

A Tale of Chaos and Convergence

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A few links

[Code repository](#)
[Direct link to the notebook](#)
[Visualisation](#)
[Composition](#)

Milestone 1

Overarching Inspiration

The piece is a study of the duality of chaos and convergence through the lens of the narrative scheme. In the same way as a disruptive element induces peripeteia leading to a resolution, a chaotic unit morphs and develops before converging again.

Final piece description

Chaos can be depicted in various ways, one of which is destructive disorder and randomness, nonetheless, the notion of chaos is always defined as opposed to some notion of convergence, we will thus also focus on chaos as remoteness from normality. To express this, the piece will be constructed so as to mirror the classic quinary narrative scheme.

As such, the *exposition* starts with Brownian noise to which are gradually added notes from some known melody, say: Ravel's Boléro, following the metrical structure introduced in the lecture about time and rhythm. This is, in a sense, calm before chaos, anchoring the listener to a familiar theme to emphasize its looming disruption.

Chaos, the *disruptive element*, comes into play by successively: sporadically removing rhythmic values, sustaining all the notes for a longer duration up to the half note or more, then removing melodic attributes, restraining their range down to a note different than the tonic, progressively forgetting the initial piece's theme, and finally replacing the original piece's orchestral timbres by less conventional tone colours, perhaps urban sounds, to signify the definitive transition into chaos. This second part has been constructed to make the listener lose their balance, abruptly going from a known melody to a rhythmically simplified theme, and then finally into urban sounds. This sudden transition makes it all the more alienating and forces the listener to fully experience the emergence of chaotic elements.

The next part, rising action, sees the morphing of the denatured theme into urban noises. Chaos being the disrupting element, this section should empower it and lend it its more conventional form as disorder and randomness. The choice of the symbolic of a traffic jam, associated with mayhem and agitation was orchestrated so as to make the listener connect with the above-mentioned definition.

Then, the rhythmical and melodic aspects reconverge to a new theme resembling the original one, symbolising narrative *falling action*. This convergence is done in two parts. Firstly, the rhythm converges to a cycle after some polymetric irregularity, then the melodic aspects of the theme come back on top, with the original tonality first. This should bring back peace to the listener, finding some sense in what had become gloomy, stressful music.

Finally, the piece converges to a *narrative resolution*, exposed for some measures before fading out. Resolution should bring satisfaction and a sense of finality, reaching some state derived from the initial

situation and theme, as a protagonist remembering the time before their adventures.

References

Max Richter’s *Recomposed by Max Richter: Vivaldi - The Four Seasons*, in particular, *Spring 1*, is an inspiration to this piece as it has given the idea of selecting themes from an original piece then trying to reconstruct that piece from these themes. This confers the piece a minimalistic setting, emphasized by the urban samples, shared with *City Life - Check it out* by Steve Reich. Another common trait of this piece and Steve Reich’s is the piecewise rhythmic regularity imposed by the *Boléro*.

In the following part, among other things, we will explain how we have created chaos then made it converge through the use of a carefully chosen L-system.

Milestone 2

I. A brief overview

Three distinct procedures enable us to achieve the desired effects.

Firstly, **Brownian motion** encompasses the exposition’s mellow beginnings and the story’s disruptive element. Indeed, this random process is able to evolve very progressively and naturally and is thus very much adapted to our storytelling needs. This is also why Markov chains were overlooked as they would not have that evolutive property we are looking for.

Secondly, we introduce the **L-System**, firstly used for the deconstruction of rhythmic regularity and then its reconstruction. It is symbolically important to use one procedure for both tasks, thereby representing the duality of chaos and convergence: this tool can achieve chaos, all the while giving enough control and creativity to the user so they can seek convergence, as demonstrated in II.4. This incomplete control lent by L-Systems is more fine-grained than a neural network’s, which we could have used too at the cost of less creative freedom.

Lastly, a **decision tree-based harmonization utility** was programmed for the *peripeteia*’s second half. We seek harmonic complexity in the descending arc of the narrative scheme to contrast with preceding urban dissonant and ambient sounds. This can be handled by the utility we have developed, which is meant to be a composer’s toolkit with abilities to activate and deactivate chord transition parameters. Therefore, the decision tree and the L-System abstraction cooperate to create the resolution and the finale.

Let’s dive in!

II. Subsections

1 Exposition: Brownian noise

1.1 Setting the stage

As implied by its name, the main motivation for the exposition is to set a stage, in our case, following the classic narrative scheme, this stage ought to be calm and peaceful. After some discussion, we turned our focus to Gaussian noise, a general type of statistical noise. Recent research showing its benefits on quietude guided our choice of this type of noise.

Our first idea was to sum a series of sine waves, rescaled accordingly to a Gaussian distribution (equation below) but this fell short due to the computational complexity generated.

$$\mathcal{N}(\mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$$

The solution was to start in the frequency domain, have vector values to sample the human hearing range and rescaling them depending on the required sound colour (e.g. $1/\text{frequency}$ for pink noise). We then simply used an inverse Fourier transform to go back to the time domain.

[Code and more explanation for Brownian noise.](#)

Once we had the Gaussian noise in place, we still needed to choose [which type of Gaussian noise we wanted to use as exposition in our piece \(code\)](#). To make this choice, we decided upon a list of criteria the noise should follow in order for it to qualify as what we consider to be a fitting introduction :

1. the noise should make the listener feel at ease
 - the timbre shouldn't be too "aggressive"
2. a sense of calm should emanate from the noise
 - ideally giving some reminiscence of the sounds of nature

These notions are obviously quite subjective but through trial and error, testing different "powers" of Gaussian noise, we found that noise with power 2 (spectrogram below) more known under the name of Brown or Brownian noise, followed our criteria nearly perfectly. Brownian noise is fairly well known for its calming effect and has some hints of the sound of breaking waves or that of wind. Other types of noise, in particular white noise and pink noise, were disqualified as they didn't induce the wanted effect on the listener due to their harsher timbres.

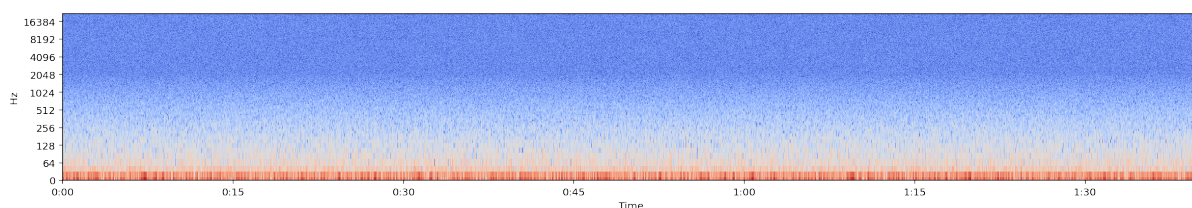


Figure 1: setting the stage with brown noise

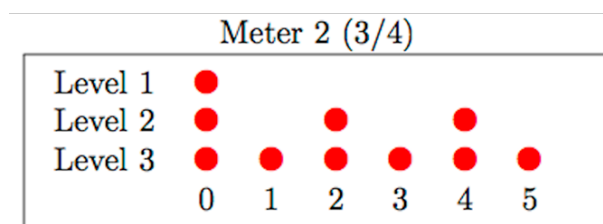
1.2) Transitioning to the Boléro: Convergence

After having set a stage in 1.1, we further delve into the exposition by establishing some zone of comfort, an echo of life before the advent of the disruptive element. Our approach to retranscribe this sense of calm before the chaos is to accentuate the imminent disruption by anchoring the listener to a recognizable melody.

We nevertheless cannot simply start playing the *Boléro*'s theme as this abruptness would clash with our objective to imbue the listener with a sense of calm. How then should we gradually introduce the melody?

Our approach was to use the [metrical structure \(code\)](#) as a guide to add notes with a certain probability whilst inducing some sense of convergence.

Thus, starting from our Brownian noise, we introduce the melodic theme of the *Boléro* by gradually adding notes following the metrical structure for a **3/4 meter**. The "number" of levels a quarter note gives us its relative probability, a probability which we increase more and more during the iterations.



After testing different speeds of melodic convergence - governed by the increase in probability at each iteration - and settling on one that kept the listener guessing long enough to satisfyingly experience the arrival to the *Boléro*, we were not happy yet and wanted to make the convergence even smoother by working in the timbre domain. A snare drum was thus sampled from the Gaussian noise and its volume decreased at the same rate as another real snare drum's volume increased. Flutes are sampled and pitched from brown noise in a similar fashion, additionally applying a low pass filter with increasing cut-off frequency to approach more and more the actual range of a flute.



Figure 2: melodic convergence

Though not quite as impressive on a score, in our opinion, the outputs of the convergence part truly give the listener a sense of fulfilment and of proximity deriving from the expectancy dynamic instilled by the algorithm used.

2 Disruptive element: Brownian motion

Following the quinary structure, the calm established in part II.1 should be perturbed by some disruptive element. Our quest is to achieve chaos by showcasing its duality, in this part, we thus consider chaos with respect to its definition as a departure from normality - normality being the *Boléro* in this case. We aimed to strip the track off of its recognisable musical attributes by diluting rhythm and melody

concurrently but independently, and this was made possible by Brownian motion.

The first step was thus to be able to [create Brownian motion in several dimensions and with several parameters \(code\)](#) among which the starting values, the number of timesteps and the time horizon of the motion.

The [Boléro's deconstruction \(code\)](#) mirrors its construction. Firstly, The stochastic process was used to remove sporadic rhythmic values by slowing down the notes. Indeed, the *Boléro*'s theme is immediately recognisable by its bold repeated triplets and the listener should be unsettled when that is taken away from them. Then, the C major melody is forgotten amidst dissonances appearing in increasing frequency to further the listener's anxiety. This is done by moving the melodic range away from the *Boléro*'s, actively pursuing this notion of chaos as a departure from normality.

We chose outputs for their abruptness and grittiness, to emphasize the listener's total alienation from the comfort achieved in part 1.

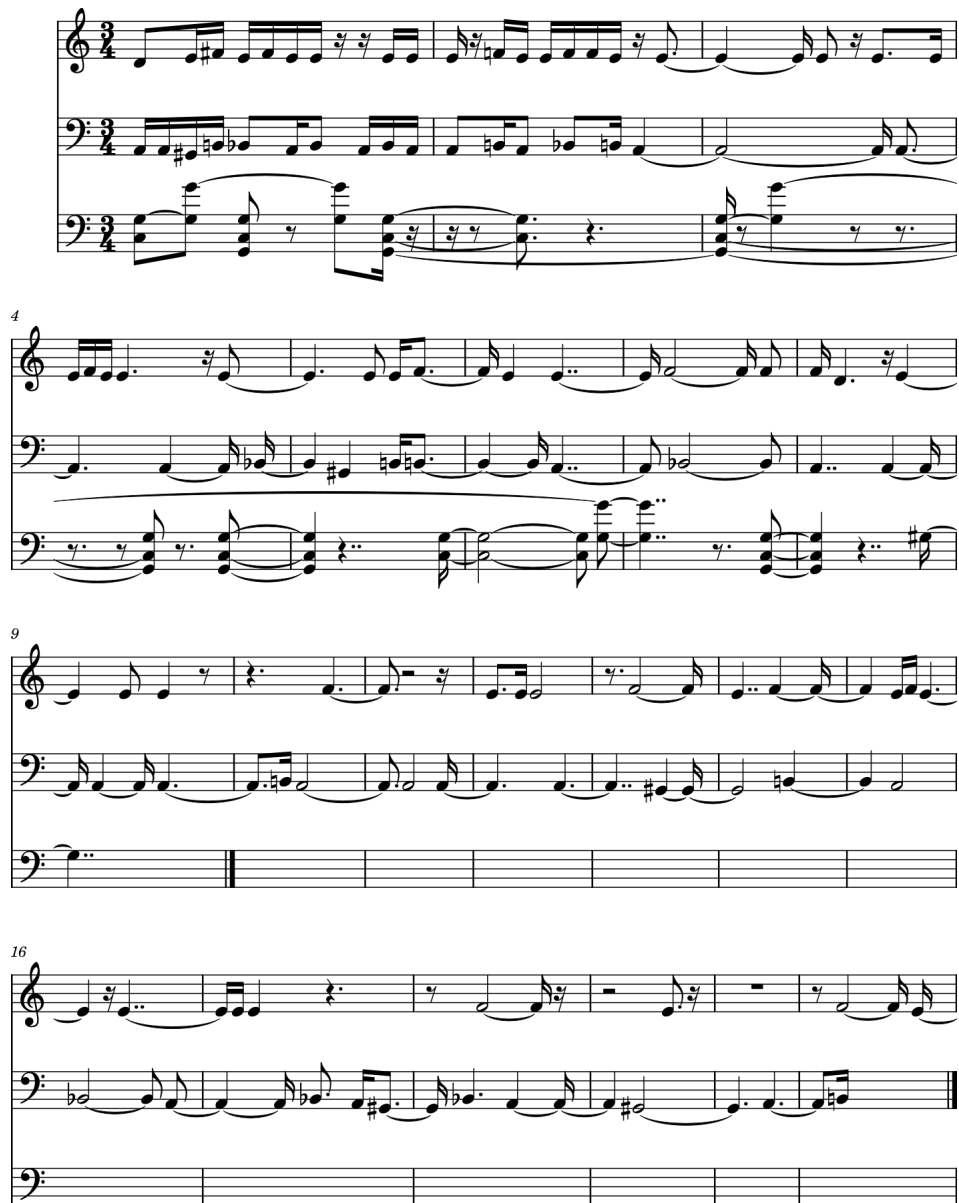


Figure 3: transition to chaos

3 Rising action: urban & drone

After encountering the disruptive element, the character's fate faces a steady shift for the worse. This turning point in the narrative structure is inherently chaotic as, through complications, it impedes the protagonist's journey. To retranscribe the peripeteia and consequent rising action, we thus again came back to the theme of chaos. Nevertheless, this time our approach to chaos was much more visceral than in part 2. This serves a twofold purpose, firstly that of making the listener fully aware of this sudden emergence of chaos, but also allowing us to show that chaos is multifaceted and can morph from a less recognisable state as in part 2 to a much more discernable one here.

The question remained, how could we depict this type of chaos musically. Our main ideas were to approach it either through the symbolism of the war or that of the city, two subjects intertwined with chaotic elements. We settled on the city as a much larger part of the audience could relate to it.

To transition from orchestral timbres to urban sounds, we had to impoverish the original sounds as swapping the instruments abruptly did not fit the composition. To do so, we tweaked multiple parameters gradually : - shortening the notes' lengths - adding a bit of attack - lowering the sustain - detuning notes randomly - crushing the sound - filtering the sound

The first three options reduce the space taken by the instruments to make the transition smoother, while the last two change the timber. The fourth change is here to help to feel that the track loses itself a bit. These changes are done in a DAW, but some could have been generated by the code below :

```
def random(max) # returns a random number between 0 and max

def shorten(note : Note, duration : int)
# to shorten a note by a specific duration

def shift_pitch(note : Note, cent : int)
# to modify the pitch of a note by a number of cents

def impoverish_notes(stream :\\ Stream):
    ratio = 0.1
    mean = 0
    range_rng = 10
    for (note,i) in (stream, range(stream.length)):
        # notes get shortened more and more
        shorten(note, random(mean)*ratio)

        # each 10 notes, the random pitch shift gets more intense
        shift_pitch(note, random(int(mean*ratio))*range_rng)
        mean += 1
```

We then progressively insert city noises (the roaring sound of a motorbike, car horns, a train whistle...) whilst fading out the orchestra until only a city-like atmosphere remains.

4 Falling action: convergence through harmonisation and L-systems

The previous part has seen a descent into chaos in its usual form, represented as urban noise. This part will seek a progressive return to senses and normality. It is conceptually divided into two parts: melody densification and rhythm construction. The aim is to progressively return to what is considered order in the story, the *Boléro*.

Rhythm-wise, we've implemented a [general L-System class \(code\)](#) that evolves an input string according to input rules into a new string. To turn the string yielded into an actual rhythm, we [attach to each character a musical significance \(code\)](#): letters correspond to durations, and non-alphabetical characters act on these durations: they can turn durations into rests, join them, split them in two, etc.

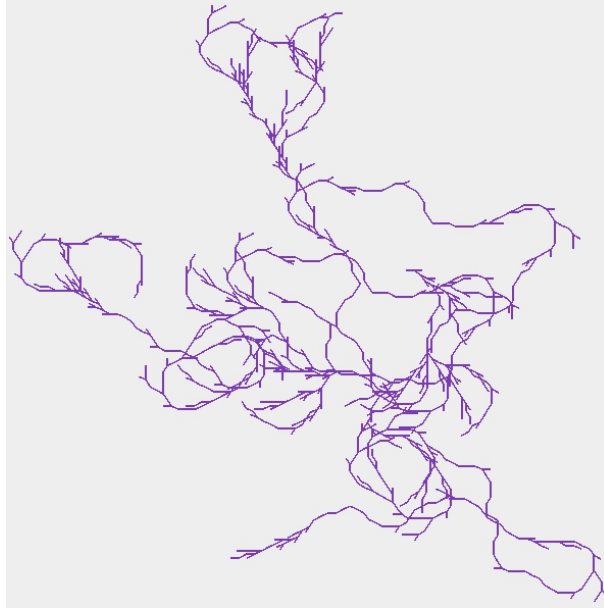


Figure 4: complex L-System

For the melody, we have developed a [harmonisation tool \(code\)](#) that takes as input a key and a bass line, along with one starting chord. From these inputs, it generates a tree of chord transitions and successions, that we call a **composition tree**, with the help of recursive methods, dynamic programming and harmonic rules coded in to make the melodic lines remain consonant. Once that tree is obtained, a [path can be selected inside of it \(code\)](#), in our case, randomly. For the entire harmonisation part, we first designed a [succession of keys \(code\)](#), each one with a specific bass line. Then, [we successively generated the compositions for each key \(code\)](#).

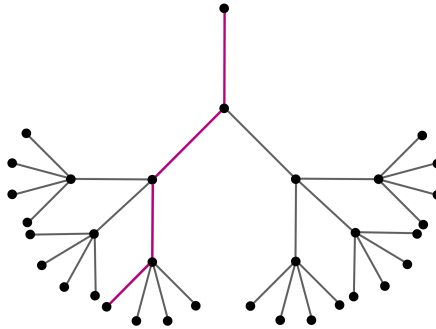


Figure 5: composition tree

Our original idea was to implement more complex chords with inversions and sevenths or ninths. However, we finally decided to concentrate on chords in the fundamental state, thus focus on complexity in terms of keys and not principally in the chords themselves. To that end, we chose a succession of keys with increasing key change frequency, climaxing to the E Major and returning to C Major, like Ravel's *Boléro*. In this way, we keep the essence of the original piece, and by extension the underlying narrative structure.



Figure 6: composition

5 Narrative conclusion: resolution through L-system

After the complexification induced in part 4, the last part of our piece mirrors the denouement of a narrative piece. This resolution is done by the rhythm converging to that of the *Boléro*. This convergence is then followed by a *tutti* in E Major.

To implement this rhythmic convergence, we reused the **L-System** functionalities already implemented (code).

In the same way as the protagonist’s identity follows them throughout the story, the *Boléro*’s theme works as a red thread through our piece.

The musical choices for this part were done to emphasize the protagonist’s reflection upon their adventures and recent discovery, leading up to a realisation embodied by the *Boléro*’s main rhythm. We implemented such a “realisation” to mimic the anagnorisis, key part of the classic narrative structure whereby the protagonist becomes aware of their circumstances or their true identity. On the way, they had distorted thoughts represented by 32nd notes in the rhythmic convergence. Then, the resolution happens in the form of chords in E Major derived from the *Boléro*’s initial state, symbolising a return to the initial situation with a twist, as the protagonist learnt something from their peripeteia.

Outlook

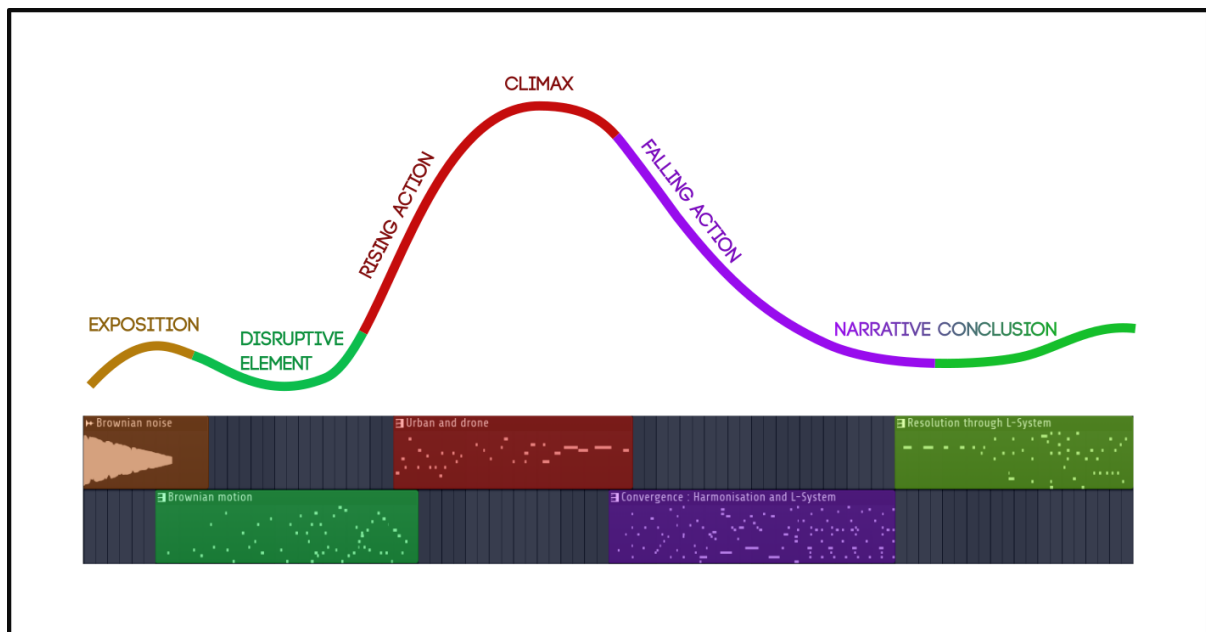
The duality of chaos and convergence permits us to express a range of emotions and events, allowing us to mirror the narrative structure. Each algorithmic method we have crafted was used for expressing both order and destruction. Transitions are embedded within the substructures as they merge into each other.



Figure 7: rhythmic convergence

III. Discussion & Critique

1 Visual representation



The first picture is an overall representation of the piece, along with the quinary structure reference.



The second picture is from **Fruity Loops 20** where, in the timeline, each box corresponds either to piano rolls of multiple instruments or to audio clips and automations.

During the introduction, we added a sampled flute and snare from Brownian noise to introduce the real ones smoothly. We can see their piano rolls on the top left of the Timeline. We also automated filters on the Brownian noise to make the intro more interesting.

In part 3, in the urban sounds, instruments' timbres morph into chaotic urban noises, e.g. a train whistle replacing the lead flute. To introduce the falling action, a ringtone is played (line 5 in the middle of the Timeline). It adds impact to the transition.



Besides, the **finale synth** in the previous screenshot is better represented in the last picture as it was created in another daw.

For this last screenshot (parts 4 and 5), deviating from our original plan, we decided to add the bass synthesiser (blue audio clip) to make the transition between the urban sounds and the quartet smoother, relaying into yet another synthesiser (click bass).

Finally, for the *tutti* that occurs after the snare drum's converging *crescendo*, we tried various instruments, but at the end, settled on a brass ensemble, the *pizzicato* of strings and the snare drum. It is this combination of instruments that provides us with a clear and dense, but not too strident sound.

2 Feedback

One point on which we dedicated a lot of time was the transitions between the different subparts. Indeed, due to our mostly linear structure, we were warned that the piece may feel like a juxtaposition of seemingly unrelated parts. This work on the weaving of the different subsections to keep some red thread through the entire composition seems to have been a great success: all the feedbacks we got positively mentioned the transitions.

Nevertheless, staying pragmatic, our complete overarching inspiration could hardly be guessed at by simply listening to the piece. Indeed, as the feedback we got shows, though the notion of chaos and convergence is quite limpid through the composition, the underlying quinary structure could be quite hard to detect without prior knowledge of its presence. Though we expected this to some extent, in hindsight, the fact that nearly nobody would think about somewhat of a more literary structure when listening to a musical composition is not truly a surprise.

3 Creative process

On one hand, it was challenging to come up with interesting compositions algorithmically. All of our methods contain some degree of randomness, and directing randomness is always a challenge. For these reasons, making melody and harmony converge to some set theme through an **L-System** and the harmonisation tool proved to be difficult, as there would have been too many details to fix after running such

an algorithm. Also, it did not fit in the narrative structure. This hastened the currently only partially satisfying *tutti* at the end.

On the other hand, algorithms gave reproducibility to our composing process: since we had access to the algorithms that composed the piece and not solely their outputs we could much more faithfully trace back and modify the ideas overarching the composition.

As such, rather counterintuitively, all these additional constraints helped spark our creativity and truly follow our overarching inspiration.