.
[53] Lerdahl, CCCS, 115.
[54] For a detailed analysis of *Le Marteau*, see Lev Koblyakov, *Pierre Boulez: A World of Harmony* (New York, NY: Routledge, 1990).
[55] Pierre Boulez, *Orientations: Collected Writings* (Cambridge, MA: Harvard University Press, 1990).

at least not one of the sort that he insists ought to be there.[56] With the CCCS, Lerdahl seems to be trying to solve a problem that does not exist, or more accurately, Lerdahl is trying to solve the very problem that Boulez is trying to solve.

As such, the CCCS is based on Lerdahl's misconstrued view of *Le Marteau*. Setting aside the theory's problematic origin, Lerdahl's attempt to bridge this gap between method and result is based on what he calls listening and compositional grammars. The listening grammar is derived from Lerdahl and Jackendoff's *A Generative Theory of Tonal Music* (GTTM), which Lerdahl claims is a 'universal musical grammar' of how listeners listen, regardless of genre.[57] The idea behind the CCCS is that Lerdahl sought a compositional system that made use of the GTTM so that the music would follow a set of rules derived from his research on 'universal' listening behaviours.

It is worth noting that Lerdahl's claim for the GTTM being universal implies a colonial mode of thought, where a theory built on Western art traditions is treated as if it were universally 'innate' to listen this way.[58] Furthermore, the GTTM's exclusive use of a tonal corpus of music also means that the CCCS's preference is inherently conservative. It is obvious that no dodecaphonic music will be able to fulfil the constraints. Lerdahl's defence is that dodecaphony is 'incognizable' even for the 'experienced' ear, which is why it will fail to achieve any meaningful structure in his listening model.

It is beyond the scope of this thesis to refute these views further, but these criticisms, especially the view that atonality is somehow hardwired to be 'unnatural' for the brain, are addressed more fully in John Croft's critique on the constraints.[59] The next section focuses on the practical use of the constraints to see how they would function as a compositional system. The constraints are as follows:

Fred Lerdahl's Cogntive Constraints[60]

Constraints on event sequences

1. The musical surface must be capable of being parsed into a sequence of discrete events.

[56] See Chapter 2.4.1 for more on *Le Marteau*. In short, Boulez deviated from the algorithm from time to time to create expression out of his materials, which is why the original tone row is not always perceptible.
[57] Fred Lerdahl and Ray Jackendoff, *A Generative Theory of Tonal Music* (Cambridge, MA: MIT Press, 1983), 282–3.
[58] Ibid., 290.
[59] John Croft, 'Musical Memory, Complexity, and Lerdahl's Cognitive Constraints' (unpublished master's thesis, University of Sheffield, Department of Music, 1999).
[60] Lerdahl, CCCS, 239–50.

2. The musical surface must be available for hierarchical structuring by the listening grammar.
3. The establishment of local grouping boundaries requires the presence of salient distinctive transitions at the musical surface.
4. Projection of groups, especially at larger levels, depends on symmetry and on the establishment of musical parallelisms.
5. The establishment of a metrical structure requires a degree of regularity in the placement of phenomenal accents.
6. A complex time-span segmentation depends on the projection of complex grouping and metrical structures.
7. The projection of a time-span tree depends on a complex time-span segmentation in conjunction with a set of stability conditions.
8. The projection of a prolongational tree depends on a corresponding time-span tree in conjunction with a set of stability conditions.

Constraints on underlying materials

9. Stability conditions must operate on a fixed collection of elements.
10. Intervals between elements of a collection arranged along a scale should fall within a certain range of magnitude.
11. A pitch collection should recur at the octave to produce pitch classes.
12. There must be a strong psychoacoustic basis for stability conditions. For pitch collections, that requires intervals that proceed gradually from very small to comparatively large frequency ratios.
13. Division of the octave into equal parts facilitates transposition and reduces memory load.
14. Assume pitch sets of n-fold equal divisions of the octave. Then subsets that satisfy uniqueness, coherence, and simplicity will facilitate location within the overall pitch space.

Constraints on pitch space

15. Any but the most primitive stability conditions must be susceptible to multidimensional representation, where spatial distance correlates with cognitive distance.
16. Levels of space must be sufficiently available from musical surfaces to be internalised.

17. A reductionally organised pitch space is needed to express the steps and skips by which cognitive distance is measured and to express degrees of melodic completeness.

2.2 CCCS in Practice

In order to understand how the constraints function as a 'compositional grammar', I designed an algorithm in Max/MSP to generate musical materials that satisfy all seventeen constraints. The algorithm outputs twelve-semiquaver phrases in 4/4 to impose a sense of discrete events in a regular meter (constraints 1, 5, 6 and 7). Every four bars form a phrase, and every six phrases form a section (constraints 2 and 7). As seen in the table below, the form is binary with a coda to imply structural prolongation (constraint 8). Structural parallelism is achieved by repeating motifs. Phrase A is repeated for four bars (constraint 4), and it is separated by phrases B to G to form an overall structure of ABACADAEAFAGA (constraint 3). The piece is written in twelve-tone equal temperament to fulfil constraints 9 to 14.

Section	I							II							CODA
Bar	1	5	9	13	17	19	21	25	29	33	37	41	43	45	49
Phrase	A	B	A'	C	A''		D	A	E	A'	F	A''		G	A
Transposition	0		+12		+8	+5	+7	0		+12		+8	+5	+7	0
Implied Key	C		C +8^{ve}		A♭	D	G	C		C +8^{ve}		A♭	D	G	C

Table 2: The Overarching Structure for *Four Pieces*

The bottom two rows in table 2 show the harmonic transpositions within the structure. The material transposes every eight bars, such that the implied harmonic movement resembles the *Urlinie* in Schenkerian analysis for a sense of completeness (constraints 8, 17). Constraints 14 to 16 are achieved by limiting polyphony to emphasise cognisable pitch relationships.

After building the algorithm, the rest of the compositional process is three-fold. In the first stage, the score only consisted of a transcription of the computer-generated pitch and rhythm. An excerpt from this version of the piece is shown in figure 3. At this point, the material can technically fulfil all the constraints regarding pitch and rhythm, but it contains no further instructions for other parameters such as tempo, dynamics, technique, articulation, and phrasing. The first observation to be made is that the constraints cannot be used as a

comprehensive music generation system because they do not consider these non-pitch and rhythm parameters which are necessary aspects in writing a piece.[61]

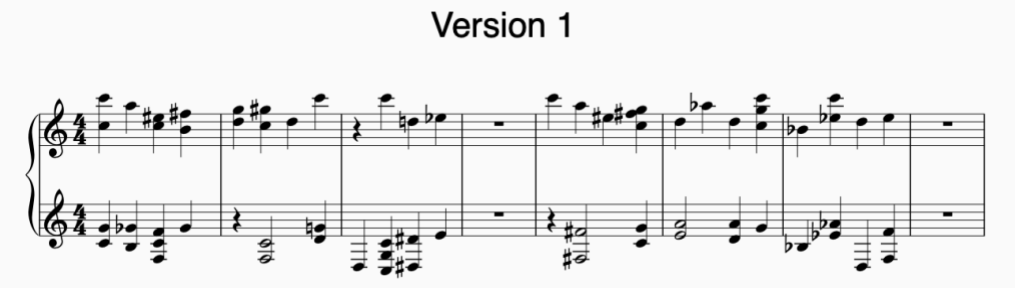

Figure 3: Excerpt from version 1 of the algorithmic material

Since there are no instructions on these non-pitch-rhythm parameters, in the second stage, I decided to impose them according to my understanding of Lerdahl's theory. For example, the tempo is moderately slow to emphasise clarity, in line with constraints 1 to 8. Dynamic markings and sustain pedal change every four bars to separate phrase structure. I chose to write for the piano because the piano can be played least problematically without concerning the remaining missing parameters such as articulation and phrasing. However, even after adding these parameters, the material still felt far from a complete piece of music. The updated notation for the same excerpt is shown in figure 4.

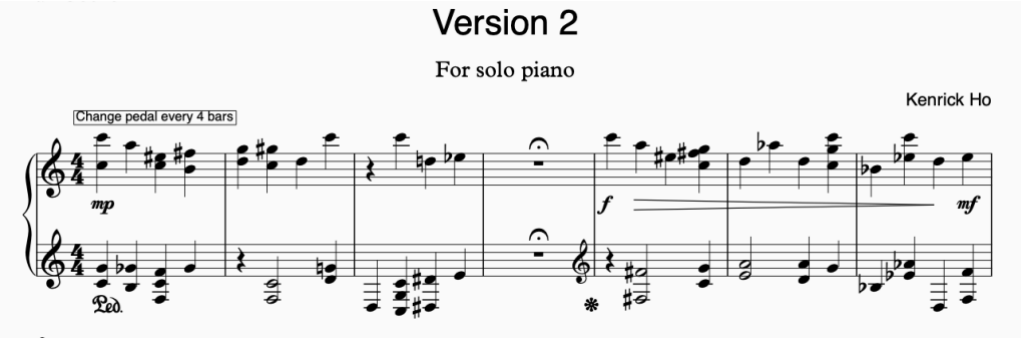

Figure 4: Excerpt from version 2 of the algorithmic material

In figure 4, all necessary parameters are given on the score: pitch, rhythm, dynamics, pedal markings, and tempo are all specified. At this stage, the piece appears complete in terms of notation, and it is doubtless playable on the piano. If the goal were to see what a 'perfect' piece that followed all the constraints would look like, this could be a passable answer.

[61] This also reveals, perhaps unsurprisingly, that the constraints have an implied emphasis on pitch, harmonic structure, and hierarchical form. This confirms my earlier criticism that the constraints are clearly built on Western art traditions and they are inherently biased towards classical music.

However, despite these refinements, there is a sense of incompleteness pervading through the work. This dissatisfaction is purely subjective, and while it is certainly possible to use figure 4 in a performance to passively observe the musical outcome—which would achieve my initial intention to experiment with it— I find the quality of the material too plain to use as a finished piece. To me, there is an odd sense of dryness to the score, with rhythm that seems too uniform, and pitch that is too repetitive for my taste. This is surprising and unusual for me, given my admiration for the music of Reich and Tenney. I will reflect on this sentiment in the following section.

For now, to address the incompleteness in practice, in the next revision, I decided to interpret the algorithmic material more freely. Since the material in itself only comprises basic structures with no particular stylistic features, and since Lerdahl does not mention any stylistic preference in the CCCS (apart from the bias towards tonal music), I attempted to adapt the material into four different musical styles to create *Four Pieces with Cognitive Constraints*.[62]

First, upon noticing the interesting sonorities in the generated pitch, in *Stillness* (figure 5), I attempted to present the material as a Feldman-esque slow piano piece. Seeing that the constraints themselves did not consider parameters such as tempo, dynamics, and phrasing, I decided to undo these parametric decisions from version two to leave these open for the performer to interpret. In that sense, *Stillness* is closer to figure 3 than figure 4 where the algorithm only provided pitch, rhythm, and form. However, I eventually removed the rhythmic aspect of the piece as I disliked the uniform crotchet rhythm in figure 3. I took away all barlines and stems from the score to let rhythm flow naturally with the performer's interpretation. Notably, despite the fact that *Stillness* is an intuitive interpretation of the algorithmic material, I still tried to follow the 'spirit' of Lerdahl's constraints. I did not necessarily want to compose a new rhythm to write over the original algorithmic rhythm. Instead, I was more comfortable with removing the algorithmic rhythm, so I was not directly acting against it. Furthermore, I kept the idea of having discrete phrases from the constraints by adding fermatas and commas at the end of each system.

[62] To be clear, when I describe the process as 'stylising' the material, I do not claim that the material is in itself stylistically neutral (even though, for some, it might seem to be the case). I am aware that the results are never truly 'unstylised', as I have indirectly influenced the outcome by designing the algorithm myself. Sofian Audry terms this long-range influence between artist and the algorithm as 'indirect feedback' where the artist experiments with different evaluation functions to produce outcomes, as opposed to directly intervening with the system (direct feedback). See Sofian Audry, *Art in the Age of Machine Learning* (Cambridge, MA: MIT Press, 2021).

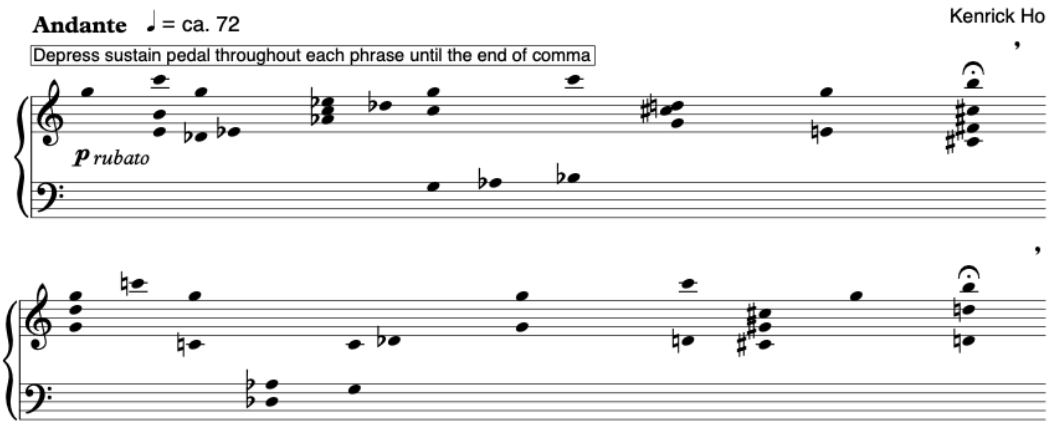

Figure 5: Excerpt from I. *Stillness*

Rather than avoiding the material's mundane rhythm, in my second piece, *Repetitiveness* for two marimbas (figure 6), I decided to embrace the uniform and mechanical character in a minimalistic process piece. *Repetitiveness* still follows the overall structure from table 2, which is ABACADAEAFAGA, where A is a recurring motif. While the order of phrases is the same, the A phrases can now be repeated between four to twelve times, depending on the second player's decision. The bars in unison function as musical cues to signify the progression into phrases B-G. It is up to the second marimba player to decide on the number of repetitions, and the first marimba player has to be constantly listening in anticipation for this cue. Notably, as is the case in *Stillness*, I tried to keep these phrases clearly segregated, here by short breaths, so that it retained structural clarity specified in the CCCS.

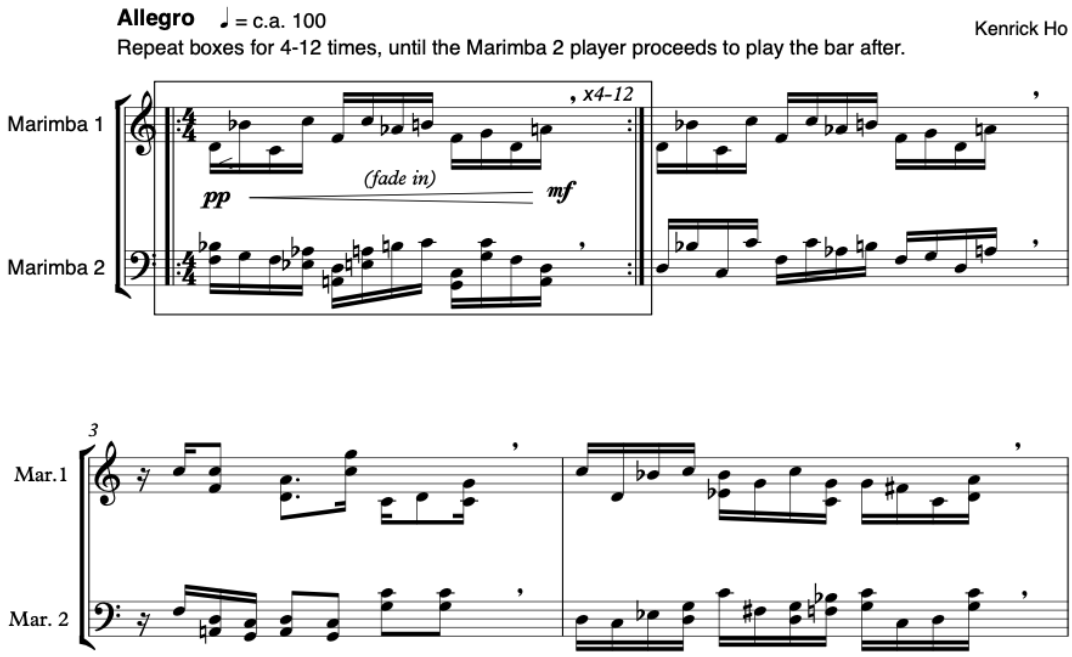

Figure 6: Excerpt from II. *Repetitiveness*

The third piece is an attempt to present the material as a quasi-spectral piece for string quartet. Even though constraint 13 clearly states that a tuning with equal division of the octave is preferred, in *Lightness* (figure 7), the string instruments are tuned to just intonation. While just intonation uses an unequal distribution of the octave, the actual extent of deviation from the constraint is relatively little given that the cent difference is not far from 12-TET. Therefore, I wanted to test if the slight deviation in tuning would affect the rest of the constraints in *Lightness.* Since I wanted to hear precisely how this tuning would work differently for the constraints, the materials in *Lightness* are written entirely on open strings and natural harmonics to maximise accuracy in intonation. Since the pitch material in itself is chromatic, each of the four string instruments uses a slightly different scordatura to account for the entire chromatic scale. Notably, these phrases are segregated by ten-second pauses on the score, again, as a gesture to follow the structural segregation required by the CCCS.

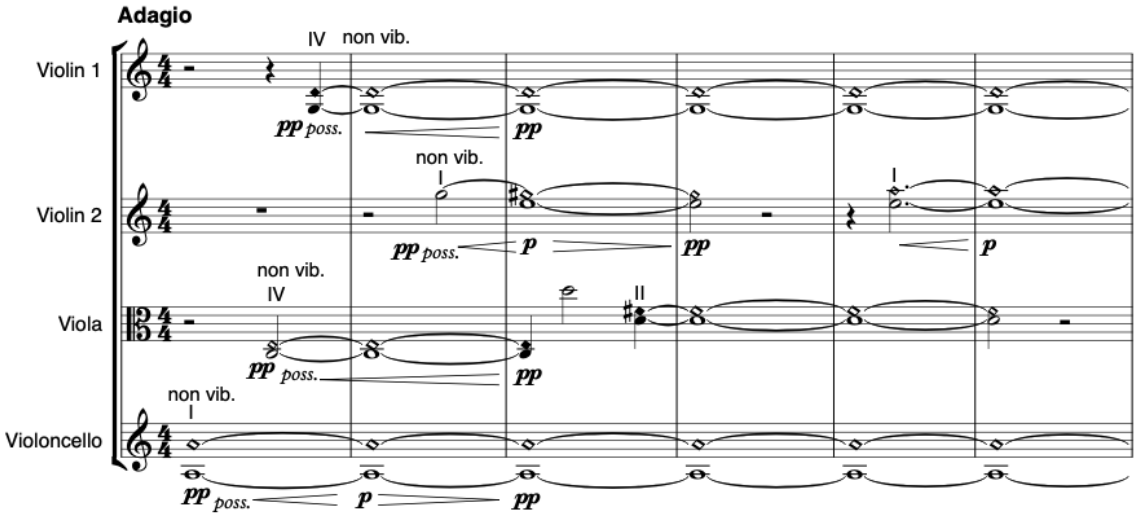

Figure 7: Excerpt from III. *Lightness*

In theory, the use of just intonation contradicts constraints 13 and 14 because the octave is not divided into equal parts. However, in writing *Lightness,* I found that the algorithm remained unaffected despite the new tuning. This led me to wonder if the constraints would still work in tuning systems that are even further from 12-TET, such as the *Pelog* scale in gamelan.

My fourth piece, *Worldness* (figure 8), is for Javanese gamelan ensemble. Gamelan is suitable for experimentation in the CCCS because there are several commonalities between its tradition and my algorithmic process. For instance, my material is motivically repetitive, the rhythm is typically uniform, and the structure is hierarchical with phrase patterns clearly segregated. Similarly, traditional gamelan typically follows a particular *gangsaran* (format) consisting of refrains and transitions. In most gamelan repertoire, at least for Javanese performances (*karawitan*), the *gangsaran* is usually divided into groups of four *gatras* (bar), which forms a *keteg* of sixteen beats (sequence). This is not far from the hierarchical structure emphasised in Lerdahl's constraints 1 to 8, especially with their mutual emphasis on structural clarity and metrical stability.[63]

In order for the algorithm to generate materials compatible with gamelan instruments, a *pelog* scale is used instead of the diatonic. *Pelog* instruments can typically play up seven scale degrees, but traditionally, two kinds of pentatonic scales are used. The *pelog tembung* uses pitches 1, 2, 3, 5, 6, and the *pelog sunarem* uses 2, 3, 5, 6, 7. The algorithm has been tweaked such that it can only select notes from *tembung* in section A, and modulate to *sunarem* in transitions. There is no underlying I-V-I relationship between these two pitch

[63] The terminology and knowledge on gamelan music came from consulting Aris Daryono, a Javanese gamelan artist who kindly looked over my score and explained these concepts to me.

spaces, but the modulation, especially with the use of note 7 in *sunarem* makes the harmonic language noticeably contrasting.

Apart from tweaking the algorithm, several interventions were imposed to further stylise the material. One of the *peking* players is encouraged to improvise based on motif A, as it is common in traditional *balungan* elaboration. Additionally, the *saron* part is divided into two interlocking voices. Lastly, a traditional gong pattern has been added, with emphasis on the fourth beat of each bar.

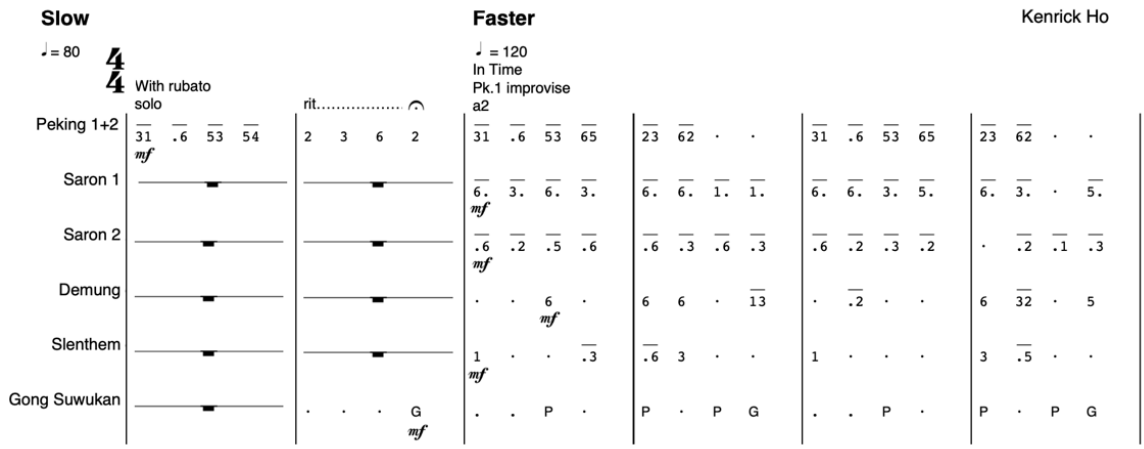

Figure 8: Excerpt from IV. *Worldness*

It is worth clarifying that I do not consider *Worldness* to be an accurate representation of gamelan music. Instead, my intention was to test how the constraints would function under a different tuning system, when performed on non-Western Classical instruments. Through consulting Aris Doryano, a specialist in the tradition, I studied the typical usage of the tuning system and the instrumental idioms. While the piece does reference traditional structures and formats, I do not necessarily think of it as part of the tradition itself.

Evidently, the idea of the constraints being applied to gamelan should not be taken as evidence that the constraints are as universal as Lerdahl claims. While the algorithm was seamlessly adjusted to accommodate a seven-note scale rather than twelve, the fact that it needed changing underscores the constraints' exclusive focus on diatonic Western music. Furthermore, the use of *pelog* tuning inevitably compromises constraints 9–14 on harmonic stability and tuning systems. This shows that the constraints themselves would not have normally been able to facilitate any gamelan music at all.

2.3 CCCS in Discussion

Reflecting on my experience composing using Lerdahl's constraints, I would like to focus on four observations. Initially, my aim was to use the constraints as autonomously as possible to explore their sounding outcome. However, as illustrated in figure 3, this proved unfeasible due to the constraints generating pitch and rhythm in abstraction. Moreover, by prioritising cognoscibility, the constraints have limited the algorithm to output simplistic structures only. For instance, the initial results were highly repetitive, lacked rhythmic variation, and neglected other parameters such as dynamics and articulation. Therefore, instead of treating the constraints as a prescriptive framework, they would be more productive functioning as underlying musical infrastructures. David Temperley compares these basic structures to 'ubiquitous' foundations, such as 'water mains and power lines', which, while 'do not normally bring us joy in themselves', they 'facilitate other things—homes, schools, showers—whose contribution to life is more direct'.[64]

Consequently, I proceeded to refine the algorithm to include more details on the score, resulting in figure 4. In this second iteration of the algorithm material, all the constraints were met, the notation was complete, and the contents were all playable. Yet, I still found myself unsettled by the outcome. I was troubled by its sense of incompleteness, where the material seemed too dry and repetitive for my taste. This is unexpected because my personal preference usually welcomes these qualities of openness and repetitiveness, especially given my admiration for musical processes and phenomena by Reich and Tenney, In fact, it is precisely this appreciation for audible processes that led me to use the algorithm in this particular way. Until now, I have been reluctant to intervene with the algorithm, because I preferred to observe the raw process. Hence, it is surprising to find myself dissatisfied with the material.

This contradiction challenges my initial intention to use algorithmic material autonomously. This reveals two aspects of my musical thinking: my preference is not as open as I thought, and I prioritise intentionality in the material. When I interpreted the material freely to create the *Four Pieces,* I did not end up altering the generated material, indicating that the material's repetitive and simplistic nature was not in itself the problem. The problem with figure 4, instead, was that the material lacked intentionality. There are pieces that I like with far simpler and more repetitive material, such as Tenney's *Postal Pieces* (1954–71). In comparison, my material, in its original form, lacked this clarity of intention, resulting in a

[64] David Temperley, *The Cognition of Basic Musical Structures* (Cambridge, MA: MIT Press, 2004), 3–4.

less ‘musical’ experience compared to Tenney’s pieces. My approach to then reframe the material into the *Four Pieces* has helped give the material the necessary musical context, explaining why they finally felt complete.

Thirdly, in my original research plan to study the relationship between cognition and composition, I was perhaps hoping to arrive at some sort of grand revelation about how cognition can be applied to composition. However, as fascinating as this topic seems, I do not have much to reveal about this relationship. In fact, for me, the biggest revelation lies in the broader notion of applying a theory into composition. Through exploring Lerdahl’s constraints, I realised that applying a theory to composition does not mean creating a piece by blindly adhering to its rules. My approach to using the constraints relied too dependently on the algorithm making its own decisions, because I was hoping to test what the constraints themselves would produce. In turn, this approach led to results that I described as ‘basic’, and ‘incomplete’, precisely because the theory cannot make its own decisions.

Ultimately, it is up to the composer to create a work out of the theory, because theories are just that—theories. This is analogous to how music theories of harmony and counterpoint work; composers can take these theories to inform their composition, but the actual work is never created solely by following the theories themselves. I will return to this relationship between theory and practice in my conclusion.

Finally, from my experience in working with the constraints, it is notable how my attempt to strictly adhere to the algorithm led to an unconventional process, creating a basic structure that required additional framing. Earlier in the chapter, I described the state of this material as ‘basic’ and ‘incomplete’, despite it being parametrically comprehensive, as seen in figure 4. From now on, I will refer to this near-complete algorithmic material as a ‘maquette’. The Tate Modern defines ‘maquette’ as ‘a model for a larger piece of sculpture, created in order to visualise how it might look and to work out approaches and materials for how it might be made’.[65] Similarly, my maquette in figure 4 contained much of the material needed to create the *Four Pieces*. In that sense, it serves as a preview of the final work, providing a test-run for the musical content, although further ‘stylising’ is necessary to turn it into the finished work. Furthermore, in visual arts, maquettes are sometimes exhibited as standalone works. While musical maquettes should already be in a playable form, due to the difference in art form, if the maquette required a live performance, it would cease to be a maquette because the performer’s interpretation completes the further stylising. In other

[65] ‘Maquette’, *Tate Modern*, n.d. <https://www.tate.org.uk/art/art-terms/m/maquette> [accessed 8 June 2024]

words, musical maquettes are comprehensive sketches, usually generated by an algorithm, with a subjective sense of incompleteness attributed by the composer.

In this mode of composing, the algorithm produces a maquette, to which the composer must then add final 'touches' to complete the piece. When I encountered my maquette, I was confronted by the algorithm to decide what kind of music I want to write. In this case, since I was hoping the constraints would provide the answer, I chose four musical styles that I felt were most appropriate for the maquette. This approach reveals an implied duality between the material and the work, where the transformation from material into work seems to be where the 'magic' of the compositional process occurs.

Curiously, the notion that maquettes require finishing implies an underlying tension between the material and the work. The following section will take a closer look into this tension, exploring how other composers have acted on their maquettes to complete their works.

2.4 Material vs. Work

Historically, there are three general approaches composers may take when working with maquettes. They might 1) deviate from the generated material intuitively, 2) adjust the algorithm so it produces a more desirable outcome, or 3) leave the algorithm incomplete and fill in the space intuitively without counteracting the algorithm. I will now explain the three approaches.

2.4.1 *Le Marteau sans maître*

The first approach, for example, can be seen in Boulez's music. Boulez's motive for using algorithms in the first place came from his dissatisfaction with Schoenberg's expressive use of dodecaphony. In 'Schoenberg is Dead', he writes:

> The persistence, for example, of accompanied melody, of counterpoint based on the idea of a leading voice and secondary voice (*Hauptstimme* and *Nebenstimme*). From Schoenberg's pen flows a stream of infuriating clichés and formidable stereotypes redolent of the most wearily ostentatious romanticism: all those endless anticipations with expressive accent on the harmony note, those fake appoggiaturas, those arpeggios, tremolandos, and note-repetitions.[66]

To be sure, Boulez was not against the idea of dodecaphony in itself. It was specifically Schoenberg's connection with the 'old ways' of using dodecaphony expressively that Boulez was against. Though it is clear that it was never Schoenberg's intention to use dodecaphony as

[66] Pierre Boulez, 'Schoenberg is Dead', in *Stocktakings from an Apprenticeship*, ed. by Paule Thévenin (Oxford: Clarendon Press, 1991), 268–275 (273).

an automatic algorithm, Boulez found Schoenberg's abstraction of dodecaphonic pitch to be lacking and wished for it to generate music more autonomously. Boulez writes: 'Schoenberg's investigation of serialism was one-sided: it neglected rhythm, and even, strictly speaking, sound, in the sense of dynamics and mode of attack... This, to my mind, is the central, provoking UNEVIDENCE of a body of work without intrinsic unity'.[67]

For Boulez, serialism paved the way for a path that helped him escape pre-established forms and styles from the historical tradition. But Boulez's ambition, inspired by Webern, was set on the expanded use of serial technique onto other parameters; 'perhaps, like that certain Webern, one could pursue the sound-evidence by trying to derive the structure from the material'.[68] Consequently, by 1951, having completed works such as *Polyphonie X* (1951) and *Structure Ia* (1951), Boulez had reached the zenith of his most rigorous phase of multi-serialism. [69] However, Boulez's experiments in working autonomously and rigidly with algorithms, as Losada notes, 'was tremendously short-lived'.[70] Boulez began deviating more significantly from his algorithm as soon as *Structure Ib* and *Ic* (1952) and subsequently in *Le Marteau sans Maître*. Rather than continuing to follow strict and automatic serial principles, despite his earlier criticism on Schoenberg, Boulez embraced a more flexible and intuitive use of serial structures as he returned to a more expressive language in *Le Marteau.*[71] However, Boulez's approach for achieving expression in multi-serialism is considerably different from Schoenberg's expressive approach. In fact, in *Le Marteau*, the creation of the work is not any less serial than *Structure Ia.* On *Le Marteau*, Boulez writes:

> There is in fact a very clear and very strict element of control, but starting from this strict control and the work's overall discipline there is also room for what I call local indiscipline: at the overall level there is discipline and control, at the local level there is an element of indiscipline—a freedom to choose, to decide, and to reject.[72]

What Boulez means by 'local indiscipline' is that he reserves his rights to make free choices to manipulate the serial organisation expressively. In *Le Marteau*, the predetermined structure alternates between movements that are strictly serial and movements with greater compositional freedom.[73] Movements that are strictly serial use predetermined materials rigidly in a similar fashion as *Structure Ia.* This is contrasted by the freer movements, determined by a higher order row, where Boulez interprets his serial structures expressively.

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[67] Ibid., 274.
[68] Ibid., 275.
[69] *Structure Ia* will be discussed in more detail in Chapter 3.3.3.
[70] Catherine Losada, 'Pierre Boulez and the Redefinition of Serialism', in *The Cambridge Companion to Serialism*, ed. by Martin Iddon (New York, NY: Cambridge University Press, 2023), 125–139 (125).
[71] Dominique Jameux, *Pierre Boulez*, trans. by Susan Bradshaw (London: Faber and Faber, 1991), 78.
[72] Pierre Boulez, *Pierre Boulez: Conversations with Célestin Deliège*, trans. by B. Hopkins (London: Eulenburg, 1976), 66.
[73] Koblyakov, 1–3.

Boulez's apparent relaxation from rigid algorithmic usage is driven by a desire to intervene with the system. As he explains:

> I have the sort of temperament that tries to invent rules so as to have the pleasure of destroying them later: it is the dialectical evolution between freedom of invention and the need for discipline in invention… The difficulty is to find a point of balance, or at least a constant interchange, between these extremes.[74]

When Boulez speaks of a 'dialectical evolution' between 'freedom of invention' and 'disciple in invention', he seems to be implying that there is an inherent tension between himself and his maquette. Evidently, Boulez seems to be aware of the same issue that the algorithmically generated results are sometimes not what he would like to write. This resonates with my experience in writing the *Four Pieces*, where I felt the need to intervene because I disliked the maquette material. However, rather than aiming to preserve the algorithmic material like I did in the *Four Pieces,* in *Le Marteau*, Boulez gives himself the agency to 'destroy' the system by deviating significantly from the original outcome. Consequently, *Le Marteau* demonstrates a highly expressive use of serial material where there is a prominent sense of melody and accompaniment throughout the piece. Similarly, the same can be said about the subsequent *Pli selon pli* (1957–62), written with arguably greater extents of freedom and choice.[75] It is indeed ironic that Boulez has come full circle to write music that is not unlike Schoenberg's more expressive use of dodecaphony, though the material generation is significantly more autonomous in Boulez. Losada concludes that Boulez's increased expressive freedom should be treated 'not as an extension, or loosening, of the serial practice, but as developments that were made possible by his redefinition of serialism'.[76] And it is this redefined serialism that starkly distinguishes Boulez's rigorous yet expressive use of maquettes.

In response to Lerdahl's critique on *Le Marteau* at the beginning of this chapter, it is precisely Boulez's desire to reinvent expressivity in the piece that Lerdahl overlooked. Had Lerdahl picked a different piece to criticise, perhaps one with more stringent pre-determined elements such as *Structure Ia*, his argument would have been more convincing. Though in the case of *Structure Ia*, his concern regarding cognoscibility in serialism would have been invalid, since the tone row is quite audible in the piece. I will explore *Structure Ia* in more detail in Chapter 3.3.3.

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[74] Boulez, *Conversations*, 64.
[75] Erling E. Guldbrandsen, 'Casting New Light on Boulezian Serialism: Unpredictability and Free Choice in the Composition of *Pli selon pli – portrait de Mallarmé'* in *Pierre Boulez Studies*, ed. by Edward Campbell and Peter O'Hagen (Cornwall: Cambridge University Press, 2016), 193–220.
[76] Losada, 'Pierre Boulez and the Redefinition of Serialism', 138.

2.4.2 *Music of Changes*

The second method, which is to make adjustments with the algorithm until the results are desirable, can be found in the music of John Cage. Coincidentally, around the same time Boulez finished working on *Structure Ia*, Cage also completed his first algorithmic composition, which is the *Music of Changes*. Cage describes *Music of Changes* as 'an object more inhuman than human, since chance operations brought it into being'.[77] By that, he means that *Music of Changes* uses chance operations exclusively such that the '[composers] are removed from the activities of sounds they make'.[78] In some ways, Cage's attitude is not too dissimilar from Boulez's multi-serialism. Boulez's view, as outlined above, pushed for serial automatism as a means to break away from historical tradition. Here, Cage resorted to using algorithms to 'let sounds be themselves' rather than 'vehicles for man-made theories or expressions of human sentiment'.[79] This is to say that both composers hoped for a radically new approach for composition that is unconcerned with the musical language of the past and also removed from personal expression. However, in spite of the friendship between the two composers, Boulez criticised Cage's method. Boulez writes: 'the individual does not feel responsible for his work, but merely throws himself by unadmitted weakness'.[80] Mutually, Cage disagreed with Boulez's work as he found that multi-serial works 'diminish the interest they enjoin'. As Cage writes: 'curiously enough, the twelve-tone system has no zero in it… there is not enough of nothing in it'.[81]

In *Music of Changes*, Cage's algorithm, or what he calls 'composing means', is extremely meticulous. For every parameter of every event on the score, Cage uses a series of coin flips to make decisions according to multiple predetermined charts. These charts are magic-square-like and organise materials into eight-by-eight grids. There are eight of these charts used to determine sound and silences, another eight used for duration, eight for dynamics, and single charts for tempi and polyphony. Each square on the charts corresponds to the 64 hexagrams of the *I Ching*, where each hexagram is made of different combinations of solid and dotted lines. To select a square, Cage uses three coin tosses to determine the corresponding types of line: two heads and a tail is a solid line, two tails and a head is a

[77] John Cage, 'Composition as Process', in *Silence: Lectures and Writings by John Cage* (Hanover, NH: Wesleyan University Press, 1961), 18–56 (36).
[78] Cage, 'Experimental Music', 10.
[79] Ibid.
[80] Boulez, 'Alea', 42.
[81] John Cage, 'Erik Satie', in *Silence: Lectures and Writings by John Cage* (Hanover, NH: Wesleyan University Press, 1961), 76–83 (79).

broken line, three tails is a solid line moving to a broken line, and three heads is a broken line moving to a solid line.[82]

The probability weighting of each chart varies depending on the parameter. For example, the sound charts have thirty-two sounds and thirty-two silences where only odd number cells contain sounds to achieve an equal probability of sound or silence. The tempo chart functions similarly where only half the cells contains a tempo, and the tempo remains constant if the coin lands on an empty cell. This probability ratio is be manipulated further for other parameters, such as in the dynamics chart, only sixteen cells are filled with dynamic changes, meaning they only occur with a twenty five percent chance.

It was important for Cage that the charts accounted for a wide variety of sounds in the gamut. The sound charts for *Music of Changes* consist of different types of sounds ranging from single pitches, intervals, aggregates, constellations, arm-clusters, string piano, lid sounds, and percussive sounds. The pitch content, inevitably, includes all twelve notes from the chromatic scale, but the algorithm is skewed towards certain notes because there are more squares in the pitch chart than there are notes in a chromatic scale. For example, row 3 of the pitch chart contains the twelve notes with an extra A and D, and row 4 has repeated A♯ and D♯.[83]

As with sound, Cage also aimed for variety in rhythm. He established rhythm charts to include all sorts of additive rhythms with units ranging from a hemi-demi-semiquaver to a semibreve, and including units of triplet, quintuplet, and septuplet in between. As a result of the vast variety and odd subdivision, the algorithmically produced rhythm is the most complex in Cage's work at that point in his career, especially comparing with his *Sonatas and Interludes for Prepared Piano* (1946–48) and *Concerto for Prepared Piano* (1951).

As such, Cage's algorithm is both elaborate and autonomous. Sound events unfold unto themselves as coin flips determine each parameter individually. Cage can afford to accept any outcome that the algorithm produces, because his algorithm is so intricately designed that he does not need to deviate from it at all. That way, the tension between material and work that I identified above, unlike *Four Pieces* and *Le Marteau*, it does not exist in *Music of Changes*. For Cage, the maquette is used as the work.

In comparison, the algorithm for *Music of Changes* is much more autonomous than the algorithm for *Le Marteau.* Cage can almost let the piece 'write itself' as long as the

[82] David W, Bernstein, 'Cage and High Modernism', in *The Cambridge Companion to John Cage*, ed. by David Nicholl (Cambridge: Cambridge University Press, 2002), 240–274 (261).
[83] Ibid., 264.

algorithm is set up properly, without the need for the composer to intervene. In my *Four Pieces*, part of the problem was that the algorithm was far from being able to run autonomously, as it was nowhere as meticulous as Cage's algorithm. This realisation led me to try a more autonomous algorithm for my next set of pieces, which I will discuss in Chapter 3 below.

However, as seen in Cage's early sketches of the *I-Ching* hexagrams, it took Cage many revisions of fine-tuning to reach this version of the algorithm.[84] In this process of tinkering with the algorithm, Cage had long-distance control over how he wanted the material to sound and he skewed the algorithm accordingly. Curiously, this laborious process of tweaking the algorithm not unlike Dadabot's description of their process in creating the *Coditany of Timeness*. As I quoted in Chapter 1.1: '[The process] was a lot of trial and error… we had been tweaking hyperparameters for months to get a speech model to make music'.[85] It is notable that even in these extreme (and extremely rare) cases of autonomous music, in both *Music of Changes* and *Coditany of Timeness*, there are still plenty of compositional decisions by the composer. It is simply the case that these decisions have been shifted to the pre-generation stage, where they are composing the algorithm rather than directly composing the music.

2.4.3 *Achorripsis*

Like Boulez and Cage, Xenakis found his own musical ideas to be in opposition with the general impression of how serial music appeared to be developing in the 1950s.[86] For Xenakis, the problem with serialism is that when one listens for polyphony in serial music by the likes of Boulez and Stockhausen, rather than hearing individual threads, one hears 'a mass of notes in various registers… [and] there is consequently a contradiction between the polyphonic linear system and the heard result, which is surface or mass'.[87] Xenakis's criticism is that serial structures have become so perceptually dense that listeners can no longer hear the method in the music. This criticism is familiar as it is notably similar to Lerdahl's take on serialism in the CCCS. However, it is ironic that Lerdahl accuses Xenakis

[84] James Pritchett, *The Music of John Cage* (Cambridge: Cambridge University Press, 1996), 60.
[85] Carr and Zukowkski, 'FAQ'.
[86] To reiterate the point from footnote 52, through discussing different examples of serial music in my thesis, I hope to demonstrate that there is, in fact, no singular dogmatic way to write serial music, at least not in the way Xenakis is describing it.
[87] Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition*, ed. by Sharon Kanach (Sheffield, MA: Pendragon Press, 1992), 8.

of being culpable of the same problem when Xenakis was in fact attempting to do the exact opposite.

Xenakis's solution to the problem avoided open form, unlike Boulez's Third Piano Sonata (1955–57) and Cage's *Concert for Piano and Orchestra* (1957–58) (both will be discussed in Chapter 4.1). Xenakis was unconvinced about giving performer freedom over how the piece is performed, because it would lead to a 'substitution of authors', which he sees as a 'resignation' of responsibility by the composer.[88]

Given his disinterest in the openness of Boulez and Cage, Xenakis resorted to using chance-based algorithms to create deterministic works, but in a way that differs from Cage's system of coin tosses. In *Formalized Music,* Xenakis describes his concept of 'real chance' as a particular 'rare thing', which he claims can only be understood properly through probability theory.[89] Rather than Cagean chance-based results, Xenakis tries to deal with 'chance' itself. For any given chance event, for example rolling two dice, given there is a finite number of possible outcomes, and assuming every outcome is independent (meaning the likelihood of each event happening is not related to the previous event), probability theory can represent the chance of each outcome occurring, which can then be processed as different kinds of distribution and functions. Xenakis argues that such stochastic thinking can be applied to music and therefore 'lead to the creation of […] new forms'.[90]

Achorripsis (1957) is Xenakis's first attempt at expanding the use of probability theory onto other parameters such as speed, density, intervals, durations, and general structure.[91] Xenakis's subsequent pieces follow a similarly formalised approach where his ST algorithm continues to use the stochastic method from *Achorripsis* for computer composition, *Herma* (1961) is based on the Boolean formula in stochastics, *Akrata* (1964–65) is based on sieve theory, and *Analogique A+B* (1959) is on Markov chains.[92]

Scored for twenty-one instruments, *Achorripsis* has been described by Xenakis as a 'cloud of sounds' where varying densities of musical events are defined by Poisson distribution, formulated as follows:[93]

$$P_k = \frac{\lambda^k}{k!}\, e^{-\lambda}$$

[88] Ibid., 38.
[89] Ibid., 39.
[90] Ibid., 43.
[91] Benoît Gibson, *The Instrumental Music of Iannis Xenakis: Theory, Practice, Self-Borrowing* (Hillsdale, NY: Pendragon Press, 2011), 71.
[92] James Harley, *Xenakis: His Life in Music* (New York, NY: Routledge, 2004), 20.
[93] Linda M. Arsenault, 'Iannis Xenakis's "Archorripsis": The Matrix Game', *Computer Music Journal*, 1, 26 (2002), 58–72 (58).

Out of mathematical 'convenience', Xenakis chose the constant $\lambda = 0.6$.[94] With this predetermined value of λ, the variable *k* determines the number of sounds used in each event. Xenakis set a maximum limit for *k* at 5, because any number exceeding this would yield a probability value too low to be significant.[95] Once the probabilities were configured, Xenakis, arbitrarily, decided on having 196 cells in *Achorripsis*. To ensure a proportional distribution of sound events over 196 cells, probabilities P_0 to P_5 are multiplied by 196. This results in a structure where one hundred and seven cells have no sound, sixty-five cells have a single sound, nineteen have double sounds, have triple, one has quadruple, and no cells have five or more sounds. The probabilities for *k* are shown in the second left column of table 3.[96]

k (frequency and event type)	Probability of occurrence (Poisson formula)	Total number of events (probability × 196)	λ (Total number of events/28)
P_o (no sound)	0.5488	107	3.82
P_1 (single sound)	0.3293	65	2.32
P_2 (double sound)	0.0988	19	0.68
P_3(tripe sound)	0.0198	4	0.14
P_4 (quadruple sound)	0.0030	1	0.04
P_5 (quintuple sound)	0.0004	0	0
Total	**1.0001**	**196**	**7**

Table 3: Table of Arsenault's calculations[97]

Furthermore, Xenakis made another arbitrary decision to subdivide 196 into a matrix of 28 × 7, which represents twenty-eight units of time columns, and seven timbre types in rows. After that, Xenakis determined the order in which specific sound events appear by reapplying Poisson's law for each kind of event to create a higher order rule that governs the overall structure of the piece (the value for λ for each type of event is listed on the right-most column in table 3). These values are then used to create what Xenakis calls the 'Matrix M', which forms the overall structure for *Achorripsis* (figure 9).

[94] Ibid., 59.
[95] Ibid., 61.
[96] Ibid., 60.
[97] Ibid., 60–61.

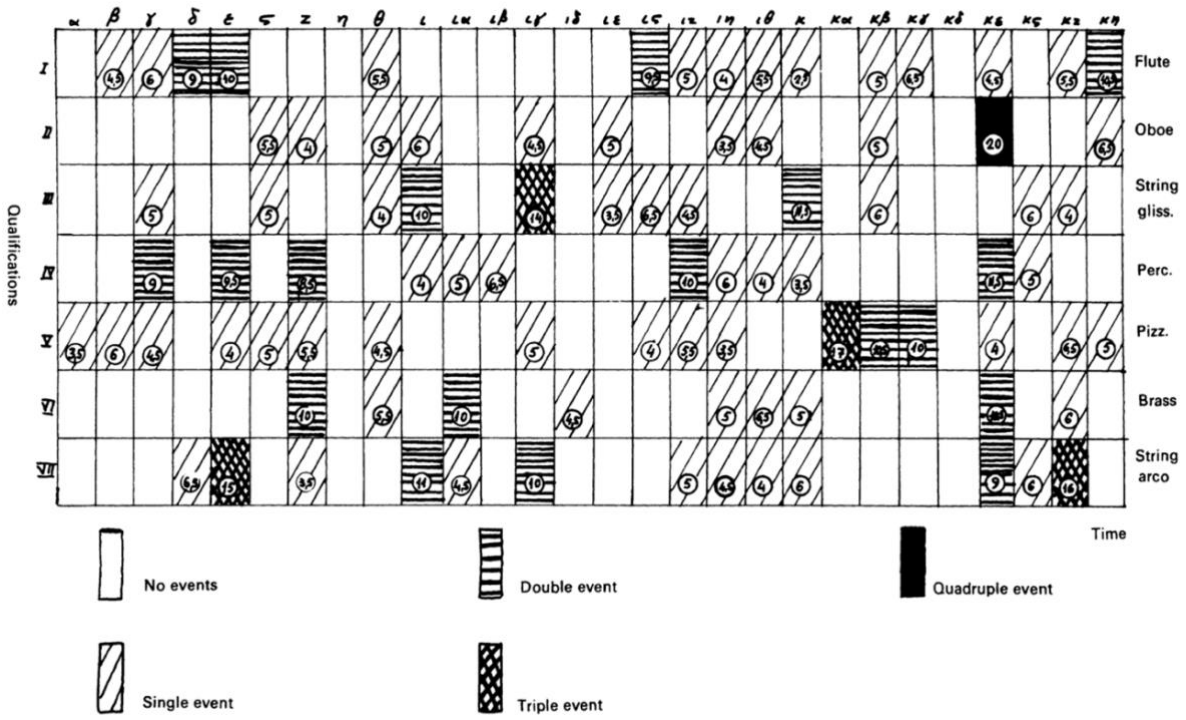

Figure 9: Xenakis's Matrix M[98]

'Matrix M' in figure 9 functions as a higher order rule that governs the overall structure of the piece. To be sure, Xenakis's labels for events do not refer 'single event' to one sound, and 'double' to two. These are specified averages for events, where zero remains zero, a single event has an average of five sounds per bar, a double event doubles it to ten, there are fifteen average sounds for triple events, and twenty for quadruple. As opposed to directly specifying the number of sounds, the idea of controlling averages enables more compositional freedom for the composer, but in a way that adheres to the structural density produced by the algorithm. For instance, a single event could have anything from 2.5 to 6.5 sounds per bar to reach the average of five.

Xenakis describes that the method to realise such a form is similar to 'a game of chess for a single player who must follow certain rules of the game'. The probability distribution has been used to automatically outline the sections of the score, but there are still plenty of possible ways to 'play the game'.[99] As remarked by Arsenault, Xenakis still has a great deal of freedom to work with decisions unspecified by the algorithm. For example, the matrix does not indicate at which point within a cell the pre-determined events need to happen. Instead, Xenakis has latitude to 'place the events as he chooses' insofar as the correct number of each event is

[98] Xenakis, 28.
[99] Ibid., 34.

distributed across twenty-eight columns and 196 cells.[100] This is to say that on a structural level, the algorithm could lead to many different ways of writing *Achorripsis*. In fact, since the algorithm only specifies a total number of events, there could even be an open form version of it that adheres rigidly to this structure.[101]

Contrary to what his advocacy of formalised composition might imply, Xenakis tends to interpret the theories behind his process more loosely than is often assumed. As Xenakis writes: 'the theory and the calculation define the tendencies of the sonic entity, but they do not constitute a slavery'.[102] Xenakis sets up his algorithms in a way that leaves certain, admittedly smaller-scale decisions open for himself subjectively. In fact, in comparing his own calculations against Xenakis's workings from *Formalized Music,* Arsenault found that Xenakis had adjusted the numbers of his matrix slightly to suit his intuitive needs for the piece's overall structure.[103] It is notable, however, that Xenakis's adjustments are truly what they are: adjustments. They are only subtle changes such as rounding 7.39 to 8 in P_2 and 5.71 to 5 in P_3 (table 3). These deviations make very little impact on the actual statistical change as the total number of events is still twenty-eight. As Arsenault puts it, these deviations feel 'consistent' with to the spirit of Poisson distribution.[104]

In some ways, Xenakis's use of algorithmic material is not too dissimilar from Boulez's compositional freedom in *Le Marteau*. In Boulez's music, the tension between what the algorithm generated and what he wants to write is resolved by allowing himself to deviate from the material intuitively. Here, Xenakis also works with his material intuitively, but he does not necessarily 'deviate' from his algorithm. Rather, he leaves blanks in his algorithm for himself to fill intuitively, and he would only intervene with the algorithm in a way that remains faithful to the 'spirit of the algorithm'. Xenakis's interventions do not 'destroy' the algorithm like Boulez's do. Instead, his interventions add expression not against, but around the material, functioning akin to 'human touches' to the algorithm. In other words, for Xenakis, the tension between material and work is resolved at the expense of automatism. Xenakis compromised

[100] Arsenault, 65.
[101] In some ways, *Duel* (1958) is not far from being an open form version of *Achorripsis. Duel* is for two orchestras where the two conductors can choose to play from any of the six musical 'tactics' precomposed by Xenakis until one of them wins. There is a fixed set of instructions to play precomposed material, but the unfolding of the piece will be different in every performance. Note that in *Achorripsis,* once the initial rules have been established, Xenakis leaves 'blanks' in his algorithm for himself to fill in. Similarly, in *Duel,* he leaves blanks in the overall structure for the conductors to fill in. See Chapter 4.1.2 for a deeper discussion of *Duel*. It is also worth noting that Gibson found a connection between *Achorripsis* and *Duel*, where tactic IV in *Duel*, described as 'stochastic percussion sounds', is a direct quotation from the percussion section in *Achorripsis*. This also supports my point that Xenakis interprets his materials loosely. As I will note immediately below, despite the description of 'stochastic', Xenakis did not make any new calculations and borrowed from his previous work.
[102] Xenakis, 34.
[103] Arsenault, 62–64.
[104] Ibid,, 62; Arsenault goes further to note that it is fitting for this imprecision to occur in the spirit of the term 'stochastic' in itself. She explains that Poisson's law is an infinite series, so it is reasonable that its values are taken only as a guide.

the comprehensiveness of the system in exchange for a compositional agency that is more narrow than Boulez's, in order to resolve the tension between what the algorithmic generated and what he wants to write.

This type of deviation is the closest to my approach in *Four Pieces*. While I ended up interpreting the material intuitively, I still tried to follow the 'spirit of the algorithm'. The step to stylise my maquette is essentially an intervention with the material to work around it without destroying it. However, it is worth noting that the gaps in my algorithm were accidental, as in they came from the inherent incompleteness of the constraints, whereas Xenakis's gaps were fully intentional as a high order function.

2.4.4 A Short Summary

In summary, my approach in writing the *Four Pieces* lies somewhere between the three approaches outlined above. Initially, my intention was to let the constraints dictate the musical outcome with minimal human intervention. In that sense, there is a Cagean tendency to accept whatever the algorithmic outcome is. However, I overlooked Cage's meticulous process of adjusting the algorithm to ensure that outcomes were always desirable. This led me to a contradictory position where I produced a maquette that I did not want to use, yet I forced myself into using it without further adjusting the algorithm.

Secondly, as discussed in Chapter 2.3, since the constraints only considers pitch and rhythm, my algorithm is inherently incomplete, like Xenakis's. While Xenakis would intuitively fill in the blanks to complete his material, I was hesitant to do so. From the conception of his pieces, Xenakis always knew that his algorithm was just a means to an end, so he would set up a flexible algorithm that lets him to write the music that he wants to write. Whereas for me, I wanted to use the algorithm as an end in itself because I was hoping to hear what the algorithm could achieve by itself. Unlike Xenakis, the blanks in my algorithm were not left strategically for me to interpret intuitively. Truthfully, I did not expect to encounter these blanks in the algorithm, so when I was confronted by the blanks to complete the piece intuitively, I was unsure of how to approach them. Hence, the decision to try four different musical styles.

Lastly, in attempting to realise the basic material in various styles, I allowed myself deviate from the material, in the Boulezian way. However, my deviations were less drastic than Boulez's, as I aimed to preserve all material if possible. These three cases form a spectrum of different relationships between the material and the work, ranging from Cage's

direct use of maquette in *Music of Changes,* to Boulez's occasional defiance of it in *Le Marteau,* with Xenakis occupying the space in between (figure 10). This Boulez-Xenakis-Cage spectrum will form the basis of the discussions in the upcoming chapters.

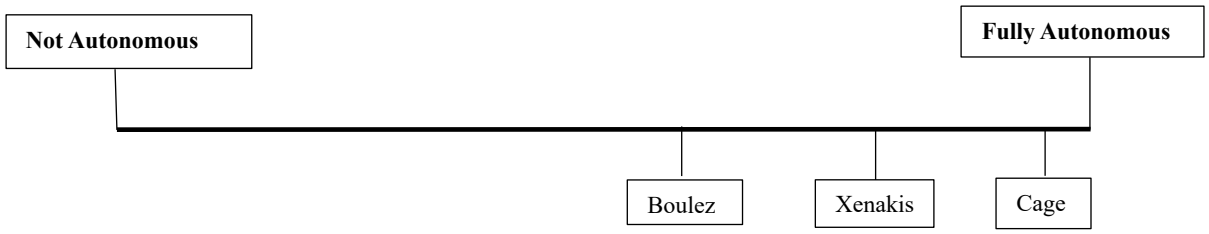

Figure 10: Spectrum of automaticism

The term 'algorithmic music', then, encompasses a wide range of automatisms, of which there are different methods to deviate at each level. To contextualise further, as mentioned in the introduction, there exists highly autonomous algorithms such as AIVA which can create music at the push of the button, but that is only one of the many ways to write algorithmic music. As demonstrated in the analysis above, in the compositional world, these kinds of one-step-processes are much rarer than is usually assumed. While some algorithmic pieces are indeed written this way, the vast majority of algorithmic music requires an additional step to act on the maquette to create the final work.

The most notable unifying factor of these algorithmic musics discussed so far, apart from the bottom line that some sort of algorithm is used, is in these composers' notable trust in their material. On Cage's side of the spectrum, the tweaking of the algorithm guarantees desirable maquettes. On Boulez's end of the spectrum, his deviations were intended to give the maquette more expression, even if that meant occasionally 'destroying it'. For Xenakis, the gaps in his algorithm are windows for him to add 'finishing touches' to his maquette. In all three cases, the composers intervened with the intention to 'make the maquettes work'. There is a notable sense of self-discipline in all three cases, working with the maquette while embracing its contents, and striving to make them more 'musical'.

The point at which the maquettes start to feel 'complete' and 'musical' is entirely subjective. It depends on the composer's intention with the algorithm, and their preference for the resulting sound. This subjectivity has enabled the rich variety of algorithmic music, and it is also why algorithmic composers have often disagreed with one another.

To conclude this section, I would like to reflect on my dissatisfaction towards the *Four Pieces.* From the outset, I assumed that all algorithmic compositions were a direct result of a one-step process. I now realise that automaticism is a spectrum, where I could have

intervened with the material in different ways and to various extents. Furthermore, my approach to using the algorithm autonomously was problematic, because I was not fully aware of that entailed. Unlike Cage, I was not prepared to embrace the openness in my music (though I thought I did), which was evident in my unexpected dissatisfaction with the initial maquette. Additionally, Cage was able to achieve near-automaticism through meticulous adjustments, which I did not do. Most importantly, Cage's adjustments were implemented with a clear intention in mind, so he could depend on the algorithm to produce desirable outcomes. In contrast, my process lacked intentionality. I did not have a clear vision of what I wanted the outcome to sound like, and this lack of intention has left me with unsatisfactory, ambiguous maquettes that I described as 'dry', 'basic', and 'incomplete'.

These issues are only problematic to the extent of how I want to write music. While the *Four Pieces* are interesting in their own right, I perceive them as errors because the compositional process unfolded differently from my expectations. I will seek to improve on these mistakes in my pieces in the next chapter.

Nevertheless, it is intriguing to have identified a common gap between maquettes and works in my discussion. Recalling figure 4, the maquette was fully playable and achieves what I set out for it to achieve, yet there is a sense of incompleteness in the work. I am fascinated by the idea that maquettes are, by definition, deemed incomplete by the composer, so they are rarely usable as complete pieces without further intervention. Composers have had to make maquettes work in their own ways, either by tweaking or deviating, but it is notable that somehow maquettes cannot become the musical work without these interventions. It is as if maquettes are incomplete because they are somehow not 'musical' yet, at least from the composer's perspective. In order to uncover what exactly is lacking about maquettes, in the next chapter, I will turn to a more comprehensive algorithm to study this relationship more closely.

3. Algorithmic Tensions

In order to examine the gap between material and work, in this chapter, I will attempt to create a more autonomous algorithm to test whether a more comprehensive maquette could be used directly as the music without any interventions. There are two reasons for exploring this. First, as noted earlier, when confronted by the CCCS to make more intuitive decisions, I was hesitant. I wanted to maintain an openness to embrace my maquette, but to be honest, I was unsure of my own musical preferences. In a way, I resorted to trying four musical styles because of my hesitation to choose. Therefore, I want to try using an algorithm that is even more autonomously to see if it could minimise my decision-making.

The second reason is that when I use an algorithm, I still want to be able to hear the algorithm. I side with Cage on the spectrum in figure 10 because I want to preserve as much of the algorithmic material as possible (and, in a way, I share the wariness in imposing my personal taste onto musical materials too). So, in my second year, I built a machine learning algorithm with hopes that it would be able to automate the compositional process completely. The algorithm takes a previously intuitively composed piece as input, and generates an output in the style of the original. This algorithm (and its eventual derivatives and extensions) is used to create the rest of the pieces in my portfolio, and I will now explain the algorithm below.

3.1 *Adrift*

Before discussing how the algorithm works, it would be useful to discuss the piece that the algorithm is trained on. I wrote *Adrift* (2021), for solo acoustic guitar, in response to a call for score at the University of Leeds to be workshopped by Seth Josel in September 2021. At the time, I had not committed to the *volte-face* from researching in cognitive theories to algorithmic music yet. Since I had not started building the new algorithm, I took the opportunity to write intuitively without using any algorithms.

With *Adrift,* I wanted to explore the perception of microtonality. Having recently written *Lightness* and *Worldness*, I was intrigued by the mathematical relationships within various tuning systems, and I sought to hear the unique sonorities that these tuning systems could produce. I was particularly drawn to James Tenney's tuning in *Water in the Mountain… Fire in Heaven* (1985), which approximates just intonation using a 72-TET system.[105] Tenney's piece was written for six guitars, each tuned to a sixth of a semitone apart, but the

[105] Giacomo Fiore, 'Tuning Theory and Practice in James Tenney's Works for Guitar', *Music Theory Spectrum*, 40, 2(2018), 338–56 (348).

call for scores I was writing for was limited to solo guitar only. I then had to pick six out of Tenney's seventy-two subdivided intervals. In my selection, since the 72-TET is known for its closeness to just intonation, I picked five just intervals on A=110Hz, but the D string is deliberately detuned to 21:16 rather than the typical 4:3. The reason for this is that I wanted to incorporate non-just intervals from Tenney's system to hear what they sounded like. Also, I wanted to test how 'out of tune' the piece would feel if only the D string was 'off'.

String	Note	Step in 72TET	Cents	Approx. ratio	Frequency (Hz)	Frequency difference from 12-TET (Hz)	Frequency difference from JI (Hz)
1	C#4	23	383	5:4	275.0	-2.2	±0
2	B3	12	200	9:8	247.5	+0.6	±0
3	F3	49	817	8:5	176.0	+1.4	±0
4	D3	28	467	21:16	144.4	-2.4	-2.3
5	A2	0	0	1:1	110.0	±0.0	±0
6	E2	42	700	3:2	82.5	+0.9	±0

Table 4: Scordatura for *Adrift*

As seen in table 4, the guitar strings are altered where string 1 is a C sharp and string 3 is an F. The reason for this further scordatura is because I wanted the piece to be played using only open strings and natural harmonics, as they are relatively easy and reliable ways to produce the precise frequencies specified in table 4.[106] Thus, the first and third strings are detuned to enable the possibility to play all twelve chromatic pitches in natural harmonics.

There are probably other ways of achieving a scordatura that is inclusive of all twelve notes in natural harmonics, but I deliberately refrained from detuning too many strings because I wanted to retain the performer's familiarity with the instrument. This is mostly a concern for playability, especially in a workshop setting where there was only forty-five minutes to work on the piece.

[106] Contrary to what my admiration for Tenney's work might imply, my desire to hear the scordatura as accurately as physically possible is not rooted in Tenney's 'naturalist' thought where he referred to the harmonic series as 'the only thing given to us by nature… except sound itself'. See Donnacha Dennehy, 'Interview with James Tenney', *Contemporary Music Reivew*, 27, 1(2008), 79–89 (86–87). I am not interested in the 'naturalist' justification to Just Intonation, and I am only interested in the experiential perception of how we hear non-standard tuning.

The opening chord pays homage to La Monte Young's theme of 'Dawn of Eternal Time' from *The Well-Tuned Piano* (1964).[107] The material then gradually drifts away from Young's theme into a slowly modulating rotation of tonal centres based on the lower open strings in the scordatura: namely E, A, D, and it finishes in F.

Upon hearing the piece, the sounding result is a noticeably 'out of tune' microtonal system because of the detuned D string. As opposed to typical JI tuning, where ratios are mathematically and perceptually more 'in tune', the D string scordatura draws listener's attention towards itself, away from the less 'problematic' strings, at least initially. I found that over the course of the structure, the supposedly 'out of tune' D string gradually blends into the rest of the system, and my ears learn to settle in it.[108] The title 'Adrift' refers to this experience where new harmonic relationships are encountered under the unfamiliar 'out of tune' D scordatura, similar to the situationist use of the term. In situationist theory, 'Adrift' is used to mean an aimless walk through the city streets, where the attraction lies in the encountered environment itself, leading to radical ways of looking at urban situations.[109] It is also fitting that in French, 'Adrift' translates to *à la dérive*, and it is coincidentally the very piece that the algorithm uses to generate other similar sounding derivatives.

Notably, Boulez wrote two pieces using the same name: *Dérive 1* (1984) and *2* (1988). These pieces, as their names suggest, are derived from Boulez's earlier pieces; *Dérive 1* comes from unused materials from *Répons* (1981), and *Dérive 2* from studies that Boulez did for part of *Répons*.[110] On the reused materials in these pieces, Boulez writes:

> My recent music… is much like a family tree—one tree spawns many other trees, and so on. *Répons* itself was my response to *Poesies pour pouvoir*, which I had written over twenty years earlier. As long as material from another piece is not used fully, I like to expand on it until it is exhausted. This is why they are all works-in-progress.[111]

As opposed to Boulez's way of reusing unused material to create new derivatives, mine is more akin to reusing the same material to create different versions of the same piece. *Adrift* is the seed of its derivatives, and the pieces are generated using *only* materials from it.

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[107] Kyle Gann, 'La Monte Young's The Well Tuned Piano', *Perspectives of New Music*, 31, 1 (1993), 134–162 (143).
[108] Although this observation does not come from a fair-tested scenario, the phenomenon is consistent with findings from research in music psychology, such as in Roger T. Dean and Yvonne Leung, 'The Difficulty of Learning Microtonal Tunings Rapidly: The Influence of Pitch Intervals and Structural Familiarity', *Psychomusicology: Music, Mind, and Brain*, 28, 1(2018), 50–63.
[109] Libero De Andreotti, and Xavier Costa, *Theory of the Dérive and Other Situationist Writings on the City* (Barcelona: Museu d'Art Contemporani de Barcelona, 1996), 4.
[110] Andy Carvin, 'An interview with Pierre Boulez', *Edweb*, n.d. <https://edwebproject.org/boulez.html> [accessed 4 June 2024].
[111] Ibid.

3.1.1. The Algorithm

I will describe below how I built a machine learning algorithm in Max/MSP to predict and replicate music in my own style. The algorithm uses a stochastic process called Markov chains, which is commonly used in data sciences of economics, communication, genetics, and finance.[112] They can also be found in music such as the fourth movement of Lejaren Hiller and Leonard Isaacson's *Illiac Suite* (1955–56), as well as Xenakis's *Analogique A+B* and *Syrmos* (1959).[113] Sofian Audry explains,

> Markov chains are probabilistic systems that model transitions between states according to fixed probabilities. These transition probabilities can be custom-crafted or learned from a corpus of existing partitions. One important property of Markov chains is that they represent transitions between sequences of events using a limited window of previous events. For example, if the note most recently played was a C, a Markov chain could give a 25 percent chance to play a C again and a 75 percent chance to play an E. Thus in Markov chains only a limited number of events from the recent past affect the future.[114]

Markov chains themselves are stochastic functions that study the probabilistic relationship between transitional states, and in the context of music generation, they can take a corpus of music as input and output a prediction based on the transitional relationships of the original input. This can be achieved using the 'ml.markov' object in Max/MSP where MIDI data of a sample piece can be uploaded, and a prediction of MIDI outcome can be created after pressing the 'learn' command.

To be sure, other machine learning methods such as recurrent neural networks in deep learning can achieve accurate predictions in different ways, but a Markov model was chosen here instead of deep learning because neural networks usually require a large database to train from. In contrast, Markov chains can conveniently work with a much smaller sample size, which is the case in my algorithm because there is only one piece to be used as sample.

While Markov chains are useful for understanding probabilistic relationships in close proximity, they are notoriously problematic when analysing long range structures. Audry notes,

> This drawback of using larger reference windows is a commonly known problem with Markov models trained on existing corpora of text or music. Markov chains often fail to grasp long-term structural dependencies between events. For example, a Markov chain trained on a database of blues music might be able to generate one or two measures but would have a hard time creating a coherent score with an appropriate beginning, middle, and ending... In other words, although Markov chains do share some properties with machine learning systems, they lack the kind of self-organizing and distributed representational capabilities offered by neural networks.[115]

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[112] Audry, 29–30.
[113] Hiller's *Illiac Suite* will be discussed at length in Chapter 3.3.2.
[114] Audry, 128.
[115] Ibid.

To make up for the model's inability to predict long range structure, my solution was to implement four sectional Markov chains to imitate the global structure of *Adrift*. As described previously, the piece is based on a cycle of four tonal centres: E, A, D, and F, and there are specific sets of pitch classes used in each subsection. To model this structure, the algorithm is divided into four sections, where there is a Markov chain within each section to learn from its corresponding part from *Adrift*. In other words, there is a dedicated Markov chain on tonal centre E, one on A, one on D, and one on F, and the generated outcome always follows this order.

In a Markov model, the nth degree Markov-order is a parameter that controls how far backward and forward the function predicts from. The higher the Markov order, the more resemblance the outcome will have to the original. I ultimately decided on the third degree based on trial and error, because it struck a balance between sounding familiar enough yet still offering some surprising moments.

Rhythmically, *Adrift* is only notated loosely in units of four note values: crotchet, minim, dotted minim, and semibreve. As is the case with pitch, there are Markov functions within each subsection to learn and predict rhythm for each section independently. This is integrated with the pitch component, so the algorithm is able to output both pitch and rhythm from *Adrift,* in the form of MIDI data.

3.2 Material vs. Idioms

3.2.1 *Markov Patterns I* and *II*

After building the algorithm, I wanted to hear what its results sounded like, so I wrote *Markov Patterns I* (2022) for vibraphone, and *Markov Patterns II* (2022) for marimba hoping to use the maquette directly as the work. The pair of pieces were for Steven Moore, who is a colleague at the University of Leeds studying for a PhD in solo percussion performance.

I was hoping that the machine learning would be sufficient for the maquette to feel complete, so I aimed to emulate Cage's approach to avoid making interventions to the algorithm. Obviously, the scordatura from *Adrift* cannot be replicated on the pitched percussion.[116] Therefore, my expectation for *Markov Patterns I* and *II* was to create non-literal transcriptions of *Adrift* that would sound similar but still offer surprises when

[116] There are only very few ways to play microtones with or on the vibraphone and the marimba, such as on the MalletKat, 'preparing' individual pieces of keys, or some form of live-electronic transformer. All of these options were ultimately deemed unviable logistically between myself and my collaborator, due to the physical set up that we had and the scope of our performance.

unpredictabilities happen. However, this transcription process proved to be less straightforward than I had anticipated.

I realised that the generated maquette continued to be in the idiom of the guitar, so there are moments that feel unidiomatic to play on mallet percussions. For example, the maquette has a range that spans five octaves (where the vibraphone typically only has three octaves), there are rapid large intervallic leaps, most frequently due to the open string notes (whereas it is physically awkward to leap across register on the marimba due to its sheer size), and vertical harmony sometimes consists of six simultaneous notes (where Moore could only play four at a time). Not to mention, other than these physical problems, the instruments themselves have idioms formed by historical traditions of existing repertoire, which my material fails to account for.

For this reason, I had to intervene with the material without compromising the 'spirit' of the algorithm. Rather than stylising the maquette like I did before, my role here is simply to fix the maquette so that it becomes playable.[117] For *Markov Patterns I*, I condensed the material from five octaves into three with my best effort to preserve the original contour of pitches. However, in *Markov Patterns II*, due to the size of the marimba, I had to adopt a more liberal approach. I rearranged registers to smooth out voicings, even if it meant compromising the pitch contour. For example, an upward seventh leap from E_3 to D_4 would be changed to a downward second step from E_3 to D_3.

Additionally, there are other non-pitch but instrument-specific incompatibilities that required 'fixing'. For example, there are no instructions in *Markov Patterns I* for pedal markings and dynamics because they were not required in *Adrift*. Notes in *Adrift* were played in natural harmonics on the guitar so sustain and dynamics did not need to be specified. Also, due the lack of sustain on the marimba, playing slow individual notes the way *Adrift* sounded would be uncharacteristic in *Markov Patterns II*, at least according to Moore. My solution for these non-pitch incompatibilities was to present these instrument-specific decisions as indeterminacies and let the performer find their own solution. For example, in *Markov Patterns I*, the pedal is simply marked by 'damp as necessary'. Moore then took the time to sit at a piano to explore how he wanted use pedals to form phrasings and harmonies from the predetermined pitch. I specified that *Markov Patterns II* should be played with tremolandi

[117] Rolf Inge Godøy discusses a similar problem of non-translatable instrument-specific idioms from the perspective of embodied musical cognition in support of Rosenbaum's theory of motor equivalence. My approach with *Markov Patterns* would be what Godøy describes as a non-literal translation that 'deviates from the note-by-note score of the original, and within reasonable limits, transform the musical material in order to make the new version loyal to… the 'spirit' of the original' See Rolf Inge Godøy, 'Motor Constraints Shaping Musical Experience', *Music Theory Online*, 24 (2018), 7–8.

throughout, but the intensity, dynamic, and duration of each tremolando is free to be interpreted by the performer. Moore then marked on his score where he felt the material had points of tension and release and he interpreted expression out of the algorithmic material.

In *Markov Patterns I* and *II*, while the generated maquette no longer felt dissatisfactory, I have not been able to use it directly as the final work. The issue concerns an interesting dynamic between the algorithm, the instrumentation, and myself. First, to continue the discussion from Chapter 2, there remains a noticeable distance between the maquette and the completed work. Although I aimed to avoid intervening with the maquette, I still encountered smaller decisions such as the choice of pedal, mallets, and octaves. In other words, while the algorithm determines 'what' to compose, it required me to decide 'how' the maquette should be executed.

To be clear, this is only an issue in the context of my goal to compose autonomously. The resulting music is not necessarily problematic, and there is nothing objectively wrong about needing to intervene. It is simply that I have not been able to successfully use the maquette as the final piece,

Furthermore, the issue with the algorithm is that it treated pitch and rhythm in abstraction, overlooking the nuances of each instrument's idiom. The smaller decisions that I had to make were all related to the physical characteristics of the new instruments. This shows that there is an additional layer of tension between automaticism and idiomaticism. Using the maquette autonomously will lead to a loss in playability, and vice versa, when the maquette is adapted to new instruments, it is no longer being used autonomously.

The third, perhaps smaller part of the fault, is that the instrumentation was not quite versatile enough to play the maquette as it is. If the instrumentation were more flexible, perhaps a piano instead, the problem would no longer exist. To reiterate, this is only a problem to the extent of the fixed position I held in the relationship between the algorithm, myself, and the instrument. Had the algorithm considered the idiomatic aspects of playing, or had I allowed myself to deviate from the material, or if the instrumentation were more versatile, these tensions would easily resolve themselves.[118]

[118] Researchers in computer science have attempted to address this issue of translating musical idioms. See: Noam Mor, *et al.*, 'A Universal Music Translation Network', *ICLR* (2019) <https://iclr.cc/Conferences/2019/Schedule?showEvent=993> [accessed 7 June 2024]. Similarly, Juslin's research attempts to model musical expression from various aspects of performance computationally in Patrik N. Juslin *et al.,* 'Toward a Computational Model of Expression in Music Performance: The GERM model', *Musicae Scientiae*, special issue (2002), 63–122. Rosenbaum's theory addresses motor equivalence between instrumental idioms, see: David Rosenbaum, *Human Motor Control* (Amsterdam: Elsevier, 2009).

3.3 Material vs. Bodies

3.3.1 *Recursion*

Almost immediately after I had written *Markov Patterns*, there was another call for scores at the University of Leeds, this time for a solo percussion workshop with Brian Archinal. Inspired by the tensions identified thus far, between material and work and between material and instrumental idioms, I finally wanted to try using the algorithm on the more liberal end of the spectrum. In *Recursion* (2022), I aimed to use the maquette freely, but the work should still be explicitly based on the algorithmic material. I would place it closer to Xenakis's deviation than Boulez's.

I did not want to write for pitched percussion again, so for the workshop, I wanted to write for unpitched, multi-percussion. Instantly, the conflict at hand is that my algorithm is based on abstracted pitch, but I chose unpitched instruments to work with. My solution was to map the twelve pitch classes to twelve sounds played on six percussions instruments. These sounds are three tom-toms, which are played either normally or at the rim, and three cymbals, which can be played normally or with mute (the performer is instructed to place a light piece of cloth to cover half of each cymbal). Sounds are mapped onto pitch based on their structural importance in the material. Since *Adrift* has four sections based on four tonal centres, I mapped the centres E, A, D, and F to the four main sound types: normal tom-tom, tom-tom rim strike, normal cymbal, and cymbal with cloth mute. In doing so, I was aiming for a sense of structural clarity, though obfuscated by the absence of pitch. I wanted the timbres to shift gradually from mainly skin sounds, to rim sounds, to muted cymbals sounds, and finally finish on cymbals. In addition, I mapped registral difference of pitch classes in the original to articulations: accent, tenuto, staccato, and normale represent four octaves on the maquette.

Apart from the pitch-to-sound mapping system, I also added an isorhythmic ostinato that runs throughout the piece. This came from my instinct that the percussion piece should feel rhythmic, so this is my take on making it more idiomatic. However, despite my intuitive intervention with the maquette, Archinal's feedback from the workshop was that the piece did not feel idiomatic to play. He noticed that accents were not aligned with how the rhythm 'feels', and he suggested that I think of my materials more gesturally.[119] This invaluable piece of advice was a wakeup call for me, revealing to me that, all along, my approach to

[119] This echoes Boulez's comment on Du Fay's isorhythm that I quoted in footnote 29, where he describes isorhythms as 'a phenomenon of dissociation'.

composition has defaulted to logic over intuition. In my mind, it felt right to add an isorhythmic loop to match the idiom of percussion. However, I did not realise that my so-called 'intuitive' decision—the isorhythm—was, in fact, another forced generative method in itself, which defeated the purpose of my intervention.[120]

The implication is that in *Recursion*, there is a disconnection between the piece and the performer's body. By 'body', I am not referring to the physical anatomy, but in the phenomenological sense of the 'lived body', or what Merleau-Ponty terms '*le corps propre*'.[121] The body, in phenomenology, is our point of view upon the world.[122] We do not merely have bodies, because it is not an object that we can possess, nor can we withdraw from it.[123] Instead, we are our bodies.[124] Merleau-Ponty explains, 'I have no other means of knowing the human body than by living it, that is, by taking up for myself the drama that moves through it and by merging with it'.[125]

My compositional process, which sought to compose by logic exclusively, implies a Cartesian separation between the music and this lived body. My desire to use the algorithm fully autonomously has led to a much smaller room for intuitive decisions. In *Markov Patterns*, since the algorithm took care of the musical contents, I only had to work with the practicalities around the musical material, such as deciding on the pedal, mallets, and occasionally changing octave displacement (though I did not want to). These are decisions that do not, or at least try not to, intervene with the autonomous maquette, so there is much less room for intuition in these pieces.

In *Recursion,* despite adhering less strictly to the algorithm, it achieved an even higher degree of automatism. I inadvertently applied systematic interventions to the maquette, such as isorhythms and mapping systems, which made the little remaining room for intuition more autonomous. By relying on these generative techniques, I focused on the maquette in abstraction, overlooking the necessity to situate the final piece as a bodily

[120] To be sure, these 'forced' generative methods such as isorhythms are not a problem in themselves. Historically, many composers have been interested in finding a balance between radically 'forced' compositional ideas versus the physical limits of the instruments. Tanja Orning discusses this tension in the context of the music by Derek Baily, Richard Barrett, Brian Ferneyhough, Morton Feldman, Helmut Lachenmann, and Klaus K. Hübler. See: Tanja Orning, 'The Polyphonic Performer: A study of performance practice in music for solo cello by Morton Feldman, Helmut Lachenmann, Klaus K. Hübler, and Simon Steen-Andersen', PhD Dissertation (Norway: Norges musikkhøgskole publication, 2014), 35–37.
[121] Maurice Merleau-Ponty, *Phenomenology of Perception*, ed. and trans. by Donald A. Landes (New York, NY: Routledge, 2012), xlvii–xlix.
[122] Ibid., xv.
[123] Mariusz Kozak, Enacting Musical Time: The Bodily Experience of New Music (New York, NY: Oxford University Press, 2020), 108.
[124] Merleau-Ponty, 151.
[125] Merleau-Ponty, 205.

experience for the performer. I will continue to discuss the implications of this disembodiment at the end of this chapter.

Consequently, through this mode of composition, I found that these kinds of decisions, though usually concerning more mundane practicalities, are no less important than the autonomous parts of the work, and in fact, they need not to be mundane. They are the only opportunities for intuition that I had left in the process. More importantly, having tried to remove intuition from these decisions, I now see them as the necessary bridge between the abstracted algorithmic maquette and the body. These practicalities take care of what the algorithm cannot do, which is to situate the material in the bodily real world. In other words, these decisions can help un-disembody (so, embody) the algorithm.

It is interesting to observe that when working with a high degree of autonomy, these decisions, despite appearing trivial, become a crucial part of the composer's expression in the piece. These practical decisions usually present themselves after the maquette has been generated, so I will call them 'post-generation' decisions from now on. In the following, I will examine pieces that are typically considered to be on Cage's end of automatism, to note what the post-generation decisions for these pieces are, and how they influence the bodily experience of their performance. This includes Hiller and Isaacson's *Illiac Suite* (1956–57), Boulez's *Structure Ia,* and Steve Reich's *Clapping Music*—before revisiting *Music of Changes*.

3.3.2 *Illiac Suite*

To make a clear exemplification, Lejaren Hiller and Leonard Isaacson's *Illiac Suite* is widely recognised to be the first piece of computer-generated music for acoustic instruments.[126] The piece has frequently been referred to as a cornerstone for autonomous computer music. For instance, Jean-Pierre Briot *et al*. write, 'the *Illiac Suite* was the first score composed by a computer'.[127] Karlheinz Essl writes: 'in 1957, the first complete computer composition —the well-known *Illiac Suite* for string quartet'.[128] James Harley writes: '[Hiller] worked with fellow chemist Leonard Isaacson on developing the software to produce the first computer-

[126] Although many literatures write about the *Illiac Suite* that way, there are several computer-music attempts that predate it, such as Pinkerton's music generation program, Klein and Bolitho's *Push-Button Bertha*, Granholm and Mitchell's orchestration computer programme, and Caplin's Mozart's Dice Game program. These are acknowledged by Hiller and Isaacson in Lejaren A. Hiller Jr., and Leonard M. Isaacson, *Experimental Music: Composition with an Electronic Computer* (New York, NY: McGraw Hill Book Company Inc, 1959), 55–57.
[127] Jean-Pierre Briot, Gaëtan Hadjeres, and François-David Pachet, *Deep Learning Techniques for Music Generation* (Cham: Springer Nature Switzerland AG, 2017), 4.
[128] Essl, 112.

generated composition, *Illiac Suite*, for string quartet'.[129] Other authors have been more explicit in claiming that the piece is the literal result of the computer program. Gerhard Nierhaus writes: 'The first example of a computer-generated composition produced by a [Generate-and-Test] method is the *Illiac Suite* of Lejaren Hiller and Leonard Isaacson'.[130] In describing Hiller and Isaacson's interdisciplinary collaboration, Curtis Roads writes: 'the initial result was the algorithmically generated *Illiac Suite for String Quartet* (1956), a landmark in the history of music'.[131]

The problem here is not that the authors have misunderstood the compositional process. In fact, these texts have an accurate grasp of the computational method which is close to Hiller and Isaacson's description of their own work in *Experimental Music: Composition with an Electronic Computer.* Rather, this is the same problem I explained in my introduction. The term 'computer-generated' is used with much ambiguity to encompass different aspects (and to different extents) of human intervention. Consequently, going back to the problem from the introduction, when a piece is described as 'computer-generated' without making clear what human decisions were involved, it implies a neglect of the role of its human creators. In the case of *Illiac Suite*, the musical material is indeed computer generated, but that is all that the algorithm has created. The role of the computer is limited to producing the maquette, and it is ultimately up to Hiller to transform the maquette into a work.

In *Experimental Music*, Hiller and Isaacson documents their compositional process with transparency. In brief, the *Illiac Suite* consists of four movements that each present results generated by the four experiments carried out on the Illiac Computer. Experiment one aimed to compose 'a simple cantus firmus' and later developed to generate 'simply polyphonic writing'.[132] The programme originally produced first species counterpoint writing in two parts, and it later expanded into four parts. Thus, the first movement of the suite consists of three sections which showcase the results from the monody, two-part, and four-part stages of the programme, respectively.

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[129] James Harley, 'Computational Approaches to Composition of Notated Instrumental Music: Xenakis and the Other Pioneers', in *The Oxford Handbook of Computer Music*, ed. by Roger T. Dean (New York, NY: Oxford University Press, 2009), 109–33 (113).
[130] Niehaus, *Algorithmic Composition*, 238.
[131] Curtis Roads, *Composing Electronic Music: A New Aesthetic* (New York, NY: Oxford University Press, 2015), 342. In comparing different author's introduction to the *Illiac Suite*, I observe that work is dated inconsistently. According to Harley, the correct account is that the first three movements were complete by June 1956 and performed in a public concert at Urbana, Illinois. The fourth movement was later added to the suite in 1957.
[132] Hiller and Isaacson, 2.

In experiment two, Hiller and Isaacson wanted to improve on the four-part counterpoint writing, so the codes were rewritten to reinforce additional rules in species counterpoint. The programme was consequently able to consider vertical relationships, voice leadings, rejection of dissonance, and preparation for the cadence.[133] These new codes have an adjustable strictness parameter, so the second movement presents material from 'purely random white note obeying no rules', to the most restricted settings which applies the full set of rules.[134]

In experiment three, Hiller and Isaacson switched from studying generative species counterpoint to writing music that is of 'greater contemporary stylistic interest'.[135] Therefore, new functions were implemented to devise rhythmic patterns, dynamic markings, and playing techniques for string instruments. Additionally, the system was expanded to include control over the degree of chromaticism. Hiller also found a method for creating melody by using rules that govern octave range, stepwise resolution of tritones, and 'skip-stepwise' motion.[136] Thus, the third movement features various degrees of control over parameters such as chromaticism, rhythm, dynamics, and playing technique. More specifically, Hiller describes the first section as 'basic rhythm, dynamics, and instrumentation', the second section as 'random chromatic music', the third as 'modified rhythm, dynamics, and instrumentation', and the fourth as 'controlled chromatic music'.

Finally, experiment four studies broader formal principles of organisation to generate Markov chain music, in a way that is not too different from the process described in Chapter 3.2.2. For successive note selection, there are two defined sets of values assigned to absolute and conditional transition probabilities. One of the sets is based on the overtone series and the other is on leading-note function. The transition probabilities from these two sets of values are combined to inform characters such as skips and stepwise motions, consonant to dissonant intervals, and tensions and resolutions. As a result, the fourth movement consists of contrasting sections with varying nth degree Markov chains.

At the beginning of this section, I noted that Briot, Harley, and Essl described the *Illiac Suite* as 'the first score composed by a computer', 'the first complete computer composition', or 'the first computer-generated composition'. Without the correct contextual knowledge of the compositional process, I initially read these descriptions and assumed that Hiller and Isaacson created a computer program that would generate the score for them

[133] Ibid., 86.
[134] Ibid.
[135] Ibid., 80–81.
[136] Ibid., 80.

autonomously with a push of a button. From the discussion in Chapter 2, I was already aware that for autonomous pieces like the *Illiac Suite*, the points of decisions were shifted to the pre-generation stage. But I assumed that being an autonomous computer-generated composition, the *Illiac Suite* would have used the maquette directly as the work. Even though the *Illiac Suite* was intended not as 'a work of art' but 'a research record—a laboratory notebook', I was surprised to learn that Hiller still had to go through a significant number of decisions after the generation of the maquette-as-work. I call these decisions post-generation decisions.[137]

Evidently, the computer programme in *Illiac Suite* only led to experimental results, which in itself are not yet the final piece of work. After the initial material generation, the rest of the compositional process required significant human decisions to 'organise the raw results into a playable, relatively coherent whole'.[138] Hiller described these human decisions outside of the algorithm to be 'elements' that were 'inserted or adjusted as a result of practical necessity'.[139] Since the programme produced a lot more musical output than what could be included in the piece, Hiller and Isaacson implemented an 'unbiased screening procedure' where passages were selected impartially and 'not on the basis of aesthetic evaluation'.[140] Every tenth cantus firmus setting was used in the first movement, and sometimes examples were chosen at random with a random integer table. Also, the choice of tempi for the four movements and their respective structures were decided by Hiller, since there was no tempo nor structure-devising component in the codes. Furthermore, the choice to present the generated materials using a string quartet was based on Hiller's personal preference, as he felt that it was the most 'logical' and 'convenient' for the purposes of his experiments.[141] To transcribe the materials into a score for the quartet, Hiller transposed voice 1 two octaves downward for the cello, voice 2 one octave lower for the viola, and voices 3 and 4 for violins 1 and 2. Notably, these interventions were made with an explicit effort to 'minimise the amount of arranging of the materials', so that most of 'the musical content of the suite could be said to be computer produced'.[142]

[137] Ibid., 55.
[138] Ibid., 52.
[139] Ibid.
[140] Ibid., 153. This procedure is notably similar to Dadabot's process for *Coditany of Timeness* from Chapter 1.1, where there is a need to curate selections from a vast amount of generated material into the work. However, it is different here because, as mentioned above, Zack from Dadabots hand-picks his material to include, whereas Hiller and Isaacson tries to make a selection without bias.
[141] Ibid. Notably, this decision has already been made in the algorithm design phase, as experiment three clearly incorporated string techniques as a parameter in the algorithm.
[142] Ibid.

Hiller avoided intervention wherever possible and his interventions, such as the selection of cantus firmus, are themselves mostly systematic. The fact that the computer only created a maquette for Hiller to build on means that the *Illiac Suite* is not as wholly autonomous as is often implied. In terms of the overall degree of automaticism, returning to the Cage-Xenakis-Boulez spectrum, the *Illiac Suite* is situated between Cage and Xenakis because the algorithm was not as comprehensive as Cage's but Hiller's interventions were more systematic than Xenakis's.[143]

3.3.3 *Structure Ia*

As mentioned in Chapter 2.4.1, before his eventual reconciliation with expression in serialism in *Le Marteau*, Boulez was inspired by Webern to use expanded serial technique on other parameters to escape pre-established forms and styles.[144] For example, in his piece for two pianos, *Structure Ia*, Boulez wanted to 'find out how far automatism in musical relationships would go', in hopes that it would be able 'to bring everything into question again', to 'make a clean sweep of one's heritage'.[145] The result is a highly automatic and algorithmic piece for two pianos which Ligeti has described in his analysis of the piece as a 'textbook example' of multi-serialism.[146]

The tone row that Boulez chose is from Messiaen's *Mode de Valeurs et d'intensities* (top left of figure 11). The row is then transposed in its original form, its retrograde, inversion, and retrograde inversion to create forty-eight rows in total. Piano 1 is assigned all twelve original series and retrograde inversions, while piano 2 is given all inversion and retrograde rows.

[143] See footnote 18 for Hiller and Cage's collaboration on *HPSCHD*.
[144] Boulez, 'Schoenberg is Dead', 275.
[145] Boulez, *Conversations*, 56–57.
[146] György Ligeti, 'Decision and Automatism in Structure 1a' in *Die Reihe*, 5, trans. by Bryn Mawr (London: Theodore Presser Co and Universal Edition, 1961), 36–62 (36).

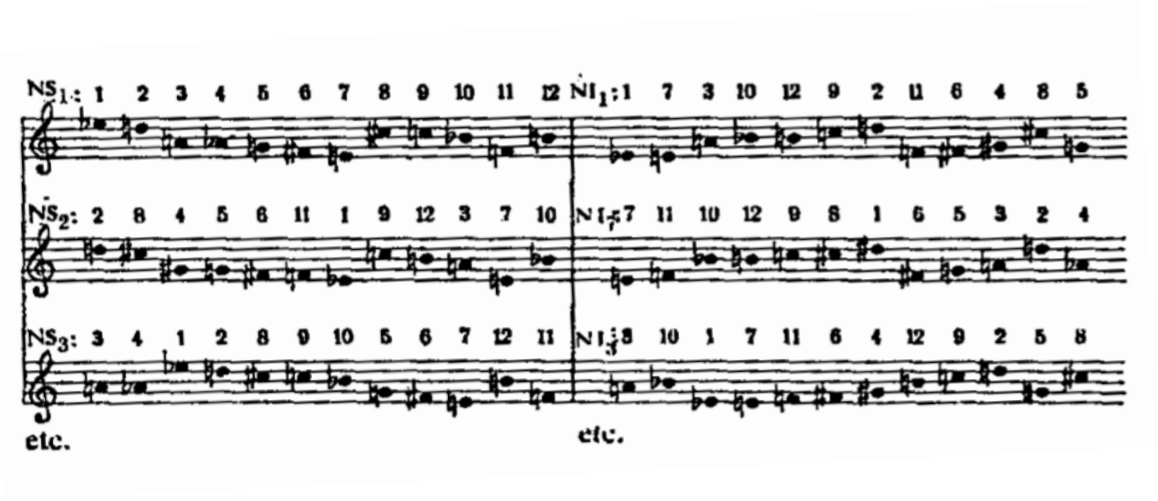

Figure 11: Matrix of rows for Structure Ia[147]

The same process is then applied to duration to generate rows of rhythms consisting of unique combinations of note values. Dynamic and playing technique were treated differently as these parameters do not need to be varied as extensively and frequently as pitch or rhythm. Twelve dynamic levels and twelve playing techniques were selected by Boulez but underwent a different ordering process that are mapped to a different graph diagonally. See figure 12 for the duration, playing technique, and dynamics row.

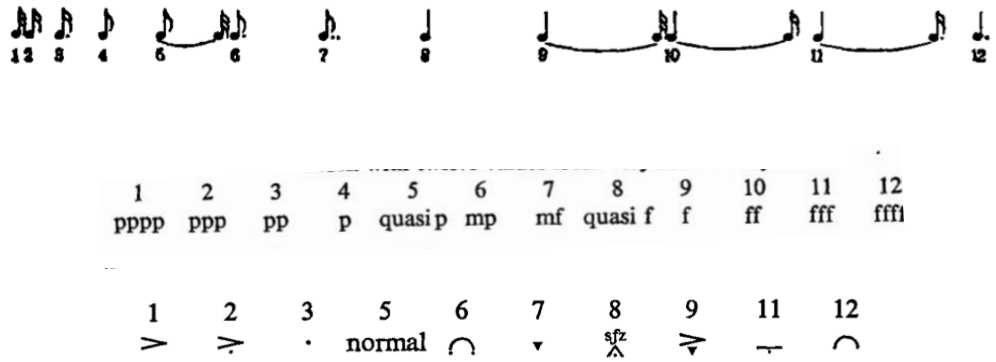

Figure 12: Rows for various parameters in *Structure Ia*[148]

Once the determining system for each parameter had been set up, the next step was to formulate a system of assembling these independent sound elements. This was achieved by creating a higher order row to govern the overall structure of threads and level of density

[147] Ibid., 38.
[148] Ibid., 39–43.

throughout the piece. Each section in *Structure Ia* consists of bundles of one to three threads per piano. Since durations are derived from the variations of the same rows, sections are clearly segregated in the way the pianos always start and finish together. There are eleven sections overall, which can be divided into two sections of A and B (5+6). Piano 1 plays all twelve original pitch series in retrograde inverted durations in A, then switches over to retrograde inversion pitch in inverted duration series in B. Piano 2 starts with inverted pitch series in retrograde rhythm series in A, and finishes with retrograde notes in original duration series in B. This diagonal exchange of material where pitch series in piano 1 in section A appears in retrograde in piano 2 in B, and inverted pitch series in piano 2 in section A is found in retrograde inversion in B in piano 1, and likewise for duration series. This is what Boulez calls 'X-polyphony'.[149]

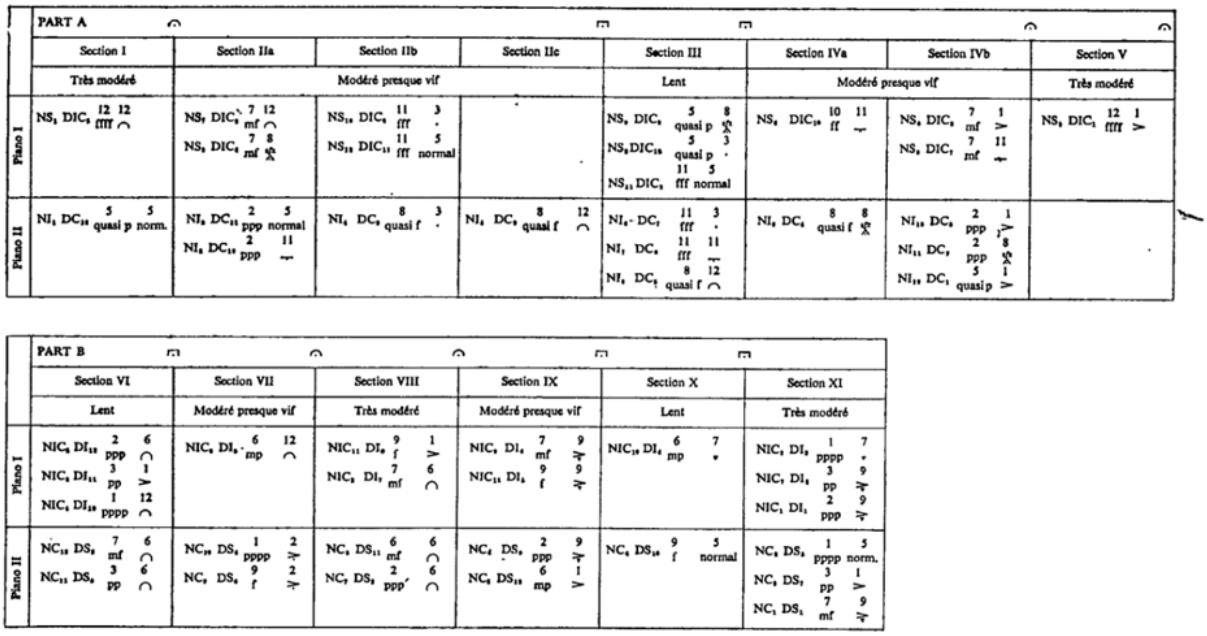

Figure 13: Structure for *Structure Ia*[150]

There is not enough scope here for a full analysis of Boulez's intricate algorithm in *Structure Ia.*[151] In addition to the parameters mentioned above, there are many further compositional decisions, such as the distribution of threads and the tempi of each section, that are determined algorithmically. As such, it may be easy to assume from the very brief analysis thus far that Boulez wrote the piece completely autonomously by only following the rules of

[149] Ibid., 46.
[150] Ibid., 52.
[151] See ibid. for a more detailed analysis of *Structure Ia.*

his algorithm. However, while it is undeniable that Boulez did aim to remain 'faithful' to his algorithm, it would be a misimpression to think that this was how the piece was actually generated. If that were the case, the piece would be reduced to what Ligeti calls a 'pointless transplantation of a system'.[152]

Despite the comprehensiveness of the system, in *Structure Ia*, there is, again, a set of interventions that transformed the maquette into the work. For example, the generation of dynamics, which Boulez already made an explicit effort to serialise differently by using a separate diagonal graph, is pursued less rigidly than it seems. Since dynamic level cannot be perceived or played with exact quantitative precision anyway, the score only roughly indicates the approximate shape of dynamic gestures following the diagonal graph. For instance, in bars 32–39, the second piano is meant to be ***fffff***, but it would be too loud on top of the quasi ***p*** in piano 1. Boulez then intervened by bringing the second piano down to ***fff***, and the bar after from ***fff*** to ***ff*** to retain the contour of the original maquette.

Another, freer intervention is in octave displacement. This is not necessarily a deviation from the system, but Boulez has given himself a small degree of freedom to decide on register intuitively. Upon superimposing rows into threads, Boulez decided to avoid any octave recurrences on the score, meaning that each of the twelve pitches is fixed within a specific register. The sounding result is that repeated notes are frequently heard because the same pitch can only reoccur in the same register. Where there are many rows bundled together within a single section, due to the sheer number of pitch classes that will be repeated there is less freedom of choice in register. Vice versa, there is most registral freedom when only one thread is used, and in that case, any pitch can be placed on any register.[153]

The most significant deviation from the algorithm in *Structure Ia*, as revealed by Ligeti, is in the order of duration series in the broader structure.[154] The duration series is theoretically meant to follow the concept of 'X-Polyphony' with piano 1 starting on the IR duration series, in which the order of rows is governed by a higher order row using IR_1.[155] IR_1 is supposed to consist of 5, 8, 4, 6, 11, 2, 9, 12, 10, 3, 7, 1, but piano 1 in section A has it as 5, 8, 4, 6, 11, 2, 12, 3, 10, 3, 7, 1. This may appear to be a minor mistake on paper, but on the score, this means a whole series, DIR_9, was missing and DIR_3 appeared twice. Since this deviation would hardly make any perceptible difference for the listener, Ligeti believes this

[152] Ibid., 41.
[153] Ibid., 55.
[154] Ibid., 47.
[155] Ibid., 48.

was most likely caused by human error. If the change is inaudible, there would not be any reason for Boulez to make the change that he did.

Boulez's *Structure Ia* is between Cage and Hiller on the spectrum of automaticism. In comparison to Cage, Boulez had a little more agency to intervene on his maquette, but there is less freedom than Hiller because there are more fixed parameters here than in the *Illiac Suite*. To be sure, *Structure Ia* is rigorously algorithmic where the majority of the piece 'writes itself' according to Boulez's rules. For a piece that is this autonomous, it was, again, notable for me to find human agencies in the post-generation stage (such as decision on pitch register, and even the erroneous duration series). Without a detailed understanding of the piece, I would have thought the piece was fully automatic where all decisions could be made in the pre-compositional stage. Hence, I expected the maquette to be used as exactly as the work. In reality, however, the piece is still not quite fully automatic, and these small but significant post-generation decisions make the difference between material and work.

3.3.4 *Clapping Music*

As noted in Chapter 1.4, process pieces tend to be highly autonomous. Once the specific process has been set up, the music generates itself autonomously and there is rarely any room for the composer to intervene on it. The creative freedom mostly lies in the pre-compositional stage, and once this is decided, the process takes a priori status, and the composer is no longer involved in the sounding outcome.

For instance, in *Clapping Music*, once the initial twelve-quaver motif has been pre-composed, the piece 'runs itself' based on the process of phasing. The maquette created by the algorithm is the phasing process of this rhythmic motif itself. I mentioned in Chapter 1.4 that there is theoretically only one way this process can happen, but outside of the process, I crucially overlooked the fact that there can be many ways the same process can be realised in the post-generation stage.

Notwithstanding the autonomy of the maquette, Reich still has to act on it to situate the process as the final musical piece. In the performance notes, Reich specifies that the two players should match their clapping sounds, and that no additional accents should be added apart from the downbeat. This is noteworthy because for a piece that is about its audible process, Reich made an interesting decision to fuse the clapping sounds instead of letting them retain individuality. This is presumably to create ambiguity between the two parts so listeners may hear either rhythms in three groups of four, or four groups of three. These

performance instructions work not against, but around the maquette of the phasing process to encourage a more musical realisation of the maquette. Therefore, contrary to my description of the piece in Chapter 1, *Clapping Music* has not yet achieved full automation. These post-generation decisions are integral to the success of the piece, but they are often overshadowed by the focus on the phasing process in discussions of the piece, at least initially by me.

3.3.5 *Music of Changes* (cont.)

Similarly, I had overlooked the post-generation decisions in my earlier description of *Music of Changes* because I assumed it was as a fully automatic algorithm. While Cage already skewed his algorithm to avoid the need to intervene with the maquette, in the post-generation stage, the maquette depended on further intervention by its performer, David Tudor. In the score, Tudor found the mechanism for tempo changes to be confusing. The problem, as Iddon notes, lies in the notation. 'In essence, what the notation of *Music of Changes* presents is something which is not quite traditional notation, but also not yet time–space notation. The conventional barring structure collides with tempo changes determined parametrically'.[156] Put simply, Cage's notation, confusingly, is written in both time–space and traditional notation. Visually, the piece appears to be in space–time notation. As Cage explains in the performance notes, the score should be played according to spatial relations, where each 4/4 bar should be four subsections of 2.5 centimeters each.[157] However, this became more complicated because the score is also notated with traditional notation with frequent time signature and tempo changes, not to mention its already complex rhythms. The notation is conflicting because the combination of both types of notations '[cause] the temporal meaning of each 2.5 centimeters to be fluid, consistently in motion'.[158]

When asked how the ambiguities on the score should be approached, Cage acknowledged that the notation for *Music of Changes* needed work. He ultimately entrusted Tudor to do what he thinks is right, as long as he 'let[s] it be lively'.[159] With the help of Hans Rademacher, who was Tudor's former piano teacher's husband, who also happened to be a mathematician, Tudor took on the task to calculate the exact seconds, to eight decimal places precision, when each note needs be played in clock time. Rademacher helped Tudor devise two formulae, one for constant speed and the other for the rate of change.[160] This has

[156] Martin Iddon, *John Cage and David Tudor: Correspondence on Interpretation and Performance* (New York, NY: Cambridge University Press, 2013), 37.
[157] Ibid.
[158] Ibid., 38.
[159] John Cage's Letter to David Tudor on 5 August 1951, quoted from Iddon, *John Cage and David Tudor*, 21.
[160] Iddon, *John Cage and David Tudor*, 38.

apparently led to at least a hundred sheets of calculations, which Tudor took to create a 'performance aid' of the piece.[161]

Tudor's performance score has a precise clock time marked on every musical event, which he played with a stopwatch in the performance.[162] Tudor's use of a stopwatch, as he literally watches time over the performance, has made a 'basic' but significant distinction in his experience of the musical time and space of the piece.[163] Having performed part one of *Music of Changes* in a recital that also included Boulez's Second Piano Sonata, Tudor wrote to Cage: 'there is an important difference between it and Boulez: in Boulez the space seems to be in front of one, in one's line of aural vision, as it were; in your piece space is around one, that is, present in a new dimension'.[164]

As it turn out, Cage could only use the maquette directly as the work because he had Tudor who would take the additional step to bring the maquette to life. The maquette itself was unplayable in its original state, revealing a disembodied separation in Cage's approach. By rigidly adhering to his algorithm, Cage has shifted the responsibility of making necessary post-generation decisions onto Tudor.

3.4 Algorithmic Disembodiment

In Chapter 2, I demonstrated that algorithmic music comes in different extents of automaticism, as illustrated in the Boulez-Xenakis-Cage spectrum (figure 10). Within this spectrum, composers can intervene with the maquette in different ways, such as tweaking or deviating. In this chapter, I found that when the algorithm is used autonomously on Cage's side, the pieces necessitate additional decisions that function outside of the maquette. These supplementary decisions typically occur at a later stage, hence I refer to them as post-generation decisions. While these decisions may seem minor and operate in the background, they are the composerly decisions that can significantly influence the final musical work. For example, after generating the maquette for the *Illiac Suite*, Hiller had to curate a selection of materials while intuitively deciding on structure and tempi. In *Structure Ia*, Boulez determines the register of predetermined pitch semi-intuitively, though this only happens when one thread is used. In *Clapping Music*, Reich specifies performers to fuse the parts. Finally, *Music of Changes* only works because David Tudor had done the calculations of

[161] John Halzaepfel, 'Cage and Tudor' in *The Cambridge Companion to John Cage*, ed. by David Nicholl (Cambridge: Cambridge University Press, 2002), 219–39 (173).
[162] Halzaepfel, 225.
[163] David Tudor, 'From Piano to Electronics', *Music and Musicians,* 20 (1972), 24–26 (24).
[164] David Tudor's Draft Letter to John Cage in Late July 1951, quoted from Iddon, *John Cage and David Tudor,* 17.

tempi. Although these pieces are commonly thought to be fully automatic (including, for a long time, by me), they still required these post-generation decisions to transform their maquettes into complete works.[165] Consequently, achieving fully automatic algorithmic music is not only much harder than I thought, but it occurs more rarely than I anticipated.

In the following, I have revised figure 10 to include pieces discussed in this chapter. This represents only my subjective impression of how close these pieces are to being fully automatic. Due to the algorithms being intervened in different ways at various stages of the process, the diagram should only be interpreted loosely.

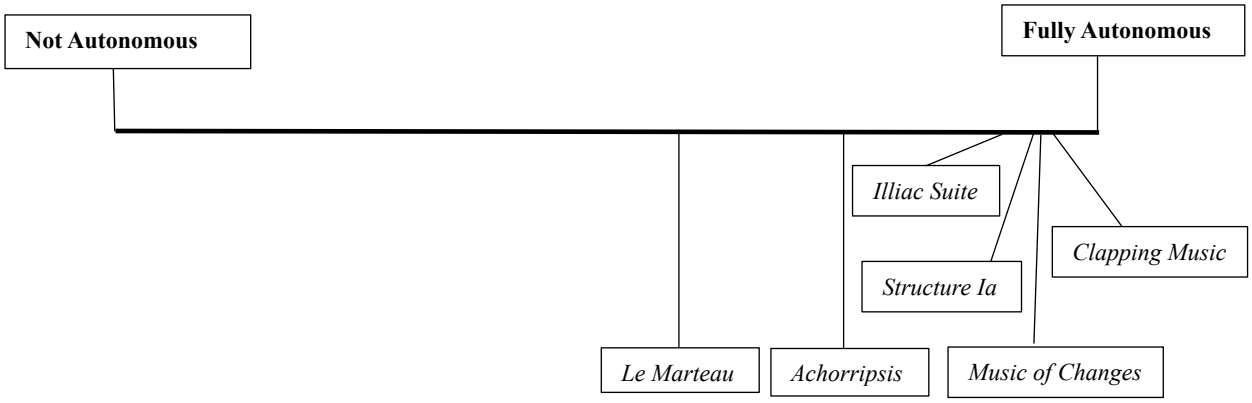

Figure 14: Revised spectrum of automaticism

Hebert Eimert has noted a similar significance of these post-generation results, but with a different terminology. ‘You can’t bring an automation to life with a watering-can’, Eimert explains, ‘this is the nature of the contradiction left behind when one builds a mechanical structure out of notes and then adds “soul” to it’.[166] When a piece is autonomously generated, it is only the maquette that is being generated, or in Eimert’s term a ‘mechanical structure’. It is then necessary for composers to add musicality to the maquette, or as Eimert puts it, to add ‘soul’ to it.

It is interesting to note that Eimert’s holds a dissatisfaction towards maquettes themselves, similar to my sentiment in the CCCS. The fact that maquettes require intervention implies that maquettes cannot become musical pieces themselves, not until the composer has added ‘soul’ to it. When an algorithm is used close to fully automatically (even

[165] Similarly, in response to footnote 7, the automatic processes described in Nils Schlechtriemen's article would still involve the same kinds of composerly decisions in the post-generation stage. Therefore, it is evidently not quite the case that 'machines make music themselves', at least not in the composers I discussed in this chapter.
[166] Hebert Eimert, ‘The Composer’s Freedom of Choice’, *Die Reihe 3*, eds. by Hebert Eimert and Karlheinz Stockhausen, trans. by Bryn Mawr, (London: Universal Edition, 1958), 1–9(6).

though that is rarely the case), there is an expectation for the performer to also adhere to the algorithmic material strictly and perfectly. The problem is if the material is physically impossible to play, performers would then be left in a conflicting position where it becomes implausible to achieve strict algorithmic adherence.

These physical conflicts are not uncommon. For example, Cage's rigid use of the algorithm resulted in the problematic score of *Music of Changes.* The score in itself is problematic and it was ultimately up to Tudor to find his own solution. Similarly, there are confusing ambiguities in *Structure Ia* due to Boulez's adherence to the algorithm. Since the playing techniques and dynamic levels were generated separately, there are sometimes conflicts in playing instructions that are unrealistic to play. For example, in bar 48–56, in piano 2, the dynamic is *ppp, poco*, and then a held *sfz*. Similarly, in bars 73–81, *pppp* is met with accents.[167] The material is physically impossible to play as notated, so these conflicts lead to an ambiguity for the performer to choose how they should be resolved. In *Clapping Music*, the maquette is used directly as the work. But Reich's decision to match clapping sounds, however, consequently implies that the performers' bodies should be hidden under the shadow of the musical process.

In that sense, algorithmic automatism is in tension with its embodiment. In all these cases, the maquette is close to being used directly as the work. However, the notion of explicitly prioritising the maquette seems to imply a problematic negation of the performer's bodies. As in, if the algorithm generates results that are physically impossible to play, there is an undertone that implies it is not the composer's problem to solve. Since algorithmic material is fixed, the composer can only respond with an attitude of 'it is what it is'. This leaves the problem for the performers to deal with themselves, and there is something inherently irresponsible and disembodied about ignoring these physical considerations over algorithmic adherence.

While the composers mentioned in this chapter may not have thought about the problem of algorithmic disembodiment in these exact terms, they have all coincidentally, in one way or another, moved from using algorithms rigidly to a more relaxed approach. For Boulez, after writing *Structure Ia*, his later works, such as *Le Marteau* and *Pli selon pli*, seek to use algorithmic material more expressively, resulting in larger extents of deviations from the maquette. Additionally, his Third Piano Sonata uses open form to let performers decide on how they want to play the material in fixed notation. For Cage, after *Music of Changes*,

[167] Ligeti, 54–55.

Music for Piano 4–19 (1953) and *Concert for Piano and Orchestra* use open scores to notate algorithmically generated materials. For Xenakis, after writing *Achorripsis*, *Duel* uses open form to enable multiple interpretations of fixed material, though Xenakis went back to continue composing using predetermined forms based on mathematical theories after that (with the exception of *Stratégie* (1962) and *Linaia Agon* (1972)). As for Reich, he started embracing a less rigid use of processes in *Music for 18 Musicians* (1974–76) where he used a cycle of eleven chords as a kind of 'pulsating cantus firmus'.[168] This approach in composition has consequently 'opened the door' for Reich to 'further harmonic development in the more than 45 years since'.[169]

In fact, this loosening trend can be observed over many other composers' compositional careers. To name a few, Karel Goeyvaerts, Karlheinz Stockhausen, Mauricio Kagel, and Henri Pousseur have all had phases of multi-serialism to experiment with strict usages of algorithms.[170] For instance, Goeyvaerts's Sonata for Two Pianos (1950–51), Stockhausen's *Kreuzspiel* (1951), Kagel's *String Sextet* (1953) and Pousseur's *Quintette à la mémoire de Webern* (1955). While these works are sometimes conjectured by scholars as automatically written, there are again many levels of decisions and deviations that add 'soul' to the maquette. For instance, there is a certain flexibility within Goeyvaerts's synthetic number to include a range of durations, dynamics, and modes of attack under the same numerical value.[171] Stockhausen's mirroring process of 'pitch crossings' in *Kreuzspiel* is found to be not as rigorous as it seems; only the general shape of the motions is followed, but the serial materials have evidently been acted upon.[172] Kagel has been said to have disregarded the predetermined serial structure in *String Sextet* as he apparently 'invents rows as he goes along, more or less at random'.[173] Pousseur reveals himself that the serial succession of vertical intervals and register distribution are left free to create the 'best "vertical" superimpositions, the best "harmonic fields", the best successive forms, and the best "melodic figures"' in his quintet.[174]

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[168] Programme note in Steve Reich, 'Music for 18 Musicians' (London: Boosey & Hawkes, 1976).
[169] Ibid.
[170] Catherine Nolan, 'Theorising Serialism', in *The Cambridge Companion to Serialism*, ed. by Martin Iddon (New York, NY: Cambridge University Press, 2023), 3–19 (14); Imke Misch, 'The Serial Music of Karlheinz Stockhausen', in *The Cambridge Companion to Serialism*, ed. by Martin Iddon (New York, NY: Cambridge University Press, 2023), 140–54 (144); Björn Heile, *The Music of Mauricio Kagel* (Oxon: Ashgate Publishing, 2006), 13; Mark Delaere, 'Serialism in Western Europe', 216.
[171] Iddon, *New Music at Darmstadt*, 60.
[172] Ibid., 73.
[173] Heile, 21.
[174] Henri Pousseur, 'Outline of a Method', *Die Reihe 3*, ed. by Hebert Eimert and Karlheinz Stockhausen, trans. by Bryn Mawr (London: Universal Edition, 1958), 44–88 (50–51).

Incidentally, perhaps owing to the algorithmic tensions I identified, these composers have all eventually decided to move towards looser usages of their algorithms. Goeyvaerts adopted the use of deterministic open form in *Litanie V* (1982), although such experiments came much later in his career. Stockhausen explored what he calls 'polyvalent form' in *Klavierstück XI* (1956) although he revisited rigid methods from time to time such as in *Gruppen* (1955–57). Kagel wrote an ambitious open form graphic score for two performers on a piano and pre-recorded tape, *Transición II* (1959), using some serial material in certain parts of the structure (more on this piece in Chapter 4.3.2). And finally, Pousseur's *Scambi* (1957) uses combinations of white noise tracks that can be assembled in different ways to generate multiple realisations.[175] This is to say that there is a wider commonality to the issues discussed so far. I chose to focus on composers that I believe illustrate the problem most clearly, but evidently these issues can be extended to include many more algorithmic composers.

To be fair, the algorithm's detachment from the bodily world is not in itself a problem. In fact, it is often the point of these algorithms in the first place. With reference to English experimental music, Michael Parsons writes:

> The use of numerical systems in this kind of music is objective, in the sense that, once the elements to be used in a piece have been chosen, it can give a detachment which makes it possible to find ways of combining them not dependent on aesthetic preference.[176]

This notion resonates with Cage's motivation for using algorithms in *Music of Changes.* As mentioned in Chapter 2.4.2, Cage sought to actively remove himself from the conventions of composition, as he aims for composers to be 'removed from the activities of sounds they make'.[177] In writing the *Illiac Suite*, Hiller also claimed that the piece is not meant to be 'a work of art', but 'a laboratory notebook'.[178] Boulez also attempted to achieve such level of detachment, where he hopes to 'make a clean sweep of one's heritage' by using a radical algorithm in *Structure Ia*.[179] It is also notable that this problem of algorithms being disembodied echoes the passage from 'Alea' that I quoted earlier: 'the individual does not

[175] Christine Wauters, Mark Delaere, and Jef Lysens, 'Karel Goeyvaerts' *Litanie V* for harpsichord and tape or several harpsichords', *Contemporary Music Review*, 19:4,115–27 (118); Misch, 147; Heile, 25; Herman Sabbe, *Het muzikale serialisme als techniek en als denkmethode* (Ghent: Rijksuniversiteit Gent, 1977), 172–76.
[176] Michael Parsons, 'Systems in Art and Music', *The Musical Times,* 117 (1976), 815–818 (816).
[177] Cage, 'Experimental Music', 10.
[178] Hiller and Isaacson, 55.
[179] Boulez, *Conversations*, 56–57.

feel responsible for his work'. This criticism is perhaps not exclusively directed to Cage, but also towards his younger self who created *Structure Ia* autonomously.[180]

Similarly, Klaus Lang embraces this disconnection between himself and his music through using algorithms. As he writes:

> For me, composing is the establishment of a system of connections that leads to the sound building. The sound architecture of a piece of music can stand for itself and no longer requires the ad hoc decisions of me as a composer—the *Deus ex Machina*, so to speak.[181]

Lang comes from the same starting point as me, where he notes that numbers are only 'meaningless compositional means or tools' because of their 'abstract quality'. However, rather than viewing this abstraction as a problem, Lang sees this as a 'liberation of sound'. He writes: 'in this way, the clarity of the form opens up the sensual beauty'.

Lang even goes as far as to reject the implication of personality in music. He argues:

> They [rules] liberate—by concentrating on the craft of composing—from the absurd demand to be compulsively 'authentic' or 'personal'. Mozart is no more authentic than Johan-Georg Lickl, because their musical style is exactly the same. Mozart could simply compose better than Lickl.[182]

While Lang advocates for strict adherence to algorithmic rules, his conclusion that 'composition' is about 'craft' is not far from my discussion. In this chapter, I found that composers often intervened with their algorithms outside of the generative process, working around the maquette. My argument is that these 'composerly' decisions are the most crucial feature of the piece of music, which are in a sense, the same decisions that Lang values in composition as craft.

Laurie Spiegel reflects on her use of algorithms over similar themes. She writes:

> I have most often listened to the output of my logic-based generative algorithms without ever recording it, not feeling it to be "my own music" yet but mere music-like texture. What do I need to do to form the material into my own personal expression, to impress upon it somehow a dramatic form that will infuse it with emotion or to invest it with my own sensuality?

Conspicuously, here, there is, again, a desire to add expression to soulless maquettes. Spiegel's contemplation aligns with my own in Chapter 2, noticing that maquettes are on their own incomplete, and empty. To summarise, while algorithms are sometimes deliberately used to create materials that feel new and detached from conventions, the caveat is that this attitude is, in itself, a disembodied way of composition. In the next chapter, I will attempt to address this implication through my music, to seek for ways to use algorithms in a more embodied manner.

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[180] This sense of distance from the material is reminiscent of the earlier comment on Walshe's *A Late Anthology of Early Music* in Chapter 1.1, where the music was described as 'alien'. I share this sentiment in my processes for *Markov Patterns* and especially *Recursion*, where I did not feel responsible for the work' because I sought to compose by logic.
[181] Lang, 11.
[182] Ibid.

4. Algorithmic Embodiment

Following my argument in Chapter 3 that algorithms are inherently disembodying, I no longer see it as necessary to treat maquettes as the final piece. My compositions in this chapter were all written in my third year, using the same algorithm as *Markov Patterns* and *Recursion*. However, due to this being my attempt at adapting the maquette more flexibily, the sounding results vary noticeably.

Given that my dissatisfaction in *Markov Patterns* and *Recursion* stemmed from my negation of the performer's body, in this next set of pieces, I aim to address the problem by placing a more explicit focus on the performer's body in my realisation of the maquette. My approach is inspired by Kozak's enactivism, which is based on the view that cognition is enactive. Colombetti explains:

> Perception is not a passive effect of an external stimulus, but rather a mutual interaction emerging from skillful bodily activity: as the world solicits certain actions by virtue of the organism's openness to its own milieu, the organism reconfigures the environment by virtue of those solicited actions. The key here is the fact that the organism is motivated to act on the world, to care about its own survival such that the world shows up as a 'correlate of [its] needs and concerns'.[183]

'In other words', Kozak summarises, '[enaction] is an activity described by the interactions between an organism and its environment'.[184]

In Kozak's idea of 'enacted time', composers 'foreground time as a point of concern' by offering 'opportunities to experience the tension between what is familiar and what is not'.[185] He writes:

> Time acquires the potential to surge out of its neutral state as the background of our lives and become an object of listener's attention. A fluctuation, a slippage, a momentary wobble or vibration in temporality knocks it out of balance and perturbs it just enough for the listener to take notice.[186]

Instead of foregrounding time, I aim to adapt Kozak's approach to foreground the performer's body. In my previous pieces, I prioritised the maquette materials to be heard in the performance. The maquette was the main object of attention, while the performer's body operated in a neutral, background state. Following Kozak's approach, I attempt to disrupt this dynamic by enacting new points of interest that originate from the performer themselves. As such, I hope to bring the performer's body 'out of its neutral state', and become the centre of attention.The following discussion will be grouped into three approaches that I explored: 1) open forms, 2) text-based transformations, and 3) the physicality of performance.

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[183] Giovanna Colombetti, *The Feeling Body: Affective Science Meets the Enactive Mind* (Cambridge, MA: MIT Press, 2013), 2, quoted in Kozak, 11.
[184] Kozak, 11.
[185] Ibid., 12.
[186] Ibid.

4.1 Open Form

One way to use algorithms while foregrounding performers' bodies is by using open form, as seen in Boulez's Third Piano Sonata, Xenakis's *Duel*, and Cage's *Concert for Piano and Orchestra*. Boulez's Third Piano Sonata is in an open form whereby the performer has limited control over form and tempo. In 'Alea', Boulez describes the inclusion of chance to have emerged as 'a legitimate desire to construct a sort of labyrinth with several circuits'.[187] To be sure, the materials for the Third Piano Sonata were rigidly and serially predetermined.[188] It is only the order of sequences that is indeterminate, so there is no significant deviation from the maquette. However, it is worth noting that if the algorithmic outcome is still largely intact given its open form, then this freedom is in a way, illusory. The pianist is instructed to find his way through the labyrinth, but from the outset, it is still going to be the same labyrinth with each performance. Nonetheless, Boulez sees these narrow avenues of choice for performers as a way of achieving 'glorification of the interpreter', as opposed to viewing performers as 'an interpreter robot of terrifying precision'.[189] The latter view was perhaps Boulez being ironic and critical of his younger self who wrote music as infamously difficult and deterministic as *Structure Ia*.

4.1.1 *Hineni: Here I am*

Hineni: Here I am (2023) was written in collaboration with a local Leeds poet, Ruth Steinberg, for the Composer-Poet Forum at the Leeds Lieder Festival. It was performed by the duo of soprano Bethan Terry and pianist Francesca Lauri. The brief for this collaboration was that we had to write a song about anyone currently living in Leeds. For the text, we decided to write about Ruth's husband, Len, who was born in Kraków in 1939 and had been a refugee in countries such as Serbia, Israel, and Ukraine before eventually settling in Leeds in 1985. When I first met with Len to hear about his life, despite having lived through the trauma of the Second World War in his childhood, his most vivid memories about being a refugee were in the more day-to-day moments such as spilling soup on a cattle truck and being by the fire in a cold winter in a little cottage. Moreover, Ruth and I found it interesting that Len did not necessarily tell his life story in chronological order, so we decided to incorporate an open form into the structure of our work. Ruth wrote nine haikus that each described Len's fragmented memories, and they can be read in any order. These nine haikus

[187] Boulez, 'Alea', 29.
[188] Losada, 127.
[189] Ibid.

are notated as cards on the score, which the soprano, Terry, then shuffles to create a new order for every performance. The six haikus that are about Len's life before he got to Leeds are recited, and the three haikus about his life in Leeds are sung. The sung cards are notated as recitative with only pitch and text notated. The use of recitative is partly a reference to Len and Ruth's Jewish heritage, but more importantly, it is because of the rhythmic flexibility that it brings. In an open form, depending on the card order and its harmonic relationship with the piano part in the moment, it is sometimes difficult for the singer to find the right pitch at the right time. Having the sung parts as recitatives can give Terry the flexibility to take as much time as she needs to find the right notes to sing, with a rhythm that feels intuitive for her.

The piano part is fixed so that the performance is always around 3'30" in duration (because it was the suggested duration from the brief). I specified that the piece would finish when the piano part finishes, so the pianist and soprano need to be in constant non-verbal communication to be aware of where they are within the piece. Notably, after several rehearsals, as the duo got more familiar with the fixed piano part, this communication became seamless where they would recognise a certain high-pitched chord, or a lower octave note as cues to indicate where they were in the structure. Having this level of familiarity with the piece is convenient because in the performance, Terry could judge if she should speed up or slow down her pace according to the piano part, so they could try to finish together.

The fixed piano part was created by superimposing two versions of the algorithmic outcome. This is because the original algorithmic outcome is harmonically too stable. It could only produce six pitch classes in each section (because of how *Adrift* is), consisting only of E, F#, G#, A, B, and D in the first section. I wanted to explore a more chromatic harmonic language, so I ran the algorithm again and transposed the second outcome up a major third so it had G#, A#, B#, C#, D#, and F#. The two maquettes were then superimposed to consist of ten pitch classes (there are no F and G naturals). That way, the harmonic language is significantly more chromatic than the original, but not overtly so. I then interpreted the maquette loosely to create rhythm and register for the piano part.

In *Hineni*, the performer's freedom of choice is arguably more limited than Boulez's Third Piano Sonata. Form is determined in *Hineni* not by arbitrary decision, but by shuffling the cards so the duo has no control over how the piece will play out. With that said, while the fixed material presents itself in a different order every time, the unpredictability from the reordering draws attention away from the score material, where the focus is on the performer's live reaction in the performance. The maquette is not more embodied because of the open form itself. It is embodied because the open form affords a kind of instability which

requires the duo's bodily musical senses to react. This interaction with the open form is self-evident in the soprano part, but I wanted to make sure the piano part was also actively engaged with the unpredictable order of cards. Therefore, I wrote in the instructions that the pianist should try to respond to the text musically. To be honest, I did not have any specific musical effect in mind, and I would not mind if none of the pianist's responses were noticeable. This instruction was intended to avoid having a piano part that sounds exactly like the maquette, without any expression injected into it. To be sure, the pianist would be interpreting the fixed material subjectively without this instruction anyway, as any human performer would try to do for a conventionally notated score. The purpose of my instruction was to encourage her interpretation more explicitly, and to assure her that the piece does not aim to be an emotionally flat experimental piano piece. Rather, she is welcome to inject expression into the maquette (however small that window of freedom is).

4.1.2 *Lorem Ipsum*

Another way of using open forms can be found in Xenakis's *Duel*. Gibson notes that *Duel* was written to prevent the foreseeable effect of stochastic music that is written deterministically like *Achorripsis*.[190] In *Duel*, Xenakis asked, 'now the question is, when heard a number of times, will this music keep its surprise effect? Will it not change into a set of foreseeable phenomena through the existence of memory, despite the fact that the law of frequencies has been derived from the laws of chance?'[191] *Duel* is for two orchestras, who play a musical game based on game theory where each orchestra's conductor can choose to play from any of the six musical 'tactics' pre-composed by Xenakis.[192] The succession of any two sonic events will produce a score of gain or loss such that eventually, one of the conductors will win.[193] *Duel* is an interesting case of open form where Xenakis has laid down a set of instructions on how to play the game, and the game will unfold differently in each performance. While the notated material within the open form is not necessarily algorithmically generated (see footnote 102), the piece is algorithmic because there is a finite number of possible combinations to play the tactics. It is notable, however, that it is extremely unlikely to have two identical performances because the resulting music depends on the coordination between both conductor's decisions. It is even more unlikely if it is taken

[190] Gibson, 124.
[191] Xenakis, 37.
[192] Gibson, 15
[193] On the use of game theory in Xenakis's music, see Christoph Schmidt, *Komposition und Spiel: zu Iannis Xenakis* (Germany: Studio, 1995), 33–62.

into account that conductors can start and finish any time on the score, as long as each tactic is played for at least ten seconds. Despite the fact that the piece can lead to different sonic results, it is always going to be the same game that is played, using the same material every time.

Lorem Ipsum uses an open form that is similarly inconsistent. The piece is for soprano and live electronics, and it was written for Stephanie Lamprea to be workshopped and premiered at the University of Leeds. The idea for the piece came from an immediate problem that I noted between my algorithm and the call for score—my algorithm can never be fully realised by the solo voice because there are plenty of dyads and chordal material in the maquette (a trait derived from the guitar writing in *Adrift*). This is more or less the same instrumental tension from my algorithm as discussed in Chapter 3.2.3 regarding *Markov Patterns*. In *Lorem Ipsum*, my solution was to use electronics to enable the possibility to include dyads and chords.

For the electronic part, I created a sort of live vocoder based on a mapping system. I pre-recorded samples of Lamprea singing five pitches: A3, C#4, D4, E4, and G4. I then created a Max patch that connects a pitch detection object (~sigmund) to a playback object (~sfplay). The pre-recorded samples are triggered by specific sung pitches. For example, singing A3 triggers the D4 sample, singing A4 triggers G4, B4 triggers E4, D5 and B ♭ 5 both trigger A3. The mapping of these notes was decided based on the possibility to realise the maquette in full. For example, there are many dyads with A and D, so the A3 sample is mapped to a low D for Lamprea's range. However, there are also a lot of dyads between A and G in the maquette. In order to enable the possibility of this dyad too, the higher A is mapped to the G4 sample. That way, Lamprea could control which dyad would appear by choosing the correct register to sing A in.

Consequently, I created the soprano part based on what notes Lamprea needs to sing in order to get all of the right dyads from the maquette. However, I was unconvinced that the piece should be about Lamprea recreating the maquette following my mapping system. After my experience of writing *Markov Patterns* and *Recursion*, I became wary of using the maquette in its raw form. If the piece simply had Lamprea follow along my system, her role as the performer would then be reduced to just an obedient follower of the system.

Since my goal is to foreground her bodily presence, I decided to tune the patch to become slightly 'glitchy' so it is a lot harder to hear the complete maquette. For example, every detected F4 would scramble the original mapping of the algorithm to a new

configuration. The microphone input has its EQ boosted at the pitch detection range, so room noises are also likely to trigger samples. Furthermore, the pitch detection object is set to consider other prominent partials, so for example, A3 is sometimes read as A4, which will lead to a completely different result. In the workshop, it was important for Lamprea and I to test the sensitivity settings in the patch, so I could find the appropriate level of 'glitchy' that is not too unpredictable, yet not too stable.

On the score, the soprano part only has pitch, and a loosely notated rhythm. There is also a second stave that shows the intended Max output so Lamprea is encouraged to try to recreate the original maquette, though it is not always achievable. As such, the idea is that Lamprea would have to attempt to realise the maquette by interacting with the unstable harmonies from the live electronic part. In order to encourage the interaction between Lamprea and the patch, she is allowed to repeat each word for as many times as she wants, as long as it is done 'musically'. That way, Lamprea has more agency to interpret the algorithmic material intuitively, therefore foregrounding her bodily presence in the process.

The piece can technically work without any text, but I thought it would be more idiomatic for the voice to sing in words. The text I chose, 'lorem ipsum', is a filler text that is frequently used as placeholders in web design. The reason for this is because I did not want any baggage of expressive or narrative connotation with my text. Also, it is fitting that for this piece, I was literally looking for a placeholder text to use with my algorithm.

Lorem Ipsum is similar to *Duel* in the way that there is extremely limited material but there are almost infinite ways the piece can unfold. In *Lorem Ipsum*, the electronic part can only play up to six pitches, and there are only three lines in the sung part. The score has to be followed chronologically, so these materials will be sung in the same order in every performance. The only agency that Lamprea has is the freedom to repeat any words. Remarkably, this narrow window of freedom is enough to open up almost infinite ways the piece can unfold due to the unpredictaility of the patch. It is necessary that the patch is not overly glitchy so that Lamprea can still aim for the original maquette. It is also important that Lamprea felt she was in control of the patch in the performance, so that her live reactions with the patch can remain 'musical'. In this piece, it is not Lamprea's decision in the number of repetitions that makes the piece embodied. Rather, it is the unpredictability from the patch that affords Lamprea's live musical response to embody the otherwise soulless maquette.

4.1.3 *Coalescence*

After writing *Music of Changes*, Cage gradually explored more expansive ways of utilising his *I Ching* algorithm rigorously, to create graphic notation such as in *Music for Piano* and *The Ten Thousand Things* (1953–56). This openness is at its zenith in *Concert for Piano and Orchestra*. *Concert* can be played by any number or combination of its instrumental part, with or without a conductor and the piano soloist.[194] The piece is notated in open form and graphic notation, which facilitates new interpretations with every performance, and each performer is given agency to interpret Cage's maquette.

I am inspired by Cage's openness in instrumentation, form, and playing technique, while working with a strict algorithm. *Concert* serves as a point of departure for me, and in *Coalescence* (2023), I aimed to explore this relationship between openness in performance and adherence to the algorithm.

Coalescence, for any five sustaining instruments, was written for a special program, Konzeptmusik, at Impuls Festival 2023. The program, led by Peter Ablinger and Dimitrios Polisoidis, asked for open-instrumentation scores for up to five players, lasting for no longer than ten minutes. The premiere was played by the PPCM Ensemble, which is formed by students studying for a degree in Performance Practice in Contemporary Music at the Kunstuniversität Graz.

As this was the first ensemble piece in my portfolio, my biggest concern was how each performer's presence could be foregrounded individually while still playing together as an ensemble. I was wary of the conventional scenario where ensemble musicians hide their individuality to play as one entity, because I viewed that as a neglection of their physical bodies under the shadow of the ensemble. Therefore, I was inspired by Cage's *Concert* to write open scores that required each performer's individual contribution to work.

I ran the algorithm five times to create five versions of algorithmic outcomes, which I then transposed to begin on A, B, C#, E, and G#. The idea is that each instrumentalist is given their own maquettes, and the maquettes are stacked in the performance to create a cluster of indeterminate sounds. To ensure that these sounds would blend well, performers are instructed to play quietly with whatever pitch-obscuring timbre that is available to the instrument. I provided a suggestive list of such playing techniques in the performance instructions, including air sounds for winds and *sul ponticello* for strings.

[194] Martin Iddon and Philip Thomas, *John Cage's Concert for Piano and Orchestra* (New York, NY: Oxford University Press, 2020), 2.

Since the piece was for open instrumentation, and considering that not every instrument can play dyads, I broke up dyads in the material into single notes to accommodate monophonic instruments. Additionally, I wrote in the instruction that each pitch can be played in any register to account for the open instrumentation. On the score, each player is given a pitch sequence to play, where the technique, register, and duration are indeterminate. The players are instructed to spread out the pace of the notes to finish at the ten-minute mark. Notes do not have to be played in succession, nor do they need to convey a continuous line. As long as these conditions are met, the interpretation of how these notes are played is entirely up to the performer. In that sense, the score functions quite similarly to *Music for Piano*, where only pitch is notated, and durations are only given in approximation. There are similar kinds of notations found in *Concert*.

While performers play their own maquettes using a technique of their choice and at their own pace, I explicitly asked the ensemble to avoid changing notes simultaneously. This encourages instrumentalists to listen attentively to one another, and make real-time decisions based on the live performance. As a result, these non-verbally communicated decisions in timbre and duration have led to surprising voice leadings and harmonies. While each individual is playing rather limited materials from the algorithm, the humanly unpredictability in the process is a crucial part of embodying the work. The title 'Coalescence' refers to the fact that all five performing bodies are interpreting their maquettes in their own ways, yet, collectively, they produce a blended cloud of sounds that is interconnected by each musician's intuition.

To be sure, *Coalescence* is not technically in open-form. The indeterminacy lies in the instrumentation, playing technique, and duration, but the horizontal order of notes remains constant. The form is only indeterminate in the sense that the surface level pitch, as in the accumulation of five maquettes, varies in pace each time to create new vertical alignments of notes in every performance. In *Coalescence*, the maquette is not embodied due to this surface level variety. Hearing the maquette is no longer the priority in this piece. The maquette serves as a guide in the background to enable a foregrounded chain of non-verbal correspondences among musicians. The maquette's embodiment is afforded by this web of musical communications, and I see the resulting harmony is a by-product of these interactions.

4.2 Text-based Transformation

In Chapter 1.3, I briefly mentioned Adorno's criticism in 'The Aging of the New Music'. To reiterate, Adorno criticised the group of young composers of the 1950s for 'attempting to eliminate compositional freedom', and to 'replace it with rigid determinacy'.[195] While I noted in Chapter 1.3 that the article was likely aimed at Goeyvaerts, Luigi Nono seems to be collaterally inescapable from Adorno's accusation.[196] Nono's name was, at least, explicitly noted in a later 1955 article where Adorno assumed Nono was part of a group of composers who held that 'objective construction must encompass all elements mathematically'.[197]

Adorno's critique, stemming from the lack of distinction in algorithmic technique explained in Chapter 1, addresses the same lack of human element in serial algorithmic music that I noted in Chapter 3. However, as Iddon argues, this kind of inhuman serial music 'could hardly be attributed to either Nono or Maderna' because 'it was precisely the "human element" that Nono had sought to highlight directly *against* "process-driven" composition'.[198] In fact, among the Darmstadt school, Nono was the most vocal in rejecting the autonomous use of algorithms to compose. Nono writes,

> [a]dherence to a schematic principle, be it of a scientific or mathematical nature, has never breathed life into an artwork; only the dialectical synthesis between a principle and its implementation in history achieves this, which is to say its individuation in a particular moment, neither earlier, nor later.[199]

Nono's remark resonates with my discussion so far where autonomous algorithms will usually lead to just a maquette, which Nono corroborates, is 'on its own useless'. In my thesis, I have focused on the pre- and post- generation decisions to turn material into work. Similarly, Nono describes his approach in three stages in an interview in 1969:

> I can only agree with the 'serialist' label with some reservations. Even back then I did not write what critics would call 'integrally organised music'. I used to work, so to speak, in three stages. First of all, I would choose the material intervallic, timbral, rhythmic. Then I would experiment with this material, perhaps I would subject it to different predetermining processes, but only so that I could see the direction towards which it could develop. And I would compose, that is I would deduce an appropriate form from the material and the possibilities inscribed in it. For me, composing was never about the concretisation of predetermined structures. Improvisational elements were always at play; I would leave decisions open until up to the last moment.[200]

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[195] Jonathan Impett, *Routledge Handbook to Luigi Nono and Musical Thought* (New York, NY: Routledge, 2019), 141.
[196] Ibid., 142.
[197] Ibid.
[198] Iddon, *New Music at Darmstadt*, 115; It is worth noting that Nono's term of 'process-driven compositions' here is different from what I categorised as process-based algorithmic in Chapter 1. Nono uses the term to refer to any compositions written based on predetermined procedures, while I use the term to refer to the specific unfolding of a musical process, i.e. *Clapping Music.*
[199] Ibid., 257.
[200] Angela Ida De Benedictis and Veniero Rizzardi, 'Luigi Nono and the Development of Serial Technique', in *The Cambridge Companion to Serialism*, ed. by Martin Iddon (New York, NY: Cambridge University Press, 2023),154–81, (168–69).

It might come as a surprise, even to scholars, that Nono does not consider himself a multi-serialist. Instead, he seeks to gather a 'feel' for the material to envision its development before working on it semi-intuitively. Many scholars have overlooked this crucially intuitive step in Nono's procedure, and assumed that pieces such as *Il canto sospeso* were conceived exclusively through mathematical procedure. For example, Reginald Smith Brindle writes: 'construction is in the essence of Nono's nature… Composition means for him the controlling and placing of every smallest element in a musical design according to a pre-conceived plan'.[201] Similarly, Hebert Eimert has described *Il canto sospeso* as 'the first purely structural music that Nono has written'.[202] Even Heinz-Klaus Metzger, who refuted Adorno's criticism in 'the Aging of the New Music', misunderstood Nono. Metzger's defence of multi-serialism excluded Nono, describing him as 'stagnant', and 'without a sense of history', thereby justifying Adorno's critique of this technique. '*Il canto sospeso'*, Metzger writes, is 'perhaps the most impressive' of Nono's serial works.[203]

Conversely, other scholars have challenged this view. Jonathan Impett argues that Smith Brindle's interpretation has 'utterly misread Nono's relationship with the stuff of his art'.[204] Having studied the sketches of *Il canto sospeso,* Carol Nielinger affirms that Nono was rigorous in his serial method, but the work itself is extremely 'moving and expressive'.[205] In response to these accusations, Nono writes:

> '[p]erhaps the superficial effect of *Il canto sospeso* was determined, at least in part, typically by an ideological reading. Not so much from listening to the music. The texts, those fragments of letters, have favoured the "easy ideology", the impossibility of analysis'.[206]

In *Il canto sospeso*, for three soloists, choir and large orchestra, Nono uses text beyond the function of lyrics, where the text's semantic and structural significance are integral to the algorithm.[207] The text that Nono chose is from the final letters of Italian resistance members before they were executed. In order to explain the structural function of the text, it would be necessary to begin from the lower-level serial material.

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[201] Reginald Smith Brindle, 'Current Chronicle: Italy', *The Musical Quarterly*, 47, 2 (1961) 247–55 (248).
[202] Impett, 123–24.
[203] Heinz-Klaus Metzger, 'Das Altern der jüngsten Musik' in *Musik wozu: Literatur zu Noten* (Frankfurt am Main: Suhrkamp, 1980), 113–28 (120–21), quoted in Carola Nielinger-Vakil, *Luigi Nono: A Composer in Context* (Cambridge: Cambridge University Press, 2015), 29.
[204] Impett, 124.
[205] Carola Nielinger, 'The Song Unsung: Luigi Nono's "Il canto sospeso"', *Journal of the Royal Musical Association*, 131, 1(2006), 83–150 (136).
[206] Luigi Nono, Interview with Enzo Restango, 1987, *LNII*, 511, quoted in Impett, 124.
[207] It is worth noting that serial composers have often used text to generate musical material. Nono's *Il canto sospeso* is cited here due to its sensitive treatment of textual material, and its direct influence on my music discussed in this chapter. Other notable examples of pieces using text include Stockhausen's *Gesang der Junglinge im Feuerofen* (1956), Maderna's *Invenzioni su una voce* (1960), and Boulez's *Pli Selon Pli.*

In general, *Il canto sospeso* makes use of the following all-interval series. Unlike the typical way of using tone rows, Impett notes that the series in *Il canto sospeso* had a different function:

> The all-interval series is a background, a musical-linguistic environment or perceptual generator, not a starting point. It is used more akin to that of tonality than theme, it generates horizon or perspective, its interval relationships permeate every surface and its internal dynamics propel the music to constant forward motion.[208]

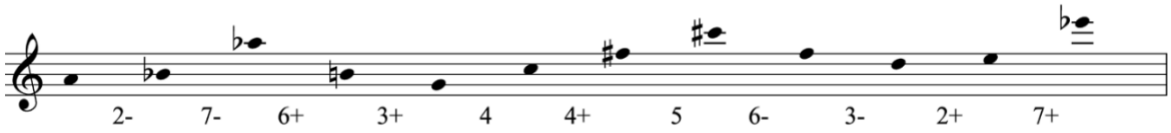

Figure 15: All interval series in Il canto sospeso[209]

Il canto sospeso consists of nine movements, which can be divided into three parts. The instrumentation of which is distributed across movements in the way shown in figure 16. The beginning (movements 1, 2) and the end (movements 8, 9) are identical. The five movements in the centre (movements 3 to 7) form a palindrome around the centre of the fifth movement.

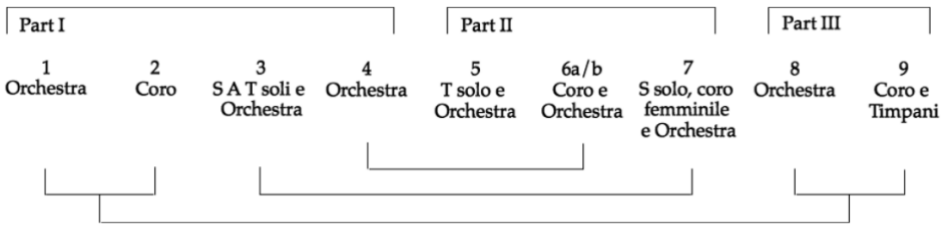

Figure 16: Overall structure in Il canto sospeso[210]

In the second movement, which is for chorus only, the all-interval series from figure 15 is seen repeated nineteen times, always in its complete and original form.[211] The movement is fifty bars long with 2/4 metre in each bar. There are 100 crotchet beats, which are used as 100 tiles for sounds to be placed on. The duration value is governed by a higher order palindromic Fibonacci sequence: 1-2-3-5-8-13-13-8-5-3-2-1. The series is rotated fifteen times in the first section with the first number shifting to the last every cycle (figure 17). Notably, the last two numbers in the rows are swapped, and the series stops rotating for the second section.

Likewise, dynamics follow a similar serial procedure of twelve dynamic levels: *ppp*, *p*, *mp*, *mf*, *f*, *ppp*, *ppp<f*, *f>ppp*, *ppp<mf*, *mf>ppp*, *p<f*, *f>p*.[212] These parameters are then

[208] Ibid., 125.
[209] Ibid.
[210] Ibid., 126.
[211] Ibid., 135.
[212] Ibid.

integrated into four planes, or 'timelines' of different duration values from quavers to the quintuplet semiquavers. Once pitches are combined with duration and dynamics, they are extended, or tied in a way such that there are no gaps across the four timelines throughout the piece.

	A	B♭	A♭	B	G	C	F♯	C♯	F	D	E	E♭
I	1	2	3	5	8	13	13	8	5	3	2	1
II	2	3	5	8	13	13	8	5	3	2	1	1
III	3	5	8	13	13	8	5	3	2	1	1	2
IV	5	8	13	13	8	5	3	2	1	1	2	3
V	8	13	13	8	5	3	2	1	1	2	3	5
VI	13	13	8	5	3	2	1	1	2	3	5	8
VII	13	8	5	3	2	1	1	2	3	5	8	13
VIII	8	5	3	2	1	1	2	3	5	8	13	13
IX	5	3	2	1	1	2	3	5	8	13	13	8
X	3	2	1	1	2	3	5	8	13	13	8	5
XI	2	1	1	2	3	5	8	13	13	8	5	3
XII	1	1	2	3	5	8	13	13	8	5	[3]2	[2]3
XIII	2	3	5	8	13	13	8	5	3	2	1	1
XIV	3	5	8	13	13	8	5	3	2	1	1	2
XV	5	8	13	13	8	5	3	2	1	1	2	3
XVI XIX	13 8 5 3 2 1 1 2 3 5 8 13 (once for each duration value)											

Figure 17: The pitch series combined with Fibonacci duration row[213]

The maquette at this stage might feel neutral for a serial grid.[214] The second part of the movement deviates from this system and instead, Nono builds a 'proportional canon' in which the Fibonacci duration series is placed from the longest to the shortest, then backwards.

The maquette from the first section is meant to function as a background row, where there is a higher-level row driven by the text (figure 18). After establishing the background row, Nono distributes text across voices and register at his own will. Generally, the text is scarcely distributed and 'floats' between registers in the first part, and it is more densely situated in the second part. The distribution of parts and is determined by the structure of the text (figure 18), where the second 'Muoio' is when the second section starts. The rotation method from the first section (figure 17) is also mapped here where rotations I–VIII

[213] Ibid., 174.
[214] Ibid., 176.

correspond to the first sentence, rotations IX–XV to the second, and the four final rotations of XVI–XIX to the coda.

> **Muoio** per un mondo che splenderà con luce tanto forte con tale bellezza,
> che il mio stesso sacrificio non è nulla.
> (Per) esso sono morti milioni di uomini sulle barricate e in guerra.
> **Muoio** per la giustizia.
> Le nostre idee vinceranno.

Figure 18: Text in second movement of Il canto sospeso[215]

The musical structures in the rest of the work are dependent on the text material. For example, Nono handpicks specific words that he can decide to repeat either in succession, in an overlapping manner, or placed apart from each other. Nono evidently chose words that have stronger semantic value and more pertinent vowel sounds (omitting function words such as 'the', 'for'). Every vowel is used in place of the word in the assigned moment. Rizzardi notes that when Nono works 'freehand' in distributing voices, registers, and durations, he tends to adopt Renaissance madrigal devices such as word painting.[216]

Finally, unlike any other composers discussed so far, Nono does not seem to follow the same narrative where he would loosen up his rigid method after trying an automatically serial approach, perhaps because his method in itself is already quite intuitive. It is worth noting that Nono's approach is unique in the position where his decisions occur. Nono's interventions happen as he works on the generative process, so they come in earlier than the post-generation stage, but later than the pre-generation stage. Therefore, Nono's algorithm is semi-autonomous, placing him in the middle of the Cage-Boulez spectrum, near where Xenakis is. Though as I have shown, Nono's method of intervention is uniquely between the line of quasi-systematic and expressive.

In works after *Il canto sospeso*, Nono continued to try new serial techniques based on the voice and its texts, such as in *Cori di Didoni* (1958) and *Sarà dolce tacere* (1960). Rather than categorise Nono's different serial works based on a timeline, Ida De Benedictis and Veniero Rizzardi suggest a kind of 'bipartition' based on Nono's different serial techniques that derived from text.[217] They note that *Il canto sospeso* is a representative example of Nono's 'new expressiveness in the song', where his selected texts provide the structural

[215] Ibid.
[216] Angela Ida De Benedictis and Veniero Rizzardi, 178.
[217] Ibid.

material to determine the choice of basic 'fields'.[218] Aside from the semantic meaning of the text, the text's formal subdivisions of single words to the number of syllables and vowels, 'regulate durations, speed, intervals, density, and every other parameter'.[219]

In *Il canto sospeso*, Nono has demonstrated a second way to use algorithms both intuitively and rigorously. To many, *Il canto sospeso* is seen as a counterexample of Adorno's critique, because it effectively deals with the very concerns that Adorno raised, of expression, tradition, and meaning.[220] In fact, Adorno has been found praising Nono in a positive light in 1958. He said, 'Nono's *Canto sospeso* is valid, healthy music, despite its "expression" of the terrible, of the massacre of resistance fighters. Furthermore, it is humane music'.[221] The three pieces to be discussed in this section follows this approach where an additional higher-level row based on text material will be used according to the 'feel' of the algorithm.

4.2.1 *Patina*

Patina (2023), for solo piano, was written for Siwan Rhys in another call for scores at the University of Leeds. Recalling the enactive approach from the beginning of this chapter, I struggled with this piece to enact points of interest that could foreground the performer's body. In earlier pieces such as *Lorem Ipsum* and *Coalescence*, my ideas always began with a physical incompatibility in the instrumentation. For instance, in *Lorem Ipsum*, the issue was that the voice cannot produce dyads. In *Coalesence*, the indeterminacies were implemented to tackle the challenge of writing for an ensemble with open instrumentation. These limitations have pushed me to reframe the maquette creatively, and I was able to situate these problems into musical challenges that foregrounded the performers' bodies, bringing them out of their unproblematic background state.

For this piece, however, the problem was that the piano was too 'unproblematic' to write for. I was unsure where to start because the piano is perfectly capable of playing the maquette in its raw form. I have had to look elsewhere for a source of transformation.

Just before writing *Patina*, I wrote a Cantonese choral piece for a call for scores in Hong Kong. I originally planned on using the algorithm for the call, as I imagined the suspended chords in quasi-tonal harmony would work well for the kind of choral piece I had in mind. However, as I began setting text to the algorithm, I realised that the Cantonese language is incompatible with the algorithm. This is because Cantonese is a tonal language,

[218] Ibid.
[219] Ibid.
[220] Impett, 142.
[221] Ibid,, 143.

where the meaning of each word changes depending on the pitch of its pronunciation. Hence, it was incredibly difficult to set text to my maquette. With pitch predetermined, the melodic contour of my maquette would drastically alter the meaning of the text I was setting to. Not to mention, some characters are pronounced with pitch shifts, making my maquette even less compatible with the language.[222] I eventually gave up on using the algorithm for the choral piece, and my piece did not get selected anyway. The piece is called *Phototaxis* (2022), and it is included in the appendix.

In *Patina*, I wanted to explore this tension between my maquette and Cantonese intonations. It struck me that I could make use of this incompatibility to introduce chromatic movements in the algorithmic material. To do so, I mapped the maquette to a Tang Dynasty (420–589 AD) poem which is about the story of Mulan. The reason is essentially arbitrary. It is simply because this poem is a classic that I can recite by heart. The following is an excerpt from the first stanza, and I ended up only using two stanzas of the poem. The Cantonese phonetic spelling is written under each line, and an English translation is provided below.[223]

唧唧復唧唧	木蘭當戶織
zit1 zit1 fuk6 zit1 zit1	muk6 laan4 dong1 wu6 zik1
不聞機杼聲	惟聞女嘆息
bat1 man4 gei1 cyu5 sing1	wai4 man4 neoi5 taan3 sik1
問女何所思	問女何所憶
man6 neoi5 ho4 so2 si1	man6 neoi5 ho4 so2 jik1
女亦無所思	女亦無所憶
neoi5 jik6 mou4 so2 si1	neoi5 jik6 mou4 so2 jik1

A sigh, a sigh, and then again a sigh —
Mulan was sitting at the door and weaving.
One did not hear the sound of loom and shuttle,
One only heard her heave these heavy sighs.
When she was asked the object of her love,
When she was asked who occupied her thoughts,
She did not have a man she was in love with,
There was no boy who occupied her thoughts.

[222] Incidentally, the organiser for this Cantonese call for choral scores, Dr. Kai Young Chan, specialises in algorithmic composition based on the intonation of the Cantonese language. There are interesting commonalities between our research, though his algorithm produces melodies directly from the input text, which he then builds into pieces. See Kai Young Chan, 'From Constraints to Creativity: Musical Inventions through Cantonese Contours in Hong Kong Contemporary Music', *Principles of Music Composing*, 21 (2021), 41–59.
[223] Shiamin Kwa and Wilt L. Idema, ed. and trans., *Mulan: Five Versions of a Classic Chinese Legend with Related Texts* (Indianapolis, IN: Hackett Publishing Company, 2010), 1.

In total, there are six tones in the Cantonese language. The numbers beside the phonetic spelling indicate the tone for each syllable. The contour of these tones is represented in figure 19. Tone 1 is a high-pitched, flat, sustained tone, while tones 2, 4, and 5 involve pitch shifts to varying extents upwards or downwards. Tones 3 and 6 are flat tones at lower pitches.

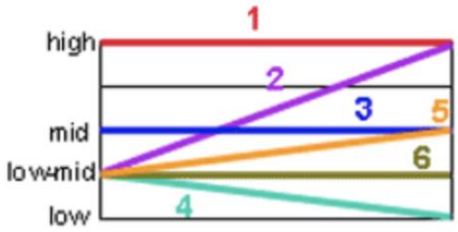

Figure 19: The six tones of the Cantonese language[224]

In the poem, every clause has five words, and in Cantonese, words are always monosyllabic. However, I chose to disregard the grouping of five-word phrases because it created a rhythm that felt too uniform for my taste.

The mapping process follows a simple 'if… else…' model, where if the algorithmic pitch (in any register) works with the text, it gets used. If the pitch fits but the tone of the word involves a pitch shift (tones 2, 4, 5 or if there are two vowels), then a new note that approximates the shift will be added. If the pitch does not fit, then its pitch class is used as a harmony note, and the next note is considered. This process repeats until a suitable pitch is found, and it may result in a dense chord if many notes are needed to find a match.

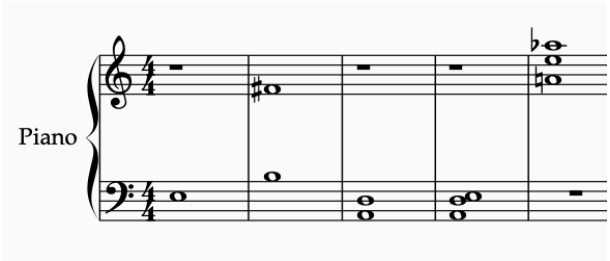

Figure 20: Algorithmically generated material for *Patina*

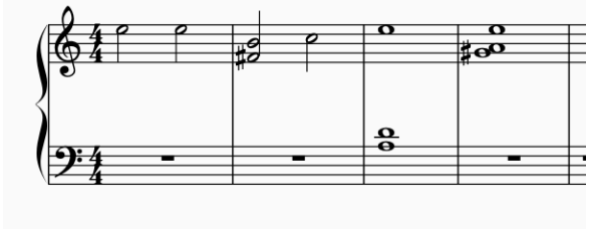

Figure 21: First line mapped onto the algorithmic material

[224] 'Tones', *Learn Cantonese*, n.d. <https://cantonese.ca/tones.php> [accessed 4 June 2024].

For example, the first two words of the poem are the same word, in tone 1, so I moved E up an octave to match their intonation. The subsequent word has a downward tone (6), for which a downward perfect fourth leap to a B would be more suitable than the F# a minor seventh lower. Hence, the dyad is inverted to reflect this shape. Although the intonation is technically a flat tone, I raised it by a semitone to C natural because it is typically recited with a slight raise for expression. This change is reflected in bar 2 of figure 21.

The fourth and fifth words are the same as the first two, In tone 1, so the only note that would fit is the E. Since there is no E in the chord in the third bar of figure 20, the D and A are kept as harmony notes. E appears in the fourth bar, so in bar 3 of figure 21, these notes are used with E brought up an octave to match the tone controur of the text. The next E is found in bar 4 of figure 21, so its register is adjusted to fit the contour of the text.

The poem follows a rhyme scheme where every line ends with tone 1, which is typical of classical poetry. It is interesting to observe that this rhyme scheme is reflected in the transformation process, where every fifth note goes back to a high note. This pattern leads to a five-note motif that mostly ended on the high E, which I personally found to be too uniform to use. Consequently, I further adjusted the register intuitively to obscure this repetition. Additionally, the poem predominantly features non-shifting tones 1, 3, and 6—a characteristic of older Chinese poems—resulting in an outcome that was less chromatic than I was hoping for. The algorithmic outcome in the form of figure 21 was still too dry and uniform for my liking. There is a notable parallel between this process and in *Recursion,* where in both cases, I defaulted to intervening with a logical system, only to end up dissatisfied with the material. Therefore, I decided to deviate further to break up the dyads to create voice leadings that are free to be interpreted by the performer. The result is shown in figure 22.

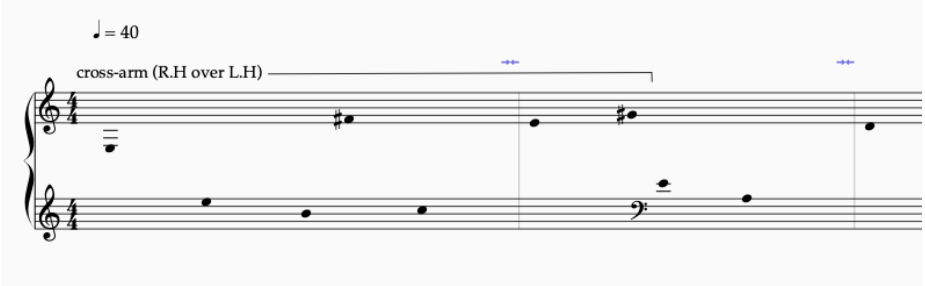

Figure 22: First line in *Patina*

After the text-inspired transformation, I continued to seek ways to foreground the performer's body. In *Patina*, I distributed the generated chords into two horizontal voices, allowing the pianist, Siwan Rhys, to interpret phrasing and voice leading freely. Noteheads are scattered across the score, with duration represented roughly spatially. Rhys is instructed to play as legato as possible while maintaining individuality in the voices of each hand. To foreground her attempt to maintain individuality, I introduced more challenging sections, such as on the last page where hands overlap in the lower register, making it harder to maintain distinctive voices.

For the same reason I used 'Lorem Ipsum' in the vocal piece, I did not want any programmatic connotations of the text in my music. Hence, the source of the text is deliberately hidden from Rhys. I wanted to prevent any interpretation that would resemble the imagery of ancient China, or one that tries to tell the story of Mulan.

The title 'Patina' refers to the ancient text that is used in the piece, without giving away where the text is from. The title also refers to the work's compositional process where the initial maquette has been generated by the computer, and it is up to the composer and performer to add a thin layer of 'musical touches' to polish off the otherwise lifeless, unidiomatic materials. Since dynamics, phrase markings, and how the voices interact are left open in the notation, Rhys is encouraged to play with her own interpretation of what feels most 'natural' or 'idiomatic' for her. In that sense, the title Patina also refers to this kind of organic transformation of material through time, similar to the unexpected yet distinctive beauty of the patina formed on aged, weathered metal.

During the workshop with Rhys, while playability was not an issue, the interpretation was. Given that I left some aspects of the score open to interpretation, naturally, she wanted to learn more about my intentions to help her with the interpretation.

On the score, I specified that the piece should be played expressively and with legato, so Rhys asked me what kind of expressiveness I was looking for. This question caught me by surprise, as this was a decision I expected Rhys to make based on the notation I provided. In creating an indeterminate score, I had not anticipated to be held responsible for decisions that I left open. This oversight reveals that I held the same issue from Chapter 2, where I was hesitant to choose.

Apart from my reluctance to choose, part of the problem was that there was not enough information on the score for Rhys to interpret effectively. With the origin of the text obscured, and no expression marking written, there are not many clues on the score to guide Rhys through her interpretation.

To address this, during the workshop, we experimented with various levels of expression for the piece. One version emphasised legato explicitly, almost in a Schoenbergian style, while the other version adopted a more experimental and emotion-less approach. There was also a third version that was somewhere in between. Despite there were significant differences in the sounding outcome, truthfully, I had no strong preference among them. Ultimately, I selected the middle version for the premiere, but I would be open to hearing alternative interpretations in subsequent performances of the piece.

With that in mind, following the workshop and before the premiere, I revised the score and incorporated several keywords from the poem. These words were placed at the beginning of systems arbitrarily. I deliberately selected words that did not give away the origin of the text. Notably, although I only chose ambiguous words, they significantly influenced Rhys's experience of playing the piece. She interpreted the placement of these words as sections of the piece, and the text provided her with a clear idea to explore the material on. To my surprise, the inclusion of the text did not result in the piece feeling overly emotional. This experience led me to reconsider my relationship with expression in music, where it is starting to feel less unwelcomed in my music.

It is noteworthy that the inclusion of the fragmented text, though ambiguous in meaning, helped encourage the embodiment of the material. To be sure, I am not asking for the performer to interpret the texts explicitly. Rather, the texts operate quietly in the background and only affect the Rhys's playing in subconscious but intuitive ways.

4.2.2 *Cho1Ha6*

On several occasions, Stockhausen expressed dissatisfaction towards Nono's intuitive use of serial structures. For example, in a letter to Nono in 1952, he criticised Nono for 'resorting to subjectivity' and relying on 'predetermined expressive content'.[225]

Stockhausen's criticisms eventually moved from a personal medium to a public one, when he delivered the lecture titled 'Sprache und Musik' at Darmstadt in 1957. The target of the lecture was precisely the second movement of *Il canto sospeso*. In brief, Stockhausen and Nono mostly disagreed on the function and significance of text. Stockhausen writes:

> In certain movements of the *Canto*, Nono composes the text as if he wanted to withdraw its meaning from a public view, in which it does not belong. The texts have moved the composer deeply; it is not only on musical grounds that he wishes to set them. In parts II, VI, and IX, and in some sections of part III too, he makes sounds, or noises, from language. He does not allow the texts to be declaimed, but rather places them in such an indiscriminately

[225] Angela Ida De Benedictis and Veniero Rizzardi, 169.

> strict and dense musical form that one can no longer understand anything of them when listening. Why, then, texts at all, and why these in particular?[226]

In response, Nono writes in 'Text—Music—Song':

> The message of those letters of people condemned to death is carved in my heart as it is in the hearts of all those who see in these letters documents of love, of conscious choice and responsibility toward life, and as an example of the spirit of sacrifice and resistance against Nazism, that monster of irrationalism, which attempted to destroy reason… The question of why a particular text and not another has been chosen for a particular composition is no more intelligent than the question of why, in order to utter the word *stupid*, one uses the specific letters *s-t-u-p-i-d*.[227]

Whittall notes that *Il canto sospeso*, and Nono's approach in general, is a 'rare occasion' where an integrally serial composer (despite Nono's rejection of the term) chooses an emotive subject rather than pursuing a structural process.[228] In turn, Nono demonstrates an 'eloquent treatment of texts', which in this case, is taken from Italian wartime resistance.[229] By that, Whittall means that Nono uses these texts as a starting point for the selection of musical materials. For example, the structure comes intrinsically from the text, such that subdivisions, verses, words, syllables, and vowels, are used to determine 'fields' that govern musical parameters such as tempo, durations, and intervals.

From writing *Patina*, I came to appreciate the importance of choosing the right text source. The problem with *Patina*, for me, was that the text had too many recurring first tones, resulting in materials that were too uniform to use. Therefore, rather than arbitrarily choosing a traditional poem, for my next piece, *Cho1Ha6* (2023), I was a lot pickier in my text choice .

Cho1Ha6, for solo flute, was written to a commission from Gey Teal Music, who are a group of Hong Kong students based in Manchester. The commission specifically asked the piece to be about the transition between spring and summer, because their concert is programmed to be about the seasons and my piece would be played as an interlude in the middle of the first half. I would normally avoid programmatic descriptions as such in my music, but since the brief calls for it, I tried to look for a poem that matched the theme of the commission.

During my search for a Cantonese poem, and drawing from my experience with *Patina*, I sought a poem that did not adhere to a uniform phrase structure. Additionally, I

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[226] Iddon, *New Music at Darmstadt*, 150.
[227] Luigi Nono, 'Text—Music—Song', in *Nostalgia for the Future: Luigi Nono's Selected Writings and Interviews*, ed. by Angela Ida De Benedictis and Veniero Rizzardi (Oakland, CA: University of California Press, 2018), 153–78 (177).
[228] Arnold Whittall, 'Serialism in History and Criticism', in *The Cambridge Companion to Serialism*, ed. by Martin Iddon (Cambridge: Cambridge University Press, 2023), 37–53 (47).
[229] Ibid.

wanted the poem to utilise a broader range of tones and consonants, to avoid encountering the same abundance of first tones in *Patina*.

After browsing extensively online, I chose a Song Dynasty poem with the same name, which translates to 'Early Summer'. The text, along with its phonetic spelling and English translation is as below:

阮郎歸 · 初夏　　蘇軾

yun2 long4 gwai1 · cho1 ha6

綠槐高柳咽新蟬，　　薰風初入弦。

luk6 waai4 gou1 lau5 yin1 san1 sim4,　fan1 fung1 cho1 yap6 yin4.

碧紗窗下水沈煙，　　棋聲驚晝眠。

bik1 sa1 chueng1 ha6 seui2 cham4 yin1,　kei4 seng1 ging1 jau3 min4.

微雨過，小荷翻，　　榴花開欲然。

mei4 yu5 gwo3, siu2 ho4 faan1,　lau4 fa1 hoi1 yuk6 yin4.

玉盆纖手弄清泉，　　瓊珠碎卻圓。

yuk6 pun4 chim1 sau2 lung6 ching1 chyun4,　king4 jyu1 seui3 keuk3 yun4

Ruan Langgui Early Summer[230]

By Su Shi

Green locust trees and tall willows pharynx new cicadas,
and the scented wind enters the strings for the first time.
The green screen window sinks into the water and smoke,
and the sound of chess startles the day sleepers.
After the light rain, the little lotus turns over,
and the pomegranate blossoms are about to bloom.
The jade basin clears the spring with slender hands,
and the Qiongzhu is broken but round.

The structure of the piece is derived from the proportions of the phrase structure found in the poem. Following the typical format of Song Dynasty poetry, the text uses a syllable subdivision of 7+5+7+5+3+3+5+7+5. I decided that each syllable would be worth five seconds, and created a time-space notation where each phrase is a system on the score following this proportion. The first system with seven words is worth 35 seconds, followed by a quicker system of 25 seconds (five words), then 35, 25, 15, 15, 25, 35, and 25.

[230] 'A poem by Su Shi', *Inews*, n.d. <https://inf.news/en/culture/4491609eb50e4c8da8cdcc9b46f66c29.html> [accessed 10 June 2023].

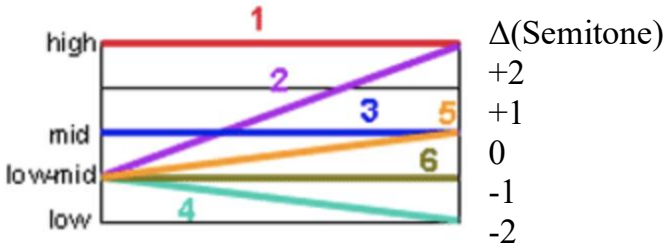

Figure 23: Pitch transformation in *Cho1Ha6*

As with *Patina,* the pitch material in *Cho1Ha6* is transformed based on the six tones of the Cantonese language. However, instead of judging the appropriateness of the transformation by intuition, I decided to implement a more systematic transformation where each note is mapped on to a word in the text, and its tone would indicate how many semitones the pitch needs to be moved. Since I wanted there to be more than seven notes in each 35-second stave, I decided that each character from the poem would control one system from the maquette. For example, the first three words are in tones 6, 4, and 1. This means all of the first row of the maquette has to be moved down a semitone (tone 6). The second row became a series of downward glissandi that moved from one semitone down to an additional semitone lower (tone 4). And all of the third row is transposed up a semitone (tone 1). It is notable that most of the text is in tone 1 (again, a characteristic of Cantonese poems), so most of the maquette ended up being transposed up a semitone.

Notably, the Cantonese language is also known for having inward consonants, which are short percussive syllables that end on ‘k’s and ‘p’s. These are neatly found at the beginning of phrases 1, 3, 7, and in the middle of phrases 6 and 8. I wanted to reflect this structural parallelism in the music, so I placed slap tongues in the corresponding places on the stave. This is, however, the only instance of a direct correspondence between the music and text in the structure. Once the pitch transformation is completed, the pitch material is used with freely within its corresponding phrase. As such, the first system consisted of a mix of materials from the first seven rows of the maquette. The second system consisted of materials from the eighth to twelfth row, and so on.

Finally, since the commission explicitly had a theme which my text is based on, I no longer felt the need obscure my text source. Rather, I acknowledged the source text in the title and in the performance note to establish that this piece is based on a poem that is about sceneries of early summer, leaving it to the performer to interpret what that means. Additionally, I attempted to use word painting to reflect the theme more closely. This can be found in the pair of three-character phrases: ‘After the light rain, the little lotus turns over’.

The flute plays quiet but rapid sounds to portrait the light rain, and the motif is then played in retrograde to signify 'the lotus turning over'. Moreover, since the flautist, Ada Poon, is also from Hong Kong, I left some of the characters in tones 2, 4, and 5 on the score so the flautist could feel the shape of the glissandi based on how she would pronounce the words in Cantonese.

To sum up, *Patina* and *Cho1Ha6* are both based on intonations of Cantonese poems. In comparison, the transformation in *Cho1Ha6* is noticeably more systematic and intuitive than in *Patina.* Having learnt from the experience in *Patina*, I was more careful in considering the source text that has the right semantic and phonetic appropriateness for my piece. The performer's embodiment of the maquette is achieved differently in *Cho1Ha6* than in *Patina.* In *Cho1Ha6*, the flautist has full knowledge of how the material is transformed, so her understanding of the piece is based on a tangible knowledge of how we speak our mother tongue language. While the score for *Cho1Ha6* is written in a more detailed notation than *Patina*, the flautist's agency is arguably more foregrounded in *Cho1Ha6* because she is able to realise the maquette based on the imagery of the poem and assert expression that way.

4.2.3 *Śūnyatā*

Śūnyatā (2023) is my third attempt at using a transformational process based on the Cantonese language. After writing *Cho1Ha6*, I realised that the relationship between text and music is much more profound than I originally thought. *Cho1Ha6*, for example, takes the original structure of the text, its proportions, pronunciation, contour, inward tones, rhyme schemes, and semantic meaning to create materials that come intrinsically from the text. But due to its programmatic setting, the connection from the poem to the maquette felt too explicitly expressive to me. To be sure, I am happy with the results of the parametric transformations in *Cho1Ha6*. However, because I have given myself the freedom to work on the note-to-note level material intuitively, I think I went overboard with the metaphorical tone to write music that represents the scenery of the summer. This is not to say that I disliked the methodology, and there is nothing wrong with using algorithmic material to create metaphorical imageries. But this made me realise that between expressive and non-expressive music, there is an in-between space filled with different levels and kinds of expression to explore. In *Śūnyatā*, I ask, if I chose a text that was less poetic and less descriptive, would I be more at ease with making full use of the text?

Therefore, in *Śūnyatā*, I chose to use the Chinese translation of the Buddhist 'Prajina-paramita Heart Sutra' for my maquette. The text is provided below, and an English translation is provided following it.

般若波羅蜜多心經[231]

觀自在菩薩。行深般若波羅蜜多時。照見五蘊皆空。度一切苦厄。舍利子。色不異空。空不異色。色即是空。空即是色。受想行識。亦復如是。舍利子。是諸法空相。不生不滅。不垢不淨。不增不減。是故空中無色。無受想行識。無眼耳鼻舌身意。無色聲香味觸法。無眼界。乃至無意識界。無無明。亦無無明盡。乃至無老死。亦無老死盡。無苦集滅道。無智亦無得。以無所得故。菩提薩埵。依般若波羅蜜多故。心無罣礙。無罣礙故。無有恐怖。遠離顛倒夢想。究竟涅槃。三世諸佛。依般若波羅蜜多故。得阿耨多羅三藐三菩提。故知般若波羅蜜多。是大神咒。是大明咒。是無上咒。是無等等咒。能除一切苦。真實不虛。故說般若波羅蜜多咒。即說咒曰。

揭諦揭諦　波羅揭諦　波羅僧揭諦　菩提薩婆訶

The Prajina-paramita Heart Sutra[232]

When Avalokiteśvara bodhisattva practiced the deep perfection of wisdom,
He saw the five aggregates as completely empty, and overcame all states of suffering.
Śāriputra, form is not different emptiness, emptiness is not different form
Form is empty, emptiness is form.
Vedanā, saṃjñā, saṃskāra, & vijñāna, are the same
Śāriputra, all dharmas are marked with emptiness;
not born, not dying; not dirty, not clean; not increasing, not diminishing
Therefore: in emptiness there is no form; no feeling, no thought, going? [choice], knowledge
No eyes, ears, nose, tongue, body, or mind;
No colour, sound, smell, taste, touch or dharmas.
no eye-element, up to no mind-cognition element
Also no ignorance of exhausting of ignorance.
And even no aging and death, no exhausting of aging and death
No suffering, cause, cessation or way. No wisdom, also no attainment
Since nothing is attained, the bodhisattva reliant on perfection of wisdom,
his heart is without hindrance. Since he is not hindered, he is not afraid,
far from upside-down dreamlike thinking and finally attains nirvana
All Buddhas of the three worlds depending on the perfection of wisdom,
attain anuttara-samyak-sambodhi.
Therefore know the perfection of wisdom,
is a great magical spell, is a great spell,
an unsurpassed spell, an unequalled spell.
It removes all suffering; it is truly real not false ,
Therefore, recite the perfection of wisdom spell.
That is to say the mantra which goes:
gate gate paragate parasamgate

In both languages, but especially apparent in the Chinese translation, the text is divided into irregular phrase lengths. However, there is still a vague sense of pattern in the form of

[231] '般若波羅蜜多心經', *The Corporate Body of the Buddha Education Foundation,* n.d. <https://budaedu.org/budaedu/buda2_02.php> [accessed 6 June 2024].

[232] 'The Heart Sutra in Middle Chinese', *Jayarava's Blog*, 15 May 2015 <https://jayarava.blogspot.com/2015/05/the-heart-sutra-in-middle-chinese.html> 15 May 2015 [accessed 6 June 2024].

occasional repetitions, palindromes, and parallel structures within phrases. For instance, the term ‘Śāriputra’ is repeated in lines three and six. The phrase ‘form is only emptiness, emptiness is only form’ is a near-symmetrical palindrome. And the frequent use of ‘no’ in lines seven to fourteen creates an irregular pattern of alliteration. Hence, unlike in traditional poems, this text has a fascinating intrinsic structure filled with palindromes and parallels that I wanted to use for the piece.

Śūnyatā, for flute, bassoon, horn, guitar, violin, and cello, was written for Ensemble Linea for Ciel Academy 2023. In the piece, I wanted to recreate these inherently symmetrical and repetitive structures from the text. Therefore, in the score, which is in time-space notation, each page corresponds to a sentence from the sutra. Long sentences will result in denser number of notes on the page, and vice versa, shorter sentences will lead to fewer notes on a page.

The pitch material, like in *Cho1Ha6*, was determined by the six tones of the Cantonese language. Each note or chord in the maquette was mapped onto a word in the sutra, and the pitch was transformed that way. Since there is no longer a rhyme scheme in tone 1, this version of the maquette consists of a lot more glissandi. Also, as before, the three inward consonants in the language were translated onto the score as percussive sounds, mostly on the guitar part, but sometimes as pizzicati by the flute or the strings. Repeated phrases, such as ‘Śāriputra’, therefore, have identical repetitions within corresponding pages on the score.

The piece is notated in time-space notation where the ensemble is instructed to play from the full score. On the score, musicians are only given noteheads and an approximate duration to play. Crucially, I have emphasised in rehearsals that performers should be constantly communicating non-verbally, where slight deviations in timing are particularly welcome if they are ‘musical’ decisions.

In the performance, the piece almost sounded like an improvisation because the musicians were able to look at the full score and find ‘partners’ to play with or against. Even though the notation is relatively detailed, at least with pitch, rhythm and timestamps marked, the piece still sounded drastically different in every rehearsal. Notably, despite this being my attempt to draw materials directly from the text, this piece cannot have any word painting. The words of the sutra are inherently difficult to word-paint into music, as it is filled with abstract terms such as ‘form’, ‘emptiness’, ‘ignorance’, and ‘Śāriputra’. But in a way, not overreading into any semantic interpretation of the sutra is perhaps in itself an act of word painting because then the form of the piece entirely depends on the text. The form is in itself

empty, and the emptiness of the text (as in the lack of semantic reading) leads to the form. The title, 'Śūnyatā', refers to this Buddhist appreciation of neutrality, openness, and emptiness, which is reflected in my relationship with the text.

4.3 Physicality of Performance

The third approach to enact interest from the maquette is by directly foregrounding the performer's bodily presence, as seen in the music of Helmut Lachenmann. While Lachenmann's music is not necessarily algorithmic, it is worth examining because it features a special emphasis on bodies that is achieved by '[promoting] the role of gestures to the centre of attention'.[233] In *Pression* (1969/2010), for example, Lachenmann is concerned with 'the way sound is produced rather than how it should be heard'.[234] Orning suggests that *Pression* reverses traditional hierarchies of *Werktreue*, where historically, performers are expected to play with 'fidelity to the work or the composer', and therefore their agency is confined to playing the score with 'authenticity'.[235] Orning notes that with Lachenmann (as well as Morton Feldman, Klaus K. Hübler, and Simon Steen-Andersen, who she examines in her thesis), the score should be viewed as prescriptive or action notation, a form of *Texttreue* instead.[236] In *Pression*, the score functions similarly to a tablature where the performer is asked to squeeze, press, jerk, slide, hit, and stroke various parts of the instrument and the bow. As Orning explains, these sound production methods are usually regarded by the instrumental performance practice as 'extra musical sounds, mistakes, mishaps, and accidents'.[237] But for Lachenmann, these techniques are the music, so 'one could not, for example, transcribe Lachenmann's three string quartets for piano four hands; the music would simply disappear'.[238] In other words, the compositional material in *Pression* is not its

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[233] Orning, 43.
[234] Ibid., 132. There is not enough scope in this thesis to discuss Lachenmann's *musique concrète instrumentale* any further. It is worth noting that Lachenmann was Nono's student, and in line with the discussion in Chapter 3.4, he developed his own style after exploring serialism. To add to my argument in Chapter 4.2, Lachenmann notes that Nono was the only composer at his time that has not 'exhausted their resources'. See Helmut Lachenmann, 'The "Beautiful" in Music Today', *Tempo,* 135 (1980), 20–24 (21).
[235] Orning, 33, 67, and 88; it is also worth clarifying that 'autonomy' here is used in the term's common usage in Romantic music, as opposed to the kind of autonomy in algorithmic music discussed in this thesis.
[236] Ibid., 88.
[237] Ibid., 135.
[238] David Alberman, 'Abnormal Playing Techniques in the String Quartets of Helmut Lachenmann', *Contemporary Music Review*, 24 (2005), 39–51 (48); There is an interesting similarity between Alberman's comment and my issue with *Markov Patterns*, where algorithmic material could not be transcribed directly for new instruments. The difference is that *Markov Patterns*' problem lies in the abstraction of pitch material not accounting for the physical playing of the instruments, whereas Lachenmann's music is not transcribable because it is about the physical gestures on the specific instrument. With that said, a version of *Pression* for trombone exists online. See: Mike Svobada, 'Helmut Lachenmann (*1935) pression version for trombone by Mike Svoboda', *Mike Svobada,* n.d. <https://mikesvoboda.net/compositions-all/articles/pression.html> [accessed 6 June 2024].

sonic outcome, but rather, the piece is written based on the physical playing of the instrument.[239]

These 'extra-musical noises' that are created by the physical gestures are not perceived as noises in the piece, because as listeners form a particular intercorporeal relationship with the performer, and they learn to situate their care for these sounds in a performance environment, which is to listen 'aesthetically'.[240] When these 'noises' are aestheticised as music, the gestures that produce them are no longer 'mistakes' in the sense of a traditional performance. As a result, these 'noise'-producing actions are enacted as musical interests and therefore foreground the performer's bodily presence. In Lachenmann's action score, the piece is no longer *Werktreue* where the performer plays in the background to realise the work autonomously. *Pression* asks explicitly for the performer to internalise and realise the score, and in turn create an embodied performance of the material where the performer's presence is an integral part of the piece.[241]

4.3.1 *Flou*

Flou (2022), for solo violin, was written in response to a call for scores at the University of Leeds to be workshopped by Mira Benjamin. Inspired by Lachemann's physical approach, I wanted to explore a method of playing the maquette that emphasised the performer's physical 'noise'-producing gestures. Upon reading Patricia and Allen Strange's book on violin technique, and by physically trying to make noises with a violin, I discovered that detuning the violin by an octave creates an eerily beautiful but unstable sound.[242]

The extreme scordatura means that the strings are physically very loose on the violin. Thus, they vibrate in a strange way that produces unpredictable timbres depending on how they are bowed. The idea for *Flou* is to have Benjamin play notes as notated in the maquette,

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[239] For more comprehensive analyses of *Pression*, see Ulrik Mosh, 'Das unberührte Berühren—Anmerkungen zur Interpretation von Helmut Lachenmanns Werken *Pression* und *Allegro Sostenuto*', in *Musik inszeniert: Präsentation und Vermittlung zeitgenössischer Musik Heute*, ed. Jörn Peter Hiekel (Mainz: Schott 2006), 25–46; or Hans-Peter Jahn, 'Pression, Einige Bemerkungen zur Komposition Helmut Lachenmanns und zu den interpretationstechnischen Bedingungen', in *Helmut Lachenmann, Musik-konzepte* (Munich: Editions Text und Kritik, 1988), 40–46.

[240] See Kozak, *Enacting Musical Tim*, 58–62. Kozak explains this aestheticisation of 'extra-musical sounds' for listeners using *temA*, another piece of *musique concrète instrumentale*, as an example. *temA* uses breath sounds extensively, and Kozak argues that in the piece, breathing becomes aestheticised in the way listeners do not perceive a 'defleshed and deboned persona injected into the music by the performer'. The breath sounds have been composed into the structure that becomes static and no longer functions in the 'natural context' of reality. Therefore, even when the singer is making gasping sounds, listeners will not have the urge to jump onto the stage to save her. This is not to say we are distanced from her, but we are immersed in a situation where we attend to the sounds in a particular manner, which is to listen aesthetically.

[241] Lachenmann asks the performer to play by heart or with a very low music stand, which shows that the visual aspect of the performance is important to him, and that he encourages the embodied process of memorising and internalising the music.

[242] The idea of the octave scordatura is inspired by the Turtle Island String Quartet's 'octave violin', which I read about in Patricia Strange and Allen Strange, *The Contemporary Violin: Extended Performance Techniques* (California, CA: University of California Press, 2001), 181.

but she will have to embrace the unpredictability in sounding result, reacting to it intuitively. Pitchwise, the detuned strings are unreliable and may go further out of tune in the middle of the performance. Therefore, I had to accept that hearing the maquette is no longer possible. In Orning's terms, my approach in *Flou* has changed from *Werktreue* to *Texttreue*. In Flou, while specifying the performer to play from the maquette, the sounding result is not specified.

There are several additional concerns to consider in using the octave scordatura. Given the physical looseness of the strings, it became harder to play double stops on the two inner strings, so I had to rewrite finger positions and move pitch registers to avoid it. Additionally, I further intervened with the maquette by adding a variety of bowing techniques (without knowing what it would actually sound like) to encourage a broader exploration of timbres. These techniques include scratch tones, *sul ponticello*, *sul tasto*, harmonics, and whispering tremolo. In order to give Benjamin more flexibility to engage with these surprising sounds, rhythm is loosely notated spatially.

The title 'Flou' describes the sounding outcome where the timbre is generally noisy and blurry yet there is a faint sense of the original notated pitch. 'Flou' can also mean 'loosening' in French, which is fitting for the physical loosening of the strings in the scordatura.

During the workshop, there were several unforeseen ambiguities that I had to address. In the performance instructions, I explained that the playing pitch is predetermined, but the sounding outcome should be a 'noisy' timbre. The first question Benjamin had was about the balance between noise and pitch. Even with the scordatura, Benjamin could manipulate timbre through nuances in bowing, adjusting bow pressure, speed, and its point of contact slightly, to create either more pitch or more noise. Admittedly, the extent of this flexibility is reduced due to the scordatura, but it was still crucial for Benjamin to note whether the preference should be steered towards pitch or noise in the playing.

My initial intention was to leave this decision open, allowing Benjamin to play with the scordatura and make this decision based on her intuition. I did not anticipate the need to specify timbre under these conditions, so during the workshop, I found myself, again, hesitant to choose.

To help me find the right balance between noise and pitch, Benjamin demonstrated the difference in timbre she could produce. To be honest, at the time, I had no clear preference as I saw the merit in each version: more noise led to an increased unpredictability, while more pitch seemed to provide a clearer direction in the musical structure. In the workshop, we agreed on a more noise-focused timbre with only subtle hints of pitch. It

appealed to the both of us because it struck a balance between variety and function. The barely audible pitch provided a vague sense of structure, yet there was enough variety in the noise to keep the piece surprising every time it is played. With that said, though I am pleased with this decision, for future performances, as a different violin would lead to a different result, I would encourage performers to establish their own position in this balance. Due to the physical unpredictability of the instrument, it is important for me remain flexible in my preference. I am fascinated by the idea that there could be different realisations of the same piece, and I would welcome even the most extreme versions that focus explicitly on pitch or noise. The only requirement in this decision making, is, above all, the process of physically rediscovering the instrument. Regardless of the sounding result, it is important to me that these decisions are made after the performer has experimented with the scordatura, as Benjamin did in the workshop. This exploration on the instrument is a crucial part of the preparation, as it encourages the performer's bodily engagement with the musical material. This is the reason the openness of sounding result exists the first place.

In exploring the spectrum of pitch and noise, I noticed that my interventions with the algorithm brought dramatic structure to the piece. For instance, by manipulating octave displacement, I intuitively decided to start and finish with the same note in the same register. This reflects a vague sense of tonality if any pitch is heard, but if not, there is still a sense of symmetry, at least on the level of intentionality. Additionally, there is a climatic point marked mezzo piano in the middle, which was again an arbitrary decision, and it has given a clear shape to the piece. Moreover, the bowing techniques that I imposed freely further contributed to this shape, creating repetitions and directionality using various gestures. These decisions are effective touches that transform the maquette into the work, and they are notably all subconscious decisions that I made arbitrarily, without any knowledge of the sounding outcome.

A further observation, relating to this sense of musical drama in the piece, is in the notation. Since the score now focuses on the playing, there is an option to notate the piece as a Lachenmann-style tablature, with finger positions and playing techniques specified more explicitly. However, upon hearing the piece in the workshop, I realised that the stave notation had retained its conventional musical connotations. The aforementioned structures, such as overarching symmetries and motivic gestures, are conspicuous in stave notation. As a result, gestures such as glissandi, tremolos, and slurs, were interpreted intuitively by Benjamin with expression carried over from common practice. For example, when notes are slurred on the page, despite an absence of pitch, Benjamin would implement gentle swells by intuition.

Similarly, glissandi were interpreted expressively with intuitive decisions in the speed, rate, and loudness of the pitch shift. These gestures would not have had the same musical effect if were not notated on a stave. It is precisely these musical interpretations of the maquette that I hope to foreground in this piece.

Finally, on the score, I specified that the bow should be loosened slightly to enable even more timbral unpredictability. During the workshop, there was a further question about how loose the bow needed to be. Benjamin explained that due to the friction in the sound production, when the bow is extremely loose, the timbre is quieter and noisier, whereas when the bow is at normal tightness, the timbre is louder and contains more pitch. However, this decision was not determined by the pitch-to-noise ratio. Benjamin explained that the tightness of bow hair direct affects her control over the instrument. When the bow hair is drastically loosened, she loses control over the instrument. While unpredictablilities and noisy timbres are desirable in this piece, this was a straightforward decision for me as I valued Benjamin's control over the instrument. In order to encourage an intuitive interpretation of the strange sounds, it was important that the tangible experience of playing was not too strange. Benjamin should still have a degree of familiarity with the instrument so that she could confidently embrace and react to the sonic outcome.

As a result, Benjamin demonstrated an active engagement with the instrument's scordatura during the performance. Other than the bowing, an important part of her expression lies in her interpretation of rhythm. She took time between gestures, and there is a prominent sense of suspense during the silences between sounds. This tension is rooted in her uncertainty of the sounding result, and she had to embrace this uncertainty by playing cautiously, which is in itself a kind of musical expression. Her presence is foregrounded not because of the interesting timbres that emerged, but because of her bodily interactions with the instrument in real time. Her active decision making in interpreting these sounds is therefore injecting 'soul' into the maquette.

4.3.2 *Mou4Gaan3*

Mauricio Kagel was another composer who saw the physicality of playing as central to the music.[243] However, Kagel differs from Lachenmann in that there tends to be a greater sense of openness in his music. Heile writes:

[243] Heile, 35.

> The focus on the tactile nature of playing creates an impression of spontaneity, as if the players were exploring their instruments for the first time, trying out different ways of producing sounds and relishing the acoustic sensations, resulting in delicately intimate and strangely sensuous sounds.[244]

This description is similar to what I aimed to achieve in *Flou*. Due to the unstable scordatura, there is 'an impression of spontaneity' in Benjamin's playing, where neither the composer nor the performer knows exactly how the piece will sound in the performance. This creates an intriguing tension in the performance, where the performer has the freedom to explore the instrument but has to play with caution. Similarly, Heile notes that many of Kagel's pieces focus on the individual's 'struggle', such as *Antithese* (1962)*, Tremens* (1965)*, Transición II*, and *Improvisation ajoutée* (1962).[245] These struggles often occur between the performer and the instrument (as is the case in *Flou)*, but they may at times involve actual opponents (such as *Match)* or music-theatre (*Atem*).[246]

To explore the concepts of physicality and spontaneity further, my next piece draws inspiration from Kagel's *Transicion II. Transición II* is an ambitious crossover between all the compositional developments in Kagel's time of writing.[247] The material is serially and chance generated, notated graphically, in open form, played on a prepared piano, performed with a theatrical element, and accompanied with live electronics. The piece is for a pianist and a percussionist who exclusively plays inside the piano. Additionally, there are two tape parts that record and play back materials from the score during the performance. The extensive sixteen-page performance instructions specify that certain parts of the score that can be or must be recorded and played back, with or without modification, such as using a ring-modulator. As Heile describes, the result is a complex sounding 'super-piano', that involves 'ordinary playing, percussive action on piano parts and electronically modified recordings… to create a haunting sound world whose origin is sometimes hard to guess'.[248]

Most notably, the performers have to collaborate closely to produce specific sounds according to the score. The percussionist is often tasked to prepare the piano in real time, but the percussionist's actions are dependent on the timing of the pianist pressing down the pedal and the keys. As such, the pianist sometimes only presses down the pedal without playing, and at other times, the pianist and percussionist collaborate to create harmonics and other prepared sounds. However, according to Heile, Kagel also planned for performers to 'get into one another's way', where the complex interaction of actions can lead to a theatrical side

[244] Ibid., 37.
[245] Ibid., 57.
[246] Ibid.
[247] Ibid., 25.
[248] Ibid.

where the two performers struggle with one another.[249] Sonically, this would lead to the instrument 'going wild' and producing 'mad sounds', which is even more chaotic when accounting for the fact that these sounds maybe recorded and played back from the speakers.[250] Heile notes that 'despite the extreme physicality of the playing, this theatrical aspect seems an almost accidental result of the structural conception of the piece'.[251] This physical struggle in *Transición II* is emphasised where the bodily sound-producing movements are made more noticeable as accidental results of the conception of the piece. Curiously, in Kagel's sketches, this sort of accidental struggle is mentioned as a 'de-humanised density', which Heile speculates to be implying the 'man-machine struggle' that Kagel foregrounds in other pieces such as *Improvisation Ajoutée* and *Zwei-Mann-Orchester* (1971–73).[252]

Inspired by Kagel's *Transición II*, *Mou4Gaan3* (2023) is for two performers on a single harp. This piece was commissioned by the Hong Kong New Music Ensemble as part of their 'Shapes Song' project which calls for pieces written for teacher-student duos. The brief asked that the student's part should be easily playable by a grade-2 equivalent standard, and the teacher's part can be as difficult as it needs to be.

To create the student's part, I simplified the maquette by narrowing down registral leaps and splitting up dense chords so the material is playable for a beginner harpist. As for the teacher's part, it is meant to function like the percussionist's part in Kagel's *Transicion II,* where their job is to disrupt the 'normal' playing and prepare the strings in real time to create unpredictable timbres. While the student plays the harp as normal, the teacher is expected to physically manoeuvre around the instrument to prepare for techniques such as harmonic sounds, *près de la table* (p.l.d.t.), vibrato, and percussive sounds. In line with Kagel's piano preparations in *Transicion II*, in *Mou4Gaan3* some moments are deliberately difficult to 'get right' where these 'mistakes' are expected to be a humanistic part of the experience in performing the piece. As with *Flou*, the goal in *Mou4Gaan3* is not to hear the algorithmic outcome. Rather, it is the performer's bodily attempt to play the algorithmic material under these difficult challenges that is important.

The title 'Mou4Gaan3' comes from the Chinese word '無間', which literally translates to 'without gaps'. The term is sometimes used to describe an inseparable

[249] Ibid.
[250] Ibid., 25–26.
[251] Ibid., 26.
[252] Ibid., 85–86.

collaborative attempt where there are no gaps left between the collaborators (合作無間), but it can also mean the hell of uninterrupted suffering in Buddhism (無間地獄). This refers to the two possible outcomes of the piece. If it goes exactly according to the score, it is an inseparable collaboration. If players are in each other's way, then it might sound more like hell.

4.3.3 *Three Meanings of Change*

Finally, *Three Meanings of Change* (2023) presents three more examples of how the algorithmic material can be embodied by emphasising the performer's physical playing. This piece was written in collaboration with a violist friend, Harry Mak. Earlier in the year, I originally wrote a totally deterministic piece using the algorithm for Mak. However, Mak's feedback was that my score was unpractical because the piece was based on double-stopped harmonics. To be sure, when I wrote the piece, I made sure that the fingerings worked. However, Mak's issue with it was that these double-stopped harmonics are incredibly fragile. Harmonics themselves can sound when bowed at a specific angle, with the right bow pressure. If single harmonics are that fragile, it is not hard to imagine why double-stopped harmonics were deemed unplayable. Not to mention, my score consisted of successive double-stopped harmonics.

The conception of the *Three Meanings of Change* is our attempt to find three possible workarounds to play this unplayable material. Therefore, these three movements are not meant to be played as a three-movement-set. To me, they are three versions of the same piece, and I would not necessarily want to hear the three versions in succession.

The title of the piece comes from Zheng Xuan's (鄭玄) *Doctrine on the Book of Changes* (易緯乾坤鑿度), written in approximately 127 C.E.[253] At the time, Scholars such as Xuan rigorously studied the *I Ching* to theorise various applications of the *I Ching* in life. Xuan argues that there are three meanings of how 'change' is used in the *I Ching.* These are: 1) at ease with change (易簡); 2) the multifariousness of change (變易); and 3) the constancy in change (不易). These three meanings reflect my approach to create each of the three movements.

The first movement is for solo viola and fixed media. Since the first draft of this piece had a lot of double-stop harmonics, I separated these double stops to create a fixed media part

[253] 鄭康成, *易緯乾坤鑿度* (Shanghai: Universal library, 2009).

with harmonics in drones, and a playing part with the rest of the harmonics. Both the fixed media part and the playing part are played in extreme *sul ponticello* to emphasise unpredictable partials of the harmonic notes. To be 'at ease with change', Xuan encourages that one should try to find peace and comfort in the ever-changing universe, to let changes happen naturally in our daily life. In the score, Mak has the agency to decide on the duration of his playing, but he has to interact with the unstable partials in the fixed media part using the predetermined pitch sequence from the maquette. Thus, the performer has to be at ease with the change, which in this case, refers to the is the unpredictable partials in both parts.

In the second movement, the performer has to interact with a live-electronic part that consists of pre-recorded samples. Similar to how *Lorem Ipsum* works, the samples are triggered by conditions set in a pitch detection object, so the maquette material can potentially be realised in full. As was the case in *Lorem Ipsum*, this simple process can lead to innumerable possible outcomes, hence the title 'Multifariousness of Change'. The difference is that rather than giving Mak the same agency to repeat notes like in *Lorem Ipsum*, he is asked to play the material as notated, and simply accept whatever ends up happening in the electronic part. Therefore, with the reduced agency, Mak assumes a more passive relationship with the maquette, embracing the maquette in a way that is akin to an observer of 'the multifariousness of Change',

In the third movement the viola plays the same material as the second movement, but here, the performer is asked to select a different scordatura for each performance. In the recording session, we tried various scordaturas, and ultimately decided on C3, F#3, C#4, and A4, because it produced more diminished chords in the sounding outcome. In this movement, Xuan's concept of 'constancy in change' is reflected in the way the playing score is exactly the same as before, but the results will be different with a new scordatura every time.

5. Conclusion

This thesis is aimed at readers who are new to algorithmic music. Some of the issues that I noted, especially in the first two chapters, are perhaps already familiar for experienced algorithmic composers. But as I stressed at the outset, those issues seem to be ones which remain commonplace in discussions of creative applications of automation and, currently, AI. The advantage of this honest documentation is that I can discuss, from my first-hand perspective, the misconceptions that I unknowingly bought into. By reflecting on these mistakes and misconceptions, I hope my readers can learn from my experience and avoid the mistakes that I made along the way.

To sum up, my research on algorithmic music is threefold. On the first level, from trying to build a basic algorithm based on Fred Lerdahl's CCCS, I found that algorithms are not always as autonomous as I thought they were. I noted three ways in which composers have used algorithms, with Cage's method being the most autonomous, Xenakis' in the middle, and Boulez's the least. This is fundamentally the same issue on AI from Chapter 1.1, where using AI does not necessarily mean it is used entirely autonomously. Some AI are more autonomous than others, but they are often used more loosely than how they are described. This point is already quite clearly illustrated in the introduction of Beethoven's Tenth Symphony, where AI was only used to write materials that informed the second half of the symphony, but there are plenty of reports that claim the entire piece was written by AI.

In noting the various methods of intervention between Cage, Xenakis, and Boulez, I found that there are generally three points of intervention by composers. Cage intervenes exclusively in the pre-generation stage and leaves his material as the work. Boulez in *Le Marteau* lets himself intervene in the post-generation stage, where his material is transformed intuitively into the work. And Xenakis is in the middle where he starts intervening mid-generation, because his algorithm is not designed to generate materials comprehensively. Consequently, I noticed that these points of intervention are positively correlated to the degree of automaticism in an algorithm. The earlier the intervention, the more autonomous the algorithm. Cage intervenes the earliest, making decisions exclusively before the generation, resulting in a highly autonomous algorithm. Boulez, on the other hand, intervenes after the generation stage, consequently being the freest to deviate from the maquette. Xenakis works with a semi-autonomous algorithm, where his intervention is at a point in the middle of the generative process.

On the second level, by trying to use a machine learning algorithm that simulates my own intuition, I noticed that there are extra decisions outside of the algorithm to be made in the post-generation stage. I realised that even in highly autonomous works that I had previously identified (such as *Music of Changes*, *Illiac Suite*, *Structure Ia,* and *Clapping Music*), human interventions are still required in later stages of the process. These are often the relatively smaller, but nonetheless significant decisions, such as tempo and structure. This made me realise that I had completely overlooked the significance of these post-generation decisions. In the context of autonomous composition, they are the most crucial difference between maquette and work.

This desire to act on autonomous works has long been noted by scholars such as Adorno and Eimert, who have claimed that maquettes are in themselves, 'useless'. This need for composers to intervene, notably, seems to imply that there is something inherently missing from maquettes that is peventing them from being musical. The *Illiac Suite* could only exist as lines of code, and at best musical excerpts, without Hiller organising the algorithmic output into a score. This is to say that maquettes can be extremely close to being the work, but by definition, they can never be the finished work as they are just an abstract state of algorithmic outcome.

This distinction is blurrier in generative software such as MusicGen and AIVA, because their algorithmic output does not require a physical performance. Hence, their maquettes can be directly taken as the finished work. However, I would argue that there are still numerous composerly decisions involved in these generative processes, which are still necessary to turn the material into music. Initially, there is a choice to be made regarding which algorithm to use, and this choice significantly impacts the output depending on the algorithm's training data and design. Additionally, there is a decision in creating a prompt, which can take various forms depending on the algorithm. Following the generative process, users can decide whether or not to rerun the algorithm based on their satisfaction with the algorithmic result, allowing them to adjust the algorithm to produce their desired outcome. Subsequently, I would argue that the transmission process of these maquettes is also a post-generation decision, because music cannot exist without being experienced by humans. Users will need to decide on the format in which the music exists, its function, where it is played, and who gets to hear it. Maquettes are not incomplete because they sound like robots (although they often do). Ontologically, maquettes can only exist as a concept in the generative process. As opposed to complete pieces of music which is physically manifested and perceived, maquettes do not normally exist in an audible form.

With that said, this would be where I draw the scope of my second argument. My thesis has only dealt with generative methods for live musicians. I am only interested in the complex relationship that algorithms can form between composers and performers, and I have tried to refrain from commenting on algorithms that concern their own sound synthesis. And in a way, this adds to my categorisation of algorithmic music: some algorithms concern a digital medium of performance, and some are meant for physical performance.

Finally, on the third level, I noticed that focusing on adhering to algorithms would imply a neglect of the bodily considerations of performance. This made me realise that fundamentally, the issue for my algorithms in the first two years was that I depended on it too slavishly. I was unreasonably expecting the algorithm to write music itself, while assuming performers would be able to play the result as it is. In this attitude of composing, despite noting the dissatisfaction, I refused to act on the algorithm and blamed it on the system.

This is stemmed from a personal struggle at the beginning of my PhD. In writing the *Four Pieces*, owing to my detachment from the algorithm, I was dissatisfied with what the algorithm generated by itself. Consequently, I was confronted by the decision of 'what music do I want the algorithm to write then?'. I was unable to answer that question, which is why the *Four Pieces* ended up becoming an attempt to try four different musical styles. Looking back, to be fair, my first year happened in an oddly confusing position. Prior to that, I had just finished my master's degree in 2020 without actually completing the final project, which would have required a physical performance of thirty minutes of my music. I started my PhD as a composition student with little practical experience, without giving much thought to what music I want to write. This hesitation to commit to a certain musical style is perhaps a common challenge for compositional students. Over my first year, I had no plans to record my *Four Pieces* due to the lockdown restrictions, which meant that I composed with midi instruments in mind. However, I would not have arrived at my current compositional thinking if I had not encountered these challenges. Consequently, these issues have led my research to focus on the embodiment of algorithms. The aforementioned problems of algorithms being blank and disembodied are, frankly, criticisms towards myself, and the discussion is largely led by my reflection on my earlier work.

But as I have shown, there is a broader issue in the disembodied use of algorithms. Drawing from *Structure Ia*, *Music of Changes*, and *Clapping Music*, I note that when algorithmic adherence goes too far, it can begin to contradict the musician's embodiment of the music. The physical conflicts found in these pieces imply that the performer's bodily existence is compromised due to the rigid adherence to the algorithm.

To address this implication, upon reflecting on my music up until this point, I learned to loosen up in my aim for adherence, and I found three ways to foreground performers' bodies in algorithmic music. The first is by open form (*Hineni*, *Lorem Ipsum*, and *Coalescence*). The second method is by intervening quasi-systematically in the middle of the generative process based on text (*Patina*, *Cho1Ha6*, and Śūnyatā). And the third way is by working directly with physical aspects of the music (*Flou*, *Mou4Gaan3*, and *Three Meanings of Change*).

In total, over the three years of my research, I gradually developed a deeper understanding of what it means to compose with an algorithm. The term 'algorithmic music' is extremely broad, and it encompasses all sorts of human decisions and deviations. Additionally, these decisions can become quite complex as there can be varying degrees of intervention and they can happen at different stages of the algorithmic process. Therefore, for writers and composers interested in algorithmic music, it might be useful to categorise and describe algorithms in the terms that I used. Some parameters to consider are listed below.

- What kind of procedure is used in the algorithm (solmisation, mapping, serial, chance, process, Markov chains, deep learning)?
- How many inputs and outputs are considered in the algorithm (one to one, one to many, many to one, many to many, and how many)?
- How comprehensive is the algorithm (from very comprehensive to singular parameters)?
- What parameters can the algorithm produce (pitch, rhythm, harmony, structure, tempo, dynamics, playing technique)?
- What parameters can the algorithm not produce (pitch, rhythm, harmony, structure, tempo, dynamics, playing technique)?
- Who uses the algorithm (the composer, the performer, the listener, or other users who want to try the algorithm)?
- How much intervention is required by its user (autonomous or semi-autonomous) ?
- How are these interventions imposed (systematically, quasi-systematically, intuitively)?
- At what stage do these interventions take place (pre-generation, post-generation, or more unusually mid-generation)?
- Who can intervene (the composer, the performer, the conductor, the listener)?

- What function do these interventions serve (filling in gaps, destroying algorithms, working around practicalities)?
- What are the interventions (altering single parameters, adding a higher-degree row, deviating in limited windows, *etc*.)?
- What medium does the algorithm work with (electronic or acoustic, or both)?

This list is non-exhaustive and there are certainly more decisions involved in creating an algorithmic composition. But it also shows that there can be innumerable ways of working with algorithms. This thesis is only focused on the pieces from the 1950s–70s to provide a historical context to the issues I noted in my music. But in the future, there is scope to explore more recent repertoire, maybe working more explicitly with AI, to expand on the issues mentioned above, under these terms that I listed here. As AI is becoming increasingly more autonomous and easier to use, the significance of my work will be on continuing to acknowledge and foreground these overlooked human agencies in algorithmic music.

I would like to conclude by returning to the opening discussion on the general relationship between theory and practice. Over the course of Chapters 2 and 3, I gradually realised that my algorithmic attempts kept failing because I had unrealistic expectations of what automation can achieve. As mentioned, there is essentially a discrepancy between my theoretical knowledge of algorithmic music and my practical experience in writing algorithmic music. Part of the blame for this discrepancy, as I have already admitted, comes from my initial naivety in not fully understanding what algorithmic music entails. However, there is a greater underlying factor at work here. I note that theory and practice, because of their epistemological difference in discipline, are rarely compatible. The notion of applying any grand theory into practice is never as straightforward as following a recipe. The reality is that most theories function to observe generality, and therefore can never comprehensively account for the level of nuance required for composition. This is the case for dodecaphony. In theory, *in general*, a dodecaphonic piece follows a twelve-tone row, and the music is created by the ordering and reordering of these twelve notes, sometimes also considering individual parameters. But in practice, no composer writes music exactly the way the theory says, and there is (almost) always discrepancy that can be observed between the theory and the music. And in pieces where the discrepancy is minimal, as in *Structure Ia*, for example, they usually become pieces decried by their own composer. In the case of Lerdahl's CCCS, as discussed in Chapter 2.3, when the constraints were used without any deviation, I described the outcome

as a maquette because it was stylistically empty. Perhaps the issue is not on Lerdahl's theory itself, but on the notion of *applying* a broader theory directly into practice. The same argument can be made with regard to traditional music theory and Bach chorales. Composers learn to observe general trends from the theory, but the practice is never a rigid adherence to the theory (a theory often generalised from existing practice, in any case). Instead, music, in practice, is always built on the foundations of the theory, where there will always be composerly deviations from the theory. My research has led me to appreciate that these composerly decisions, functioning on top of the theory, are where the 'magic' happens to turn maquettes into work.

Since theories are usually concerned with the general, they inevitably miss out the smaller details, which I have argued to be the most important aspects in the notion of applying any theory for composition. This is precisely the significance of this thesis. *Clapping Music*, for example, is easy to discuss in theoretical terms where it follows a neat process of phasing. However, the most 'magical' aspects of the piece are the things outside of the phasing process, which are often difficult, if not impossible, to contend with using a theory concerned with generalities. Notwithstanding the problematic origin of the rhythmic motif, Reich chose the ideal rhythm to phase on. When the motif phases, the metric pulse plays with the subdivisions of threes and fours, which is what makes the piece most interesting for me. This is why it is important to discuss algorithmic processes in terms of their pre- and post- generation decisions. Anyone can write a phasing piece for clapping performers, but *Clapping Music* could not be replicated if it were not for the motif that Reich chose. Similarly, it is easy to talk about the looping process in *Music for Airports* but difficult to explain how Eno decided on the pitches and timbres that the piece deploys. These inconsistent elements *feel*—even if they are not—intuitive. In *Music of Changes*, how are the biases in sound charts designed? Ultimately, the argument I am making is that as opposed to focusing on the algorithm itself, there needs to be more attention to how these algorithms are used in ways that are particular to the individual pieces. It is these elements of decision making where what is more significant—and most particular—about any individual piece may be found.

To conclude, as mentioned at the beginning of the commentary, when I enrolled to do a PhD during the pandemic, I was frankly a bit lost as a composer. I was unsure about what music I wanted to write, and I sought to compose by blindly following a theory and then 'problem-solve' it to make it playable. Consequently, this music felt impersonal to me, and I was dissatisfied with its emptiness. This is what happens when the gap between theory and

practice is squashed by force. Owing to the generality of the theory, any slavish attempt at following it will result in an empty maquette that lacks detail, as seen in my *Four Pieces*, about which I feel much as Boulez did about *Structure Ia*. Instead of chasing this implausible unity between theory and practice, I have learnt to flexibly build on the theory, to finally make space to take composerly decisions, deviating from the maquette. In my most recent set of pieces, discussed in Chapter 4, the algorithm is exactly the same as that for the pieces in Chapter 3. The only difference here, which is the source of their newness, rests not in what can be generalised about my pieces, but on the contrary, about what cannot, about what is specific to them. The maquette has remained the same, but I situated it in unique ways that come from what I want to explore with each collaborator. And as such, it is in the pieces themselves that I believe the originality to rest.

Personally, I see my compositional output over the last three years as a learning curve that follows a cycle of trial and error. Consequently, there are pieces I wrote that I really liked, but there are also pieces that I wish I had not written. But owing to the earlier erroneous pieces, I am starting to write music that feels less like trials. I think that I have finally found the kind of music that I want to write, and the courage to trust myself in writing it. Going forward, my music will continue to explore this manifold relationship between systems and bodies. My music so far has only treated them as an opposing duality, but I think I am starting to see them as a unity. When the spectrum of systems and bodies becomes fluid, as I saw in *Il canto sospeso*, there are specific points of in-betweenness in this tension that I want to explore compositionally beyond this thesis.

Appendix A: Cantonese Choral Composition

伊卡洛斯撲火

For SATB Choir, A Cappella

(2022)

Lyrics by Hou Lam Tsui

Music by Kenrick Ho

歌詞:

伊卡洛斯撲火 徐皓霖

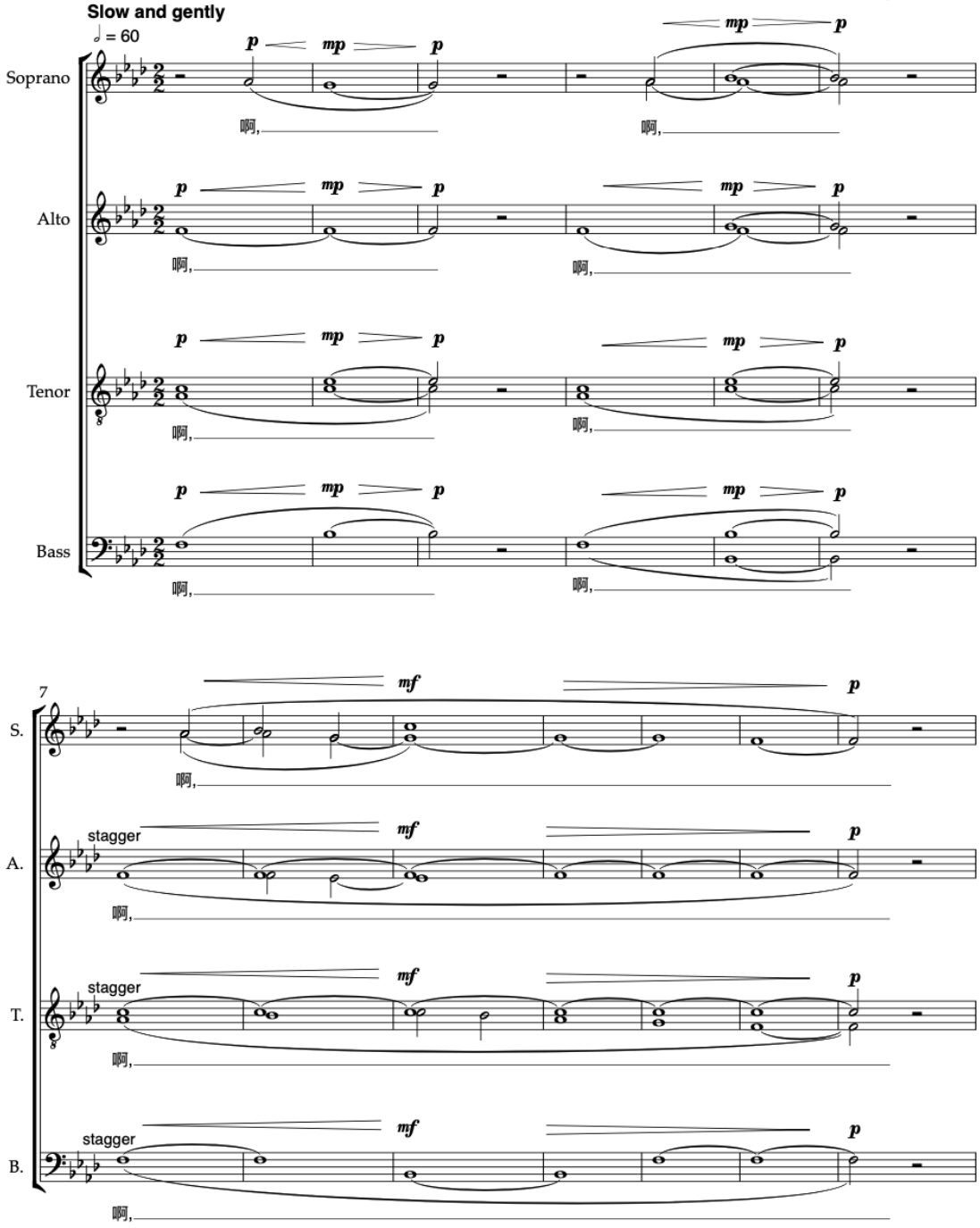
啊飛蛾——
你差一點就能成為伊卡洛斯
就差——
沒有變成神話那一部分
就差——
沒有人因你而命名一座島嶼
世界變暗了
你選擇了自己的命中註定
你做到了
讓自己摧毀屬於自己的甜夜
留一個光天化日給伊卡洛斯
腹部開始暖和了
很好

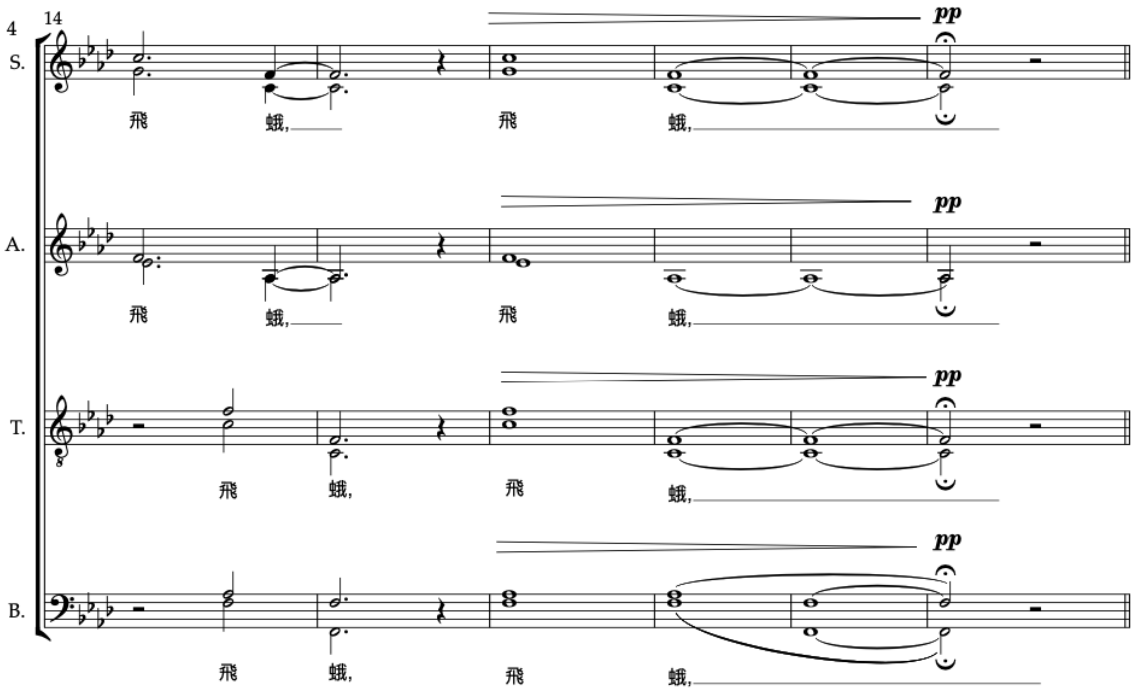
Duration: 4'30“

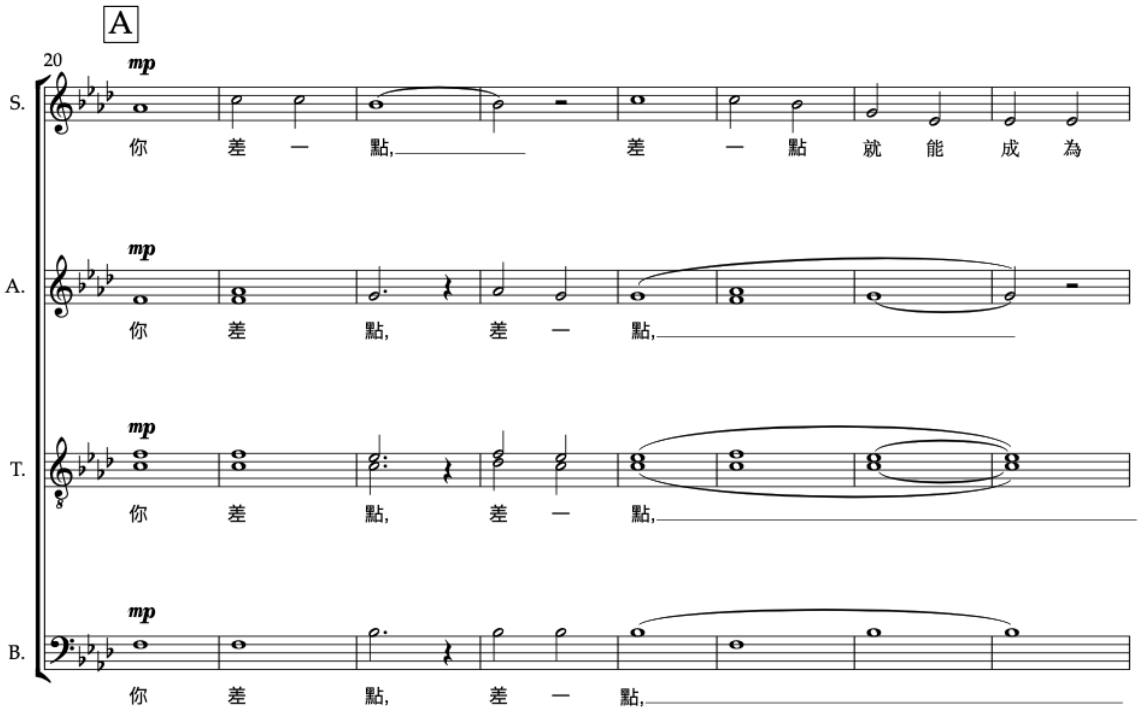
伊卡洛斯撲火

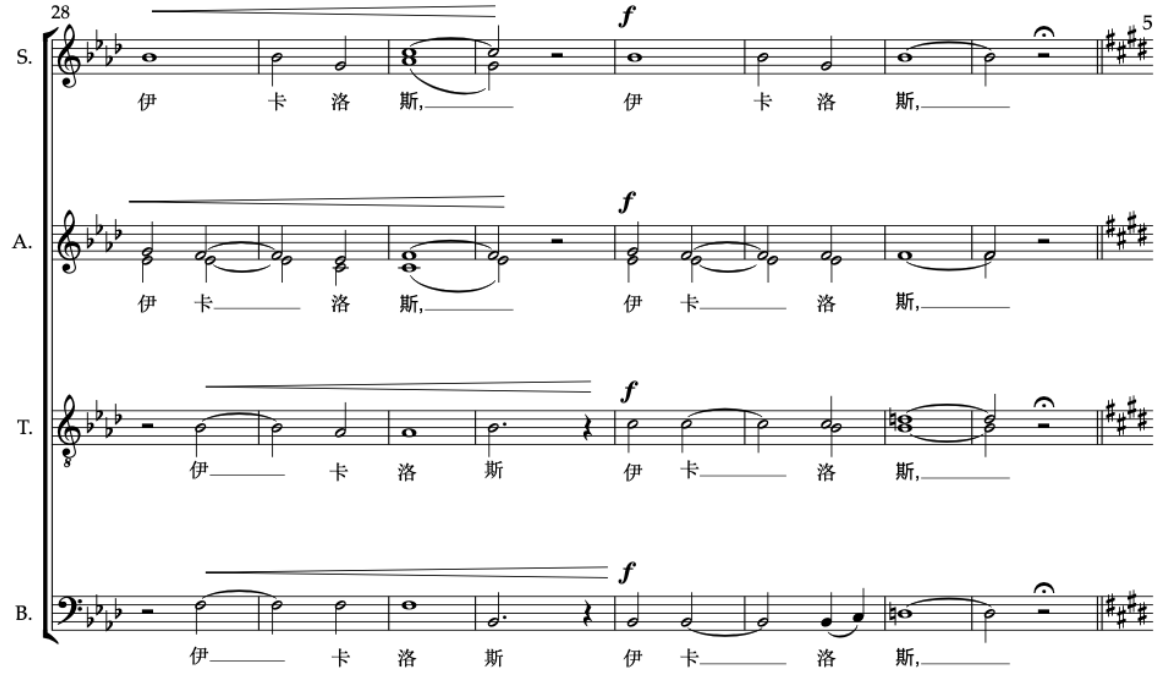
For SSAATTBB chorus

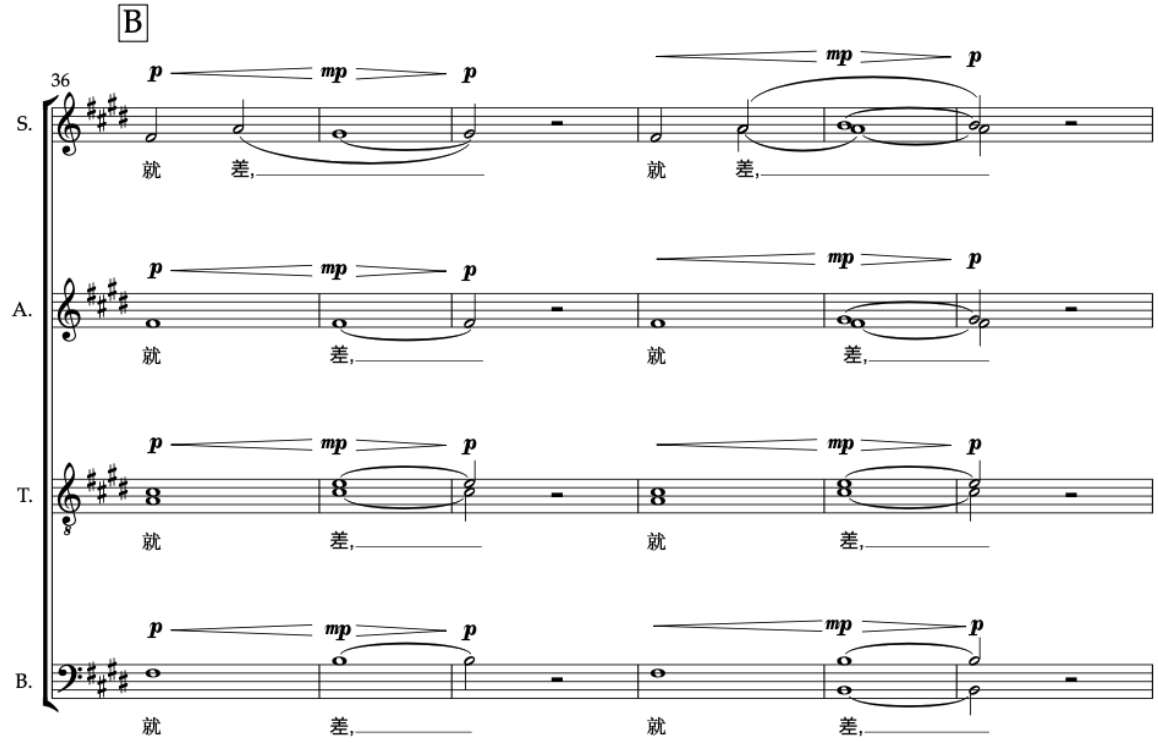
Lyrics by Hou Lam Tsui
Music by Kenrick Ho

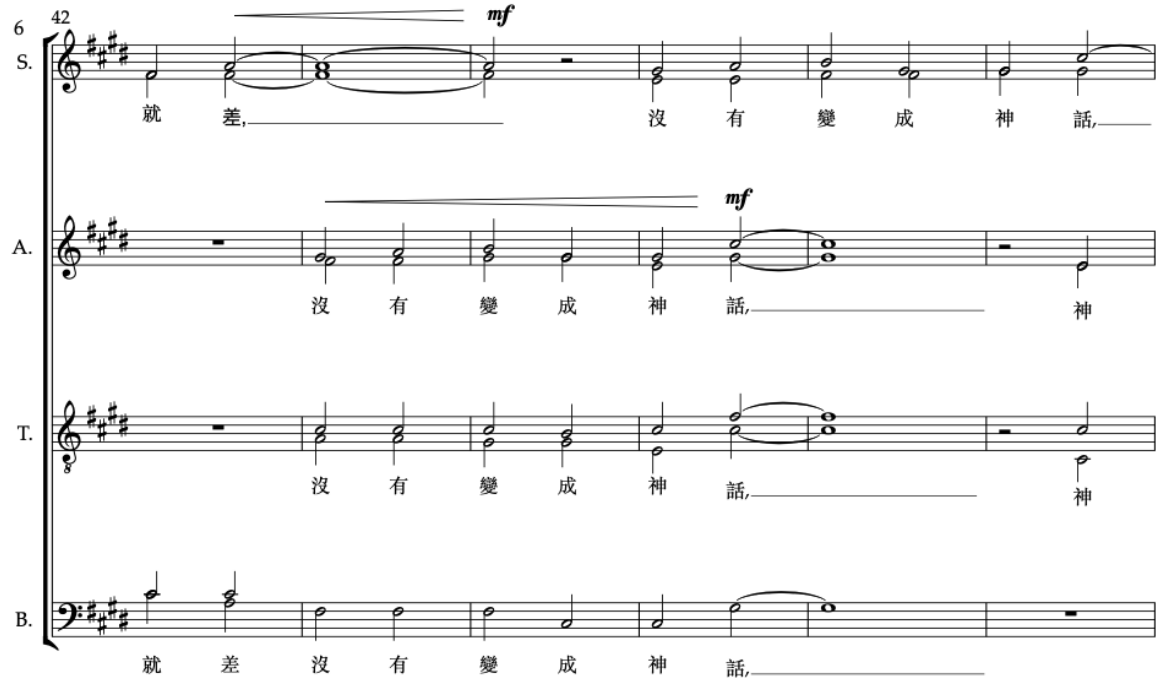


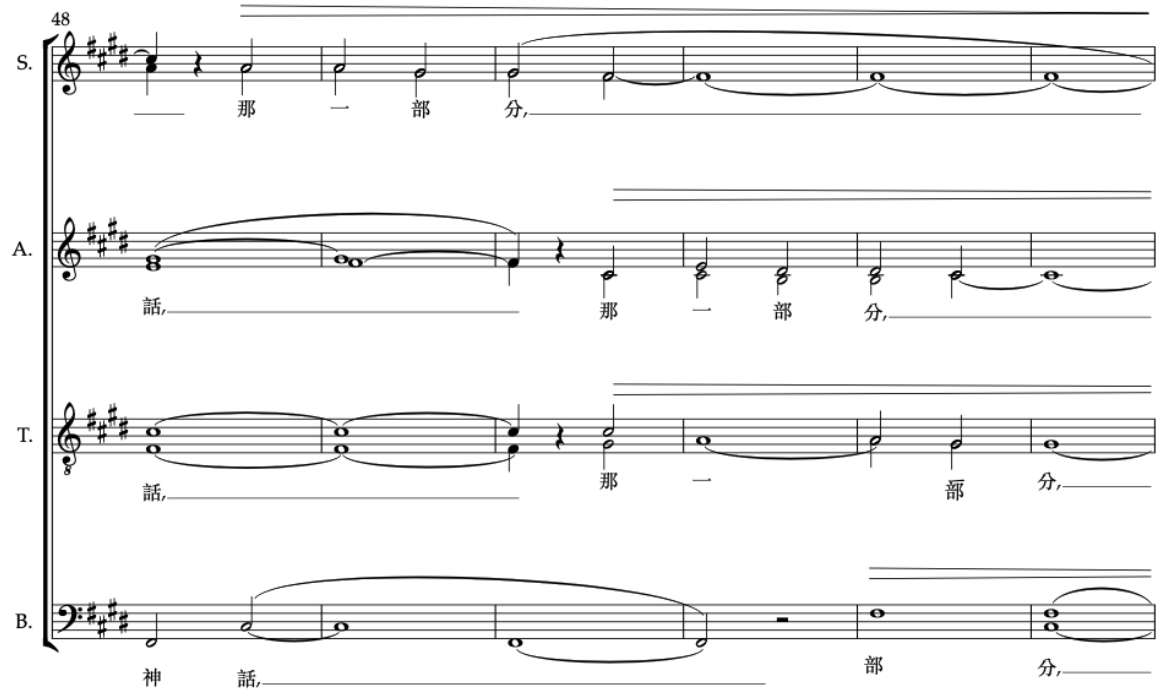

4
14
S.
A.
T.
B.
pp
飛 蛾, 飛 蛾,

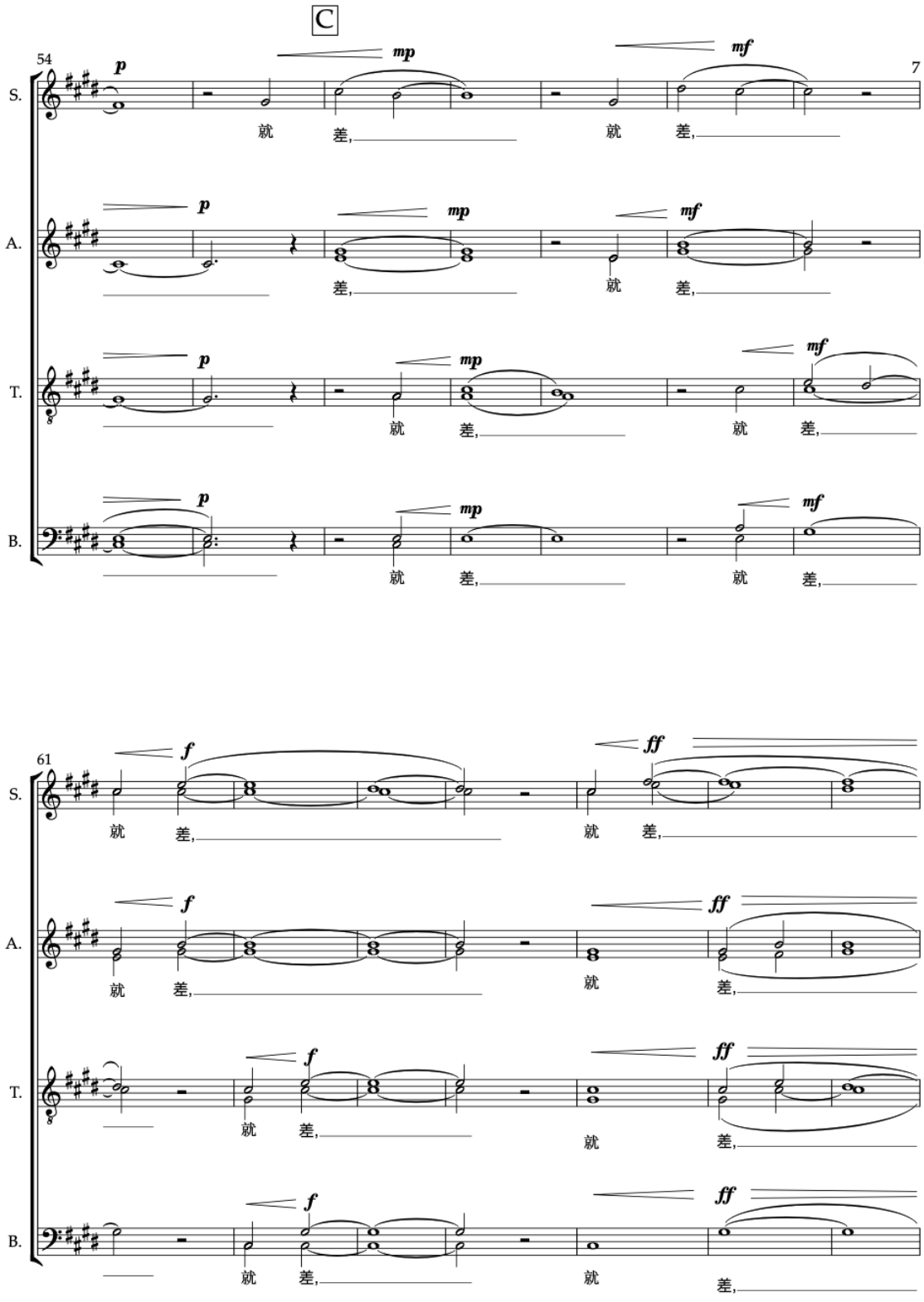

A
20
S.
A.
T.
B.
mp
你 差 一 點, 差 一 點 就 能 成 為
你 差 點, 差 一 點,

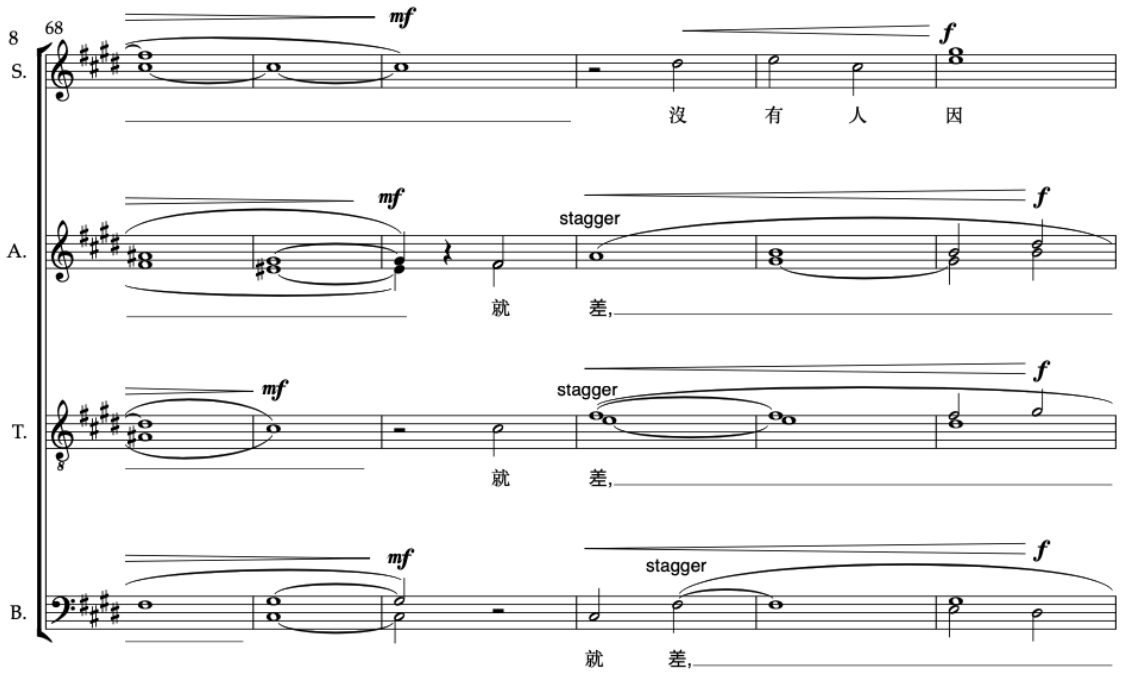

28
5
S.
A.
T.
B.
伊 卡 洛 斯,
伊 卡 洛 斯,
伊 卡 洛 斯,
伊 卡 洛 斯,
伊 卡 洛 斯
伊 卡 洛 斯,
伊 卡 洛 斯
伊 卡 洛 斯,
f
f
f
f

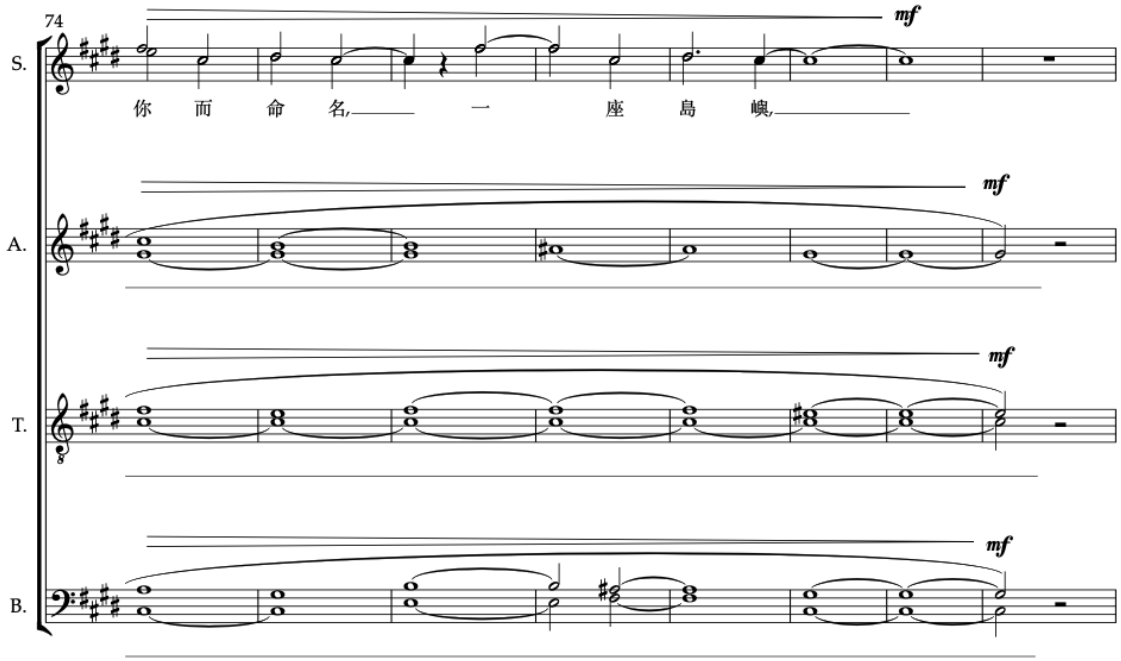

B
36
S.
A.
T.
B.
就 差,
就 差,
就 差,
就 差,
p
mp
p

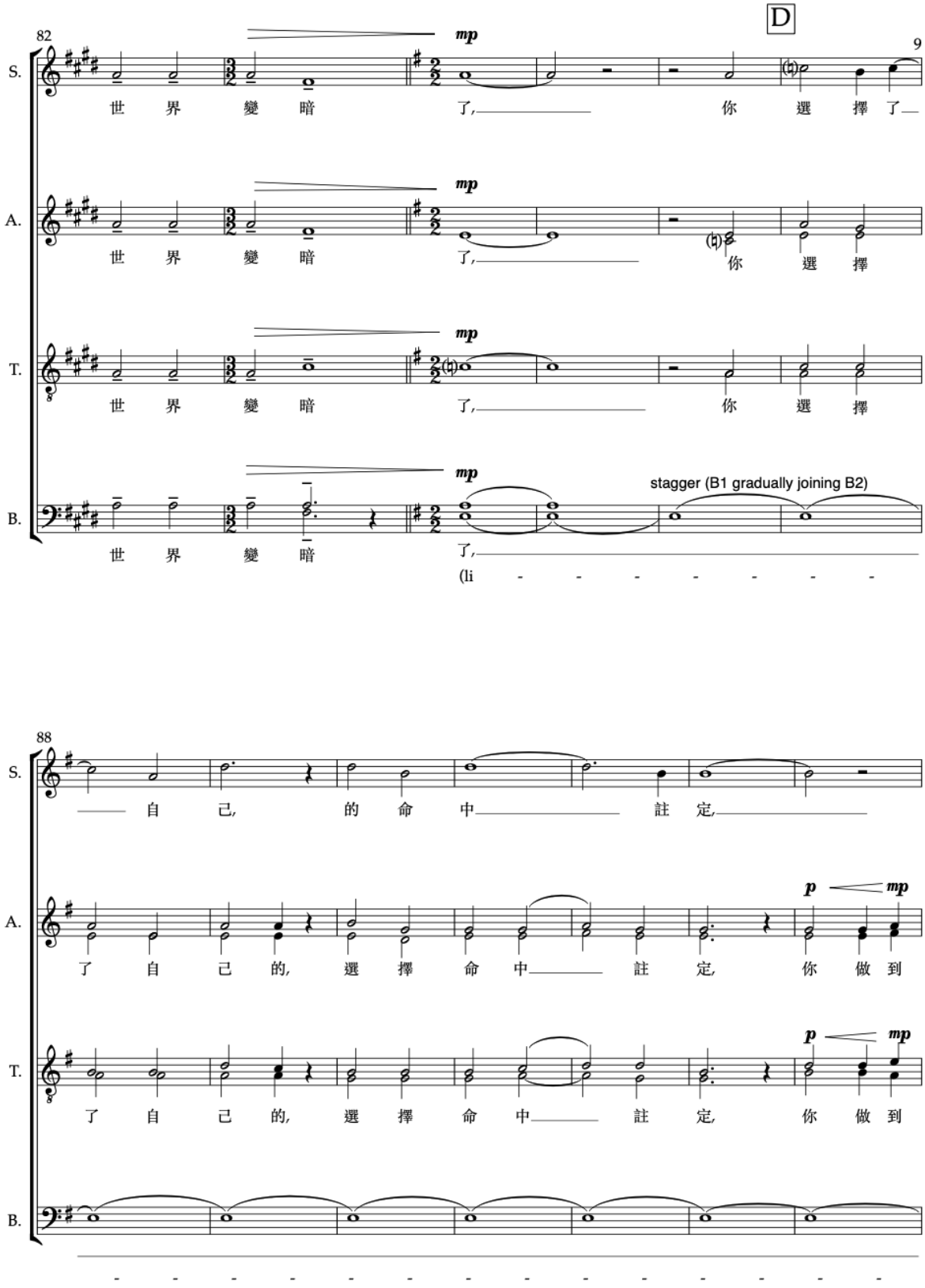

6
42
S.
A.
T.
B.
mf
mf
就 差, 沒 有 變 成 神 話,
沒 有 變 成 神 話, 神
沒 有 變 成 神 話, 神
就 差 沒 有 變 成 神 話,

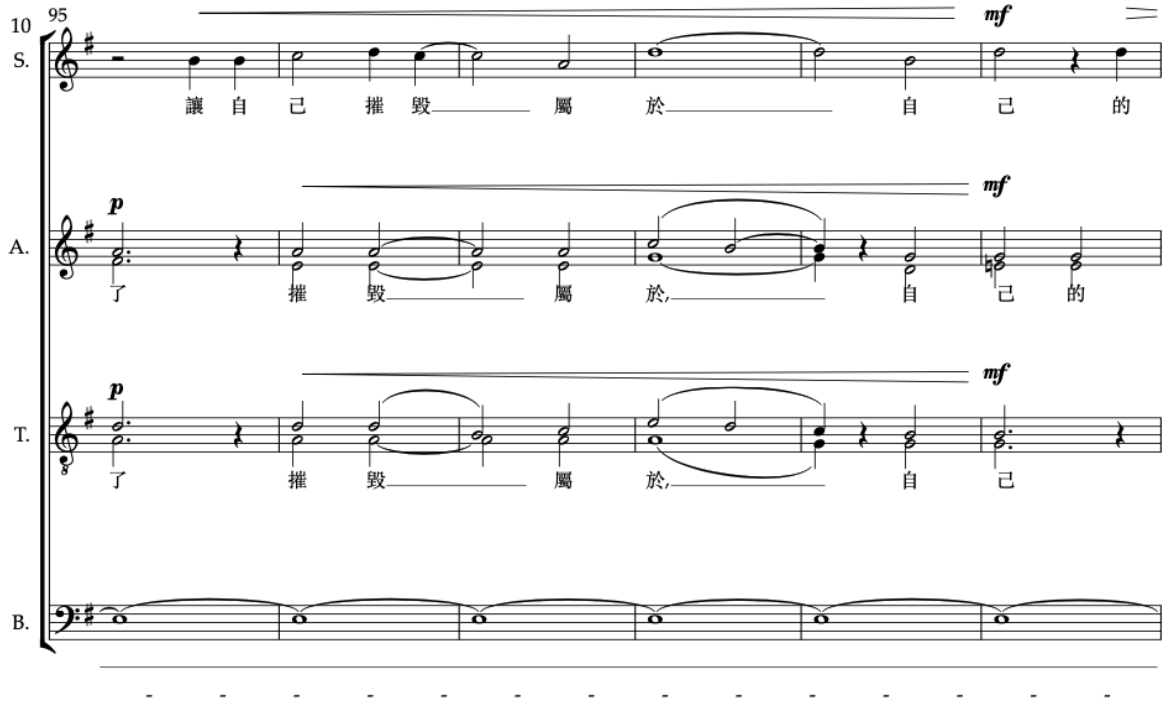

48
S.
A.
T.
B.
那 一 部 分,
話, 那 一 部 分,
話, 那 一 部 分,
神 話, 部 分,

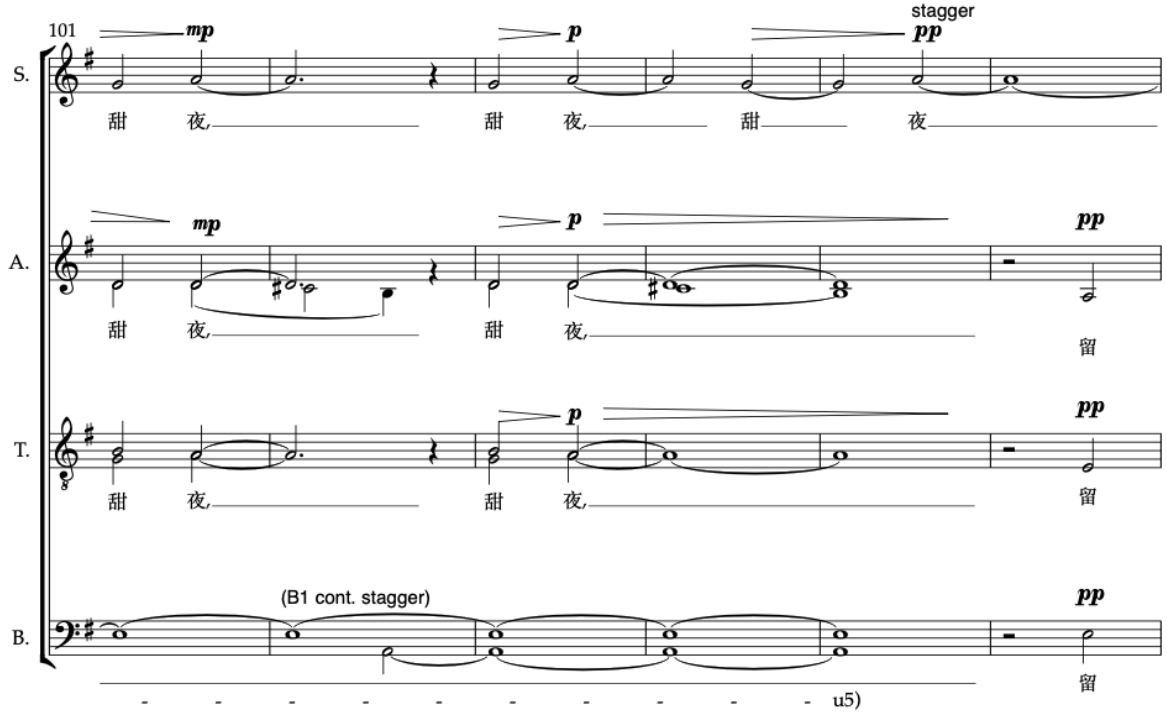

C
54
7
S.
A.
T.
B.
p
mp
mf
就
差,
61
f
ff

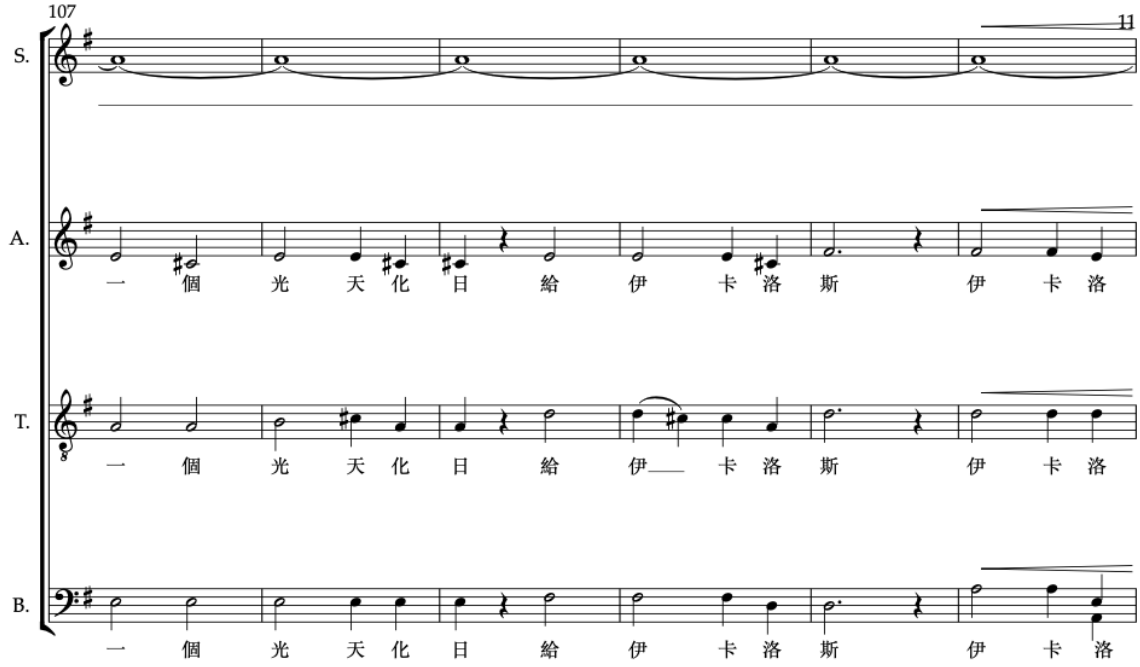

68
S.
A.
T.
B.
mf
f
stagger
没 有 人 因
就 差,
就 差,
就 差,

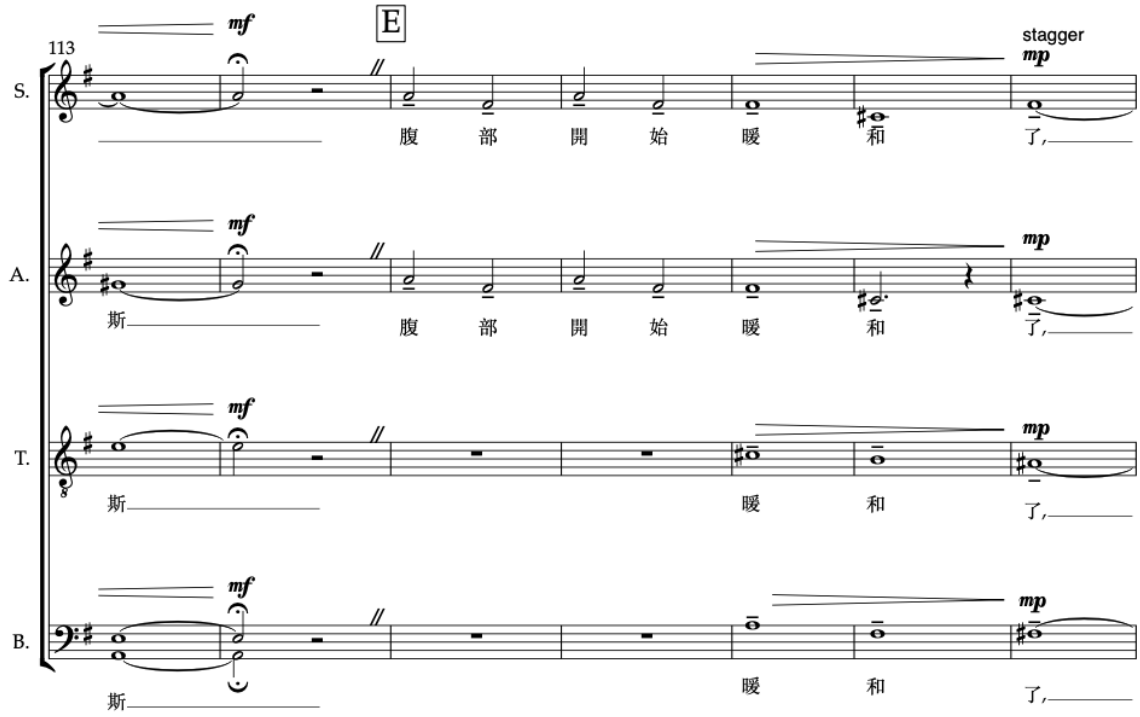

74
S.
A.
T.
B.
mf
你 而 命 名, 一 座 島 嶼,

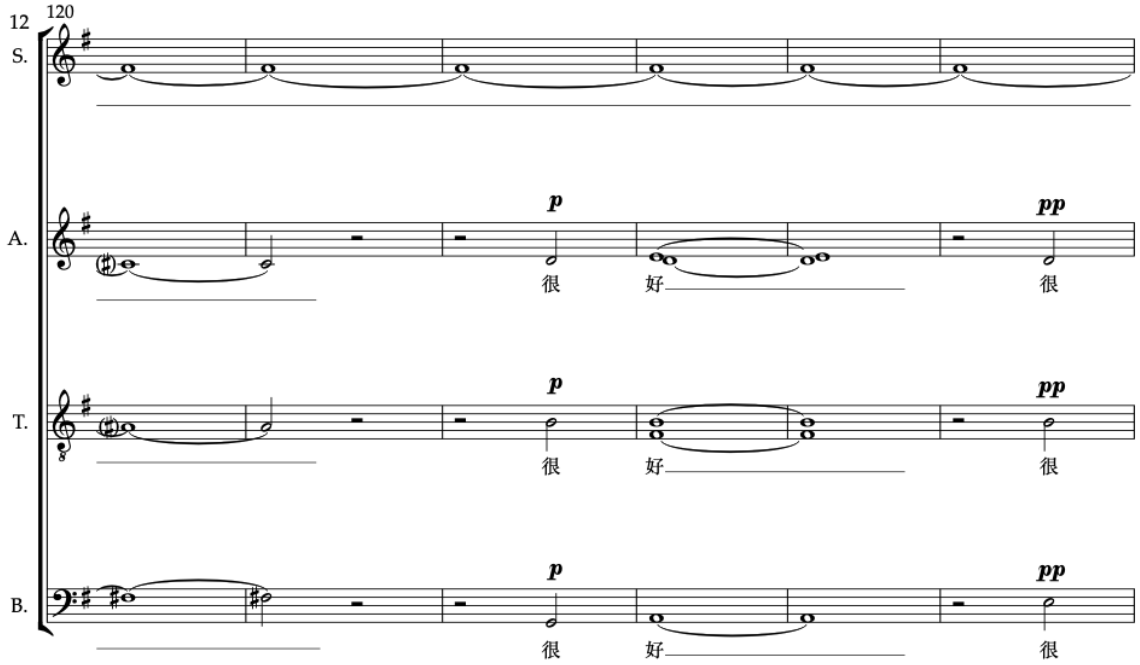

82
D
9
S.
A.
T.
B.
mp
世 界 變 暗 了, 你 選 擇 了
世 界 變 暗 了, 你 選 擇
世 界 變 暗 了, 你 選 擇
世 界 變 暗 了,
stagger (B1 gradually joining B2)
(li - - - - - - - -
88
自 己, 的 命 中 註 定,
了 自 己 的, 選 擇 命 中 註 定, 你 做 到
了 自 己 的, 選 擇 命 中 註 定, 你 做 到
p
mp
- - - - - - - - - - - - - -

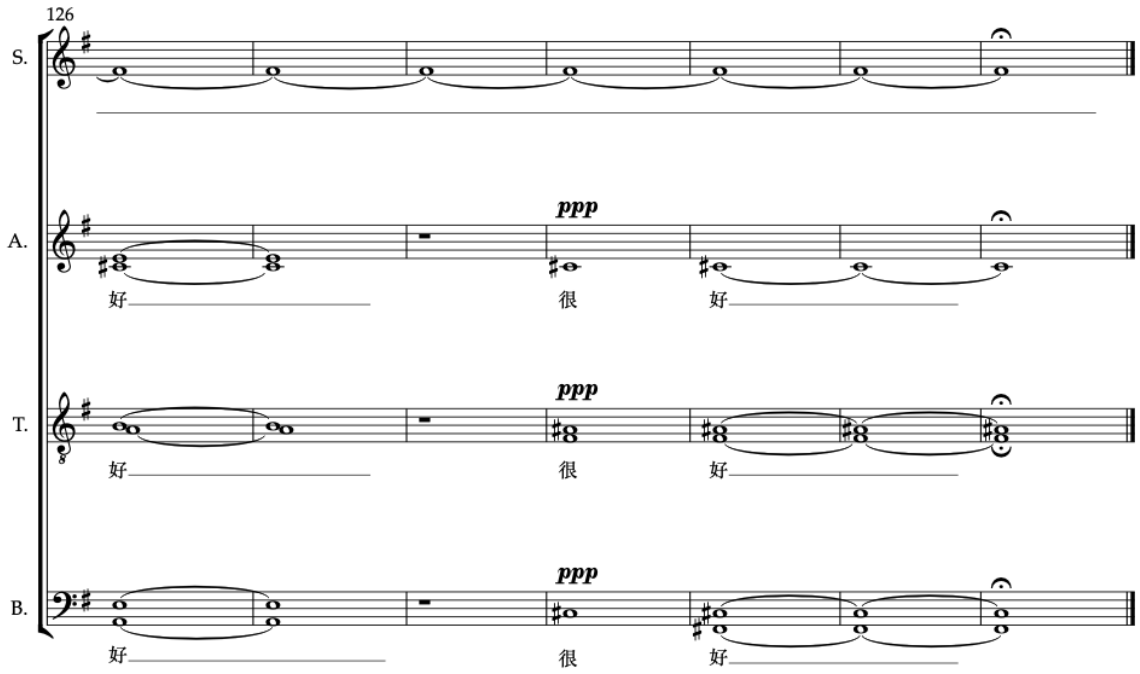

10
95
S.
A.
T.
B.
mf
p
讓 自 己 摧 毀 屬 於 自 己 的
了 摧 毀 屬 於, 自 己 的
了 摧 毀 屬 於, 自 己


101
S.
A.
T.
B.
mp
p
pp
stagger
甜 夜, 甜 夜, 甜 夜
甜 夜, 甜 夜,
留
(B1 cont. stagger)
u5)


107
11
S.
A.
T.
B.
一 個 光 天 化 日 給 伊 卡 洛 斯 伊 卡 洛
一 個 光 天 化 日 給 伊 卡 洛 斯 伊 卡 洛
一 個 光 天 化 日 給 伊 卡 洛 斯 伊 卡 洛
一 個 光 天 化 日 給 伊 卡 洛 斯 伊 卡 洛


113
E
stagger
mf
mp
S.
A.
T.
B.
腹 部 開 始 暖 和 了,
斯 腹 部 開 始 暖 和 了,
斯 暖 和 了,
斯 暖 和 了,


12
120
S.
A.
T.
B.
p
很
好
pp
很


126
S.
A.
T.
B.
ppp
好
很
好

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