Immersive spatialized live music composition with performers: a case study, *Le vent qui hurle*

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***Abstract*— This article presents reflections on theoretical and practical aspects of the composition of immersive spatialized live music with performers through a case study, *Le vent qui hurle*. This is a piece written for the *Ensemble d'oscillateurs* founded by Nicolas Bernier at the Faculty of Music of the University of Montreal, semi-modular analog synthesizers, metal sheets and sound spatialization. Initially, I present the research context, discussing the concepts of spatialization and immersion within the frame of live music. I then examine how compositional intentions can be related to the composition of the sound space. I later discuss the relationship between sound and space by introducing spatial attributes and spatialization strategies. Then I illustrate the context in which the piece was created, covering the rehearsal period and the writing of the score. I then present the immersive, spatial and musical composition strategies I used in writing the piece, illustrating techniques that explore the relationship between analog synthesis and the composition of sound space and the relationship between the spatialization created by speakers with the spatialization created with acoustic sources. Finally, I outline future developments. The perspective of this article is mainly oriented toward the compositional dimension and not the technological dimension.**

Keywords*— *immersive spatialized live music composition with performers, composition, music, immersion, live concerts, spatialization, spatialization control, electroacoustic music notation, modular synthesis

I. The research-creation context: spatialization and immersion in live music with performers

In this article I discuss theoretical and practical issues concerning the composition of spatial immersive live music with performers, presenting a case study, *Le vent qui hurle*. It is a piece I composed for the *Ensemble d'oscillateurs* founded by Nicolas Bernier at the Faculty of Music of the University of Montreal, semi-modular analog synthesizers and metal sheets. The point of view of the article is mainly oriented towards the dimension of musical composition and not the technological aspects.

The research-creation context is that of spatialization and immersion within the frame of live music. In this perspective, space is considered a compositional parameter in the same way as pitch, intensity, rhythm and timbre and not as an effect to be added at the end of the creative process [1]. In this framework, the space is conceived from the earliest stages of the creative process. Spatialized music composition is a context "where musical ideas explore the complete dimensionality of space" [2].

For this work in particular, I am referring to those situations in which sound materials are produced by both loudspeakers and acoustic instruments/devices. As far as sound diffusion systems are concerned, I'm referring to loudspeaker configurations such as domes that extend over three dimensions and not to stereo sound diffusion systems. Spatialization is intended as the projection of sound images, known as phantom images, by means of diffusion through several loudspeakers [2].

My motivations for using space as a compositional parameter depend on perceptual and aesthetic reasons. Spatial auditory perception enables us to hear the sounds all around us (including behind and above us). The auditory scenes that are part of our daily lives are characterized by multiple sound sources positioned in three-dimensional space and moving in multiple directions. It's also important to consider the complex relationship between acoustic sound and the space in which it propagates [3]. The presence or absence of this complex relationship lets the listeners know whether the sound they hear, for example, a piano, is acoustic or recorded. A mono or stereo recording will not be able to capture all the spatial cues that characterize the propagation of an acoustic sound in space.

The aesthetic reason why I chose to work with spatialization lies in the intention to create an immersive, visceral artistic experience. The idea is to envelop listeners in a sound world that can evoke emotions. That said, can the use of a three-dimensional sound system guarantee the evocation of a sense of immersion in the audience? To answer this question, it's useful to define immersion. This concept is a keyword in the contemporary art context, and this term is sometimes used with different meanings. The definition given by Agrawal and Bech is useful in framing the work I present in this article: "Immersion is a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive processes (with or without sensory stimulation) cause a shift in their attentional state such that one may experience disassociation from the awareness of the physical world" [4]. It is possible to be immersed in reading a book without needing to be surrounded by technological devices. Immersion is a subjective and psychological experience. Technology and/or content can influence this psychological experience but cannot do so independently of the person who is having this experience. Agrawal and Bech [4] indicate five factors that can influence the sensation of immersion:

- The system: which in the case of a music concert can be the sound diffusion system.
- The narrative: which in the case of a music concert can be (but is not limited to) the musical content.
- The physical environment and contextual conditions: which in the case of a music concert are the

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contextual conditions in which the work is presented. For example: is it a theatre or an open-air urban setting? Is the hall reverberant? Are there performers on stage? What is the distance between the stage and the audience? Are the spectators seated or can they move around? And any other element of the context.

- Individual factors: they refer for example to the public's predisposition.
- The interaction between the individual and the experience: for example, how significant the content of the experience can be to the individual.

Referring to this paradigm, I discuss below the choices made within the context of *Le vent qui hurle* regarding the first three points.

The chosen system is a dome of speakers which is a three-dimensional sound diffusion system. Although the use of a three-dimensional sound system does not guarantee immersion, this type of configuration can help in evoking it. In the case of this piece, loudspeakers are used to diffuse the sound materials created by the ensemble playing semi-modular analog synthesizers.

Concerning the musical content, I decided to compose a spatialized music piece inspired by a natural immersive phenomenon such as the wind. The concept and the compositional choices will be detailed in the next paragraphs.

Concerning the contextual conditions, I decided on an occupation of the space by the musicians that aims to reduce the distance between the audience and the performers and to elicit a reflection on the ritual of the concert. In respect to this, Pedro Rebelo points out how eliminating the clear separation between stage and audience can foster a sense of immersion in the audience, as listeners are invited to feel "a participatory and active part of the environment as opposed to being a passive agent" [5].

Still talking about contextual conditions, it is important to be concerned with the spatial arrangement and behaviour of every element that may be part of a compositional work, including the system and the content. It is possible to compose the space in a live music context taking into consideration the possible presence, position and movements of the following elements:

- sound materials diffused by loudspeakers
- sound materials diffused by instruments and physical devices
- video elements
- performers
- conductor
- public
- loudspeakers and their configuration
- visual aspects (tables, scenic objects, etc.)
- lights
- the type of the venue and its acoustic characteristics
- the relationships between all these elements.

In the initial and final sections of the *Le vent qui hurle*, some of the performers move around the audience walking and playing metal sheets, with the idea of enveloping the spectators and reducing the distance between the listeners and the performers. The idea of the musicians walking while playing was inspired by Pierre Michaud's ... *niente* ... [6], a piece for amplified string quartet and audio-visual device, composed in 2018. In this work, the performers occupy different positions depending on the section of the work and play instruments as they move. Michaud's idea was to create a unique experience for the audience by changing the ritual of the concert, for example through the performers' displacements [7]. For a historical review of spatial arrangement in the context of concerts with an ensemble, see, for example, Jason Wyatt Solomon's doctoral dissertation [8].

Having defined the general framework of spatialization and sound immersion in the context of live music with performers, I now examine the conceptual elaboration phase that can initiate a composition project.

II. Compositional intentions and spatial intentions

Concerning sound spatialization, I've often wondered about the choices that should guide the composition of the space. Why put a sound in one position rather than another? Why use one trajectory rather than another? There is certainly no single answer, and probably no right or wrong answer either, but considering space a parameter of composition, I believe that space strategies fall into the more general category of composition strategies which can depend probably on the intentions and concepts that can get a creation project started.

A. Compositional intentions

The conceptual elaboration stage, like the entire compositional process, can be seen as an intimate cognitive act. Nicolas Donin, in a musicological study [9] about this process, indicates how composers can adopt two different approaches to conceive a work. The first is *synoptic planning*, in which composers enact certain global concepts that guide the evolution of sound materials. The second is a more instinctive approach characterized by *the primacy of heuristic ideation*, where the properties of a work are defined all along the writing process. These two approaches can coexist and complement each other. Whether the approach is more planned, or more instinctive, the composition of music is usually guided by certain intentions. For example, a piece of music can be composed with the intention of:

- Evoking/exploring
  - a concept/idea
  - an entity (an animal, a person, a robot, a group of them)
  - an idea
  - a feeling
  - a political subject, a historical fact
  - a phenomenon of nature
  - a soundscape
  - a physical/sound material
  - a form/structure (musical or derived from other domains)

    - a composition technique
    - an instrument/device
    - a system
- Creating a device and exploring that device
- Creating a system and exploring that system.

This is a non-exhaustive list[1], and various intentions could cohabit in the same composition project. Once the initial intentions have been established, composers could consider which composition strategies and which technologies to use. They also could decide if using a three-dimensional diffusion device with immersive potential, and which spatialization strategies and arrangements to use. If the goal is to compose an immersive spatialized piece, one might ask if the choice of a starting concept with a spatial/immersive reference could foster the creation of an immersive listening experience. Some starting concepts might probably offer particular properties suitable for spatialization work. For example, Barrett, in the program notes of Hidden Values [10] states: "I chose themes that would yield to the compositional use of space, the projection of near and far information and the transformation between sound masses, sound scenes and precise spatial points". Or to cite an example from my works, I decided to compose a piece of immersive acousmatic music inspired by the king cobra, *For Hannah* [11], because the sounds produced by this snake could easily evoke sinuous, enveloping circular trajectories. What's more, their hissing sounds are easily localizable, since human beings have developed a very good ability to spatially locate sounds that may refer to danger [12]. I was also inspired by the way they behave when threatened: they raise their body, assume the so-called hood position and hiss loudly [13]. Inspired by this behaviour, I created a sound space characterized by sudden and enveloping movements of the sound materials.

In the case of *Le vent qui hurle*, the inspiration comes from the wind, when it whistles loudly. The idea is to evoke this unpredictable, immersive spatial natural phenomenon and its sonic characteristics. From a broader point of view, the intention is to highlight and question the tension between human beings' desire for control and nature's uncontrollability[2]. Wind makes spaces it encounters resonate. Air currents cause the materials to vibrate at different speeds, creating sounds of various kinds at various pitches. One can think of the sound of tree leaves or window glass moved by the wind. When the speed of the passage of air currents is high, the wind causes sounds characterized by a high-pitched tone that can resemble howling. That is the wind howling, *Le vent qui hurle*. The idea is to be guided in the creation of materials by the unpredictable sound and spatial behaviour of the wind when it whistles loudly. I made numerous recordings of this phenomenon. I analyzed its spatial-morphological variations for inspiration in writing the musical parts and their spatialization.

B. Spatial intentions, composing the space

Once the intentions have been established, it is possible to consider the strategies for composing the sound space to realize the intentions. But before talking about spatialization strategies, it can be useful to address some questions about the relationship between sound and space.

1) Space and sound

Probably, every time music is composed, space becomes part of the factors involved, if space is considered a musical parameter. But even if we do not start from a perspective in which space is considered a parameter of composition, sound and the act of listening can still always be considered spatial [5]. For example, by simply establishing a figure/background relation in an orchestration, one can also establish internal spatial relations within a work, e.g. by deciding to foreground one sound element over others. Furthermore, a sound work will be influenced by the context of its diffusion, e.g. the acoustic characteristics of the venue, as already discussed. According to Chion [16], there are two spaces concerning acousmatic concrete music: an internal space within the work set by the composer and the external space in which the work is performed in a concert. Translating this to live music context, we could consider a written score as a way of fixing the sound and thus the space beforehand. But for example, in the case of algorithmic composition sound, and thus the space, may be different at each new iteration of the work. Furthermore, in the internal/external space relationship in live music, the presence, position and possible movement of the performers must be taken into account. These factors can be fixed in a score, but performers, especially if they play acoustic instruments/devices, interact with the acoustic features of the concert space and the other contextual elements. All the elements[3] that are part of a work should harmonize with each other every time the work is performed, according to the different presentation contexts. As Emmerson [17] points out, an interpretation of the work is necessary.

The relationship between a work and its presentation contexts can take different forms concerning issues of adaptation and portability. One can think of portable works that can adapt (probably more or less) to any presentation context. For example, the reproduction of an acousmatic stereo track is potentially possible in any context in which a stereo speaker system is present. Of course, the piece will always sound different, depending on the acoustic characteristics of the venue and because of the eventual interpretation of the piece at the diffusion console. The diffusion of an acousmatic multi-channel work, on the other hand, requires a loudspeaker system that extends at least on the horizontal axis (e.g. a quadraphony or an octophony) or even on the vertical axis (e.g. a loudspeaker dome). A specific multi-channel render must also be prepared according to the loudspeaker configuration available in the presentation contexts. A piece characterized by performers, their movements, and visual elements will probably require more tuning work compared to acousmatic diffusion. Also, on some occasions, one can compose for a specific space, the context in this case affecting the compositional work and the

[1] The list comes from the class *Atelier de composition électroacoustique* that I taught in 2022 at the University of Montreal. It is inspired by the teaching materials created by Nicolas Bernier and Ana Dall'Ara-Majek.

[2] This theme has characterized some of my works for years, for example in *Inner Out* [14], *For Hannah* [11], *Expansion* [15].

[3] These elements are those mentioned in section I as factors to consider when composing the space in live music.

compositional work affecting the context. In 2021, I composed *Rebonds* [18] for the sound window of Sporobole, a contemporary art centre in Sherbrooke, Quebec, Canada. The sound diffusion system of this center consists of sixteen speakers installed side by side on the exterior façade of the centre. The sound works are played throughout the day and blend into the existing urban soundscape. The soundscape and the type of device had a decisive influence on the composition I created. I aimed to create a sound work that would harmonize and dialogue with the existing soundscape and take advantage of the particular arrangement of the loudspeakers.

In the case of *Le vent qui hurle*, I composed the piece taking into account its initial presentation venue, the Claude Champagne Hall, together with its long reverberation, its lighting, the arrangement of the audience's seats, and the general atmosphere in the hall.

2) Spatial attributes

When composing a sound space, it is useful to keep in mind spatial attributes, which define the relationship between listeners and the sound scene they are listening to. James [19] proposes a classification that brings together concepts developed by various researchers. James divides the spatial attributes into dimensional and immersive. Dimensional spatial attributes include the width, distance and depth [20], direction and height [21] of a sound source. Concerning immersive attributes, Rumsey [20], and Sazdov, Pane, and Stevens [22] indicate spatial clarity, envelopment and engulfment. Spatial clarity refers to how easy it is to identify the location of the sound sources that compose a spatial sound scene. For example, therefore, one can compose space having the intention of making polyphony clearer and more intelligible by distributing various sound sources in different parts of the space. It must be kept in mind, however, that if an orchestration is to be understood as such, spatial proximity can help perceive various sound elements as being part of a single orchestration [23]. Orchestration and spatial clarity are therefore two aspects to be considered together. Envelopment refers to sound content that envelops the listener along the horizontal axis. Engulfment refers to sound content placed above the listener. The sensation created is that of being covered by the sound. We can think of envelopment and engulfment as two specific spatial attributes of immersion[4]. The distinction between envelopment and engulfment is proposed by Sazdov, Pane and Stevens [22].

During the composition of *Le vent qui hurle*, I took into account the dimensional and immersive spatial attributes of the acoustic sound sources and those diffused by the loudspeakers. For example, thanks to the movement of the performers who play the metal sheets, I was able to explore the depth and distance of acoustic sources. Concerning the width and the height of synthesis sound sources, for most cases, the width corresponds to a quarter of the circumference of the dome of speakers, while the height corresponds to a third of the elevation axis of the dome (fig. 1). The size was controlled by SpatGRIS, the spatialization system which is presented in section IV. Sources with similar sound content were sometimes used to create even bigger images. The size was chosen to take into account the maximum number of available sources, i.e., 10. When these sources are all present, they are generally distributed four in the lower part, four in the middle part and two in the highest part of the speaker dome (fig. 2). In section V, I will detail compositional choices concerning the other spatial attributes.

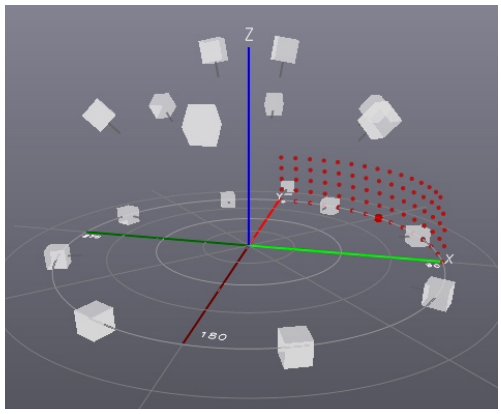

Fig. 1- Standard width and height of synthesis sound sources. Screenshot of the SpatGRIS spatialization system.

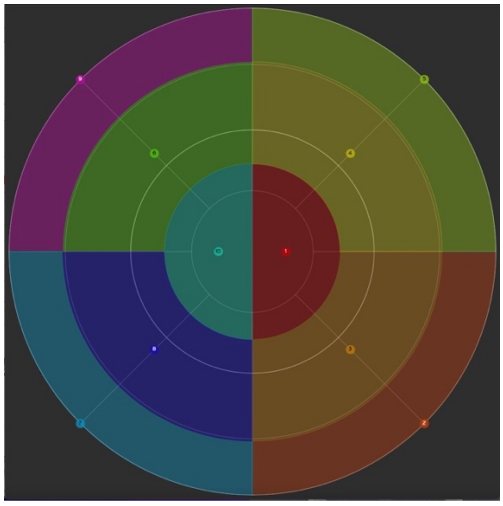

Fig. 2- Example of the distribution of the 10 synthesis sources, top view. Screenshot of the SpatGRIS spatialization system.

3) Spatialization strategies

Guided by compositional intentions, sound space can be composed using spatialization strategies. In this paragraph, I present some of the strategies developed by researchers and composers as part of their compositional practice. Some researchers propose models in this regard, e.g. Sazdov, Paine and Stevens [22], Baalman [24], Carpentier [25], and Rebelo [5]. These strategies also involve different ways of controlling spatialization: direct control by the composer, e.g. through writing automations in a Digital Audio Workstation, physical control through controllers, control through mapping, and control through machine learning strategies.

Evocation of a concept/phenomenon/model: Sounds are positioned and moved according to a model that can, or cannot, include spatial references. Examples of this strategy can be found in my piece *Eyes Draw Circles of Light* [27], where fast handwritten space trajectories are put in place to evoke the fast involuntary monuments that can characterize the moment when we are about to fall asleep. A special case of this strategy concerns when the spectromorphology of sounds is taken as a reference model. In this case, a spatial

[4]Here the term immersion refers specifically to the spatial attribute that combines envelopment and engulfment, while in Paragraph I, the term immersion refers more generally to the subjective and psychological experience.

variation, such as a space trajectory, can emphasize a spectromorphology variation, such as a musical gesture. For example, an increase in volume can be emphasized by a bottom-up trajectory. This is probably one of the most used spatialization strategies [26].

Mapping between spatial positions and data from a concept/phenomenon/model. In contrast to the evocation in the case of mapping, data can directly control the spatialization. One example is the work of Kim-Boyle, who uses an algorithm that recreates the flight characteristics of a flock of birds to drive spatialization. The algorithm is called *boids* and was implemented by Craig Reynolds [28].

Machine learning strategies that correlate a phenomenon/model with spatialization: Machine learning can be used to drive sound spatialization. For example, Einbond and al. [3], in the context of the creation of the work *Cosmologies,* created a system that uses machine learning and audio descriptors to relate the spatialization of input live signals to the radiation patterns of acoustic instruments.

Hyper-realistic landscape: This technique illustrated by Barrett [2] proposes a hybrid approach that integrates ambisonics and mono recordings. A spatial sound scene can be recorded simultaneously with an ambisonic microphone and mono microphones, allowing the total sound field and details to be recorded. The two kinds of recordings can later be recombined to obtain a hyper-realistic landscape. Barrett uses this technique in *Hidden Values* [10].

Soundscape recreation: This strategy refers to the placement of sounds in space to create a soundscape, either abstract or real, through the use of field recording or synthesized sounds. In the case of soundscapes made with field recordings, this strategy can recall Barrett's *Hyper-realistic landscape*. I used this strategy in its most abstract form in my piece *Rebonds* [18], where for the melodic, rhythmic profiles of the synthesis sounds and their spatial location, I was inspired by a real soundscape.

Images in space: This Barrett [2] technique involves the assembly of spatial sound images through the combination of individual sound sources. The aim is to represent the complex phenomenon of the propagation of a real sound source, which can also be in motion, in terms of its interaction with the environment and the listeners. A real sound source creates a complex sound image characterized by spectromorphological micro-variations, for example, concerning the angle and distance from the listener. Barrett proposes this technique as an alternative to point sources to better represent this complex phenomenon and thus be able to allude to the life-like character of real sound sources. Barrett uses this technique in *Dusk's Gait* [29].

Timbre spatialization: This technique proposed by Normandeau [1] involves the fragmentation of the sound spectrum into frequency bands that are spatialized in different parts of space. The aperture of the filters can be modulated in time. Normandeau uses this technique in *StrinGDberg* [30].

Decorrelation: This technique discussed by Kendall [31] involves the generation of multiple sound signals from a single sound. These signals have small differences between them but are recognizable as belonging to the same source. If these signals are arranged in different parts of space, the result can be a diffuse sound field. As an example of decorrelation, one can think of the technique of recording an identical vocal line twice to obtain a wider spatial image because of the small differences between the two performances.

Movement through the repetition of similar materials in different parts of the space: This technique involves placing spectromorphologically similar materials in different parts of the space. These positions are adjacent to each other. If similar sounds are repeated one after the other in adjacent positions, it is then possible to form spatial trajectories. I use this strategy in *Rebonds* [18].

Orchestral metaphor[5]*:* This technique involves using the different sectors of the sound space, or directly the loudspeakers that are part of a configuration, as if they were different voices of an orchestra. This technique can therefore be characterized by a very precise localization of sounds. Dall'Ara-Majek uses this strategy in the multi-channel versions of the pieces of the album *Nano-Cosmos* [32].

Spatial counterpoint: This technique involves using simultaneous sounds whose movements in space can be perceived as linked. I use this strategy in *Eyes Draw Circles of Light* [27].

Spatial call-and-response: This technique involves the use of sounds that are connected in a call-and-response perspective in different parts of the space. I use this strategy in *For Hannah* [11].

Now, I focus on which strategies can be used to try to foster immersion, which can be considered a combination of envelopment and engulfment at the same time. These strategies aim to stimulate the audience with the idea of "being enveloped and engulfed" by a sound. Researchers propose different strategies to achieve this. Barrett [2], in this regard, illustrates how Emmerson [17] indicates that to elicit immersion is necessary for sounds not to be clearly localizable. In contrast, Lynch and Sazdov [33] argue that the sources must be clearly localizable. Barrett, in light of these differences, proposes to take into account lateral reflections and late reverberations, to avoid spatial movements that emphasize spectromorphological variations, and to use a large number of sources so that listeners cannot focus too long on any one of them. Barrett also proposes to assume the perspectives of the listener and the composer at the same time. The composer used this approach in *Optical Tubes*, the second movement of *Hidden Values* [10]. As I already mentioned, also decorrelation could help create a diffuse sound field.

In the case of *Le vent qui hurle*, I was inspired by a natural phenomenon, the wind, concerning the composition of the spatial and spectromorphological behaviour of the sound sources. At some points in the piece, the idea is to recreate a windy soundscape. I made extensive use of decorrelation techniques, taking advantage of the specificity of modular synthesis, which makes it possible to create sources that are very similar but not exactly identical to each other. I also used *Movement through the repetition of similar materials in different parts of the space*, *Orchestral metaphor*, *Spatial counterpoint*, *Spatial call-and-response,* and strategies aimed

[5] This metaphor is used to indicate the idea of fixed spatial positions and not that of the orchestra of loudspeakers in the sense of an acousmonium.

at creating a feeling of engulfment, envelopment and immersion. In section V, I will detail how these strategies were used, highlighting their relationship to other compositional strategies. The next section focuses on a few aspects of the context of this creation.

III. *Le vent qui hurle,* the context of creation and the score

The piece was written for the *Ensemble d'oscillateurs* founded by Nicolas Bernier's at the University of Montreal's Faculty of Music. The performers were the students of the electroacoustic music ensemble class of the 2023 winter term[6]. The piece was premiered during the University of Montreal's *Ultrasons* concerts series on April 20, 2023[7]. These concerts take place on the stage of the Claude Champagne Hall, where a dome of 16 speakers and one subwoofer is installed, under which the audience is seated, oriented toward the side where the artists' performances take place.

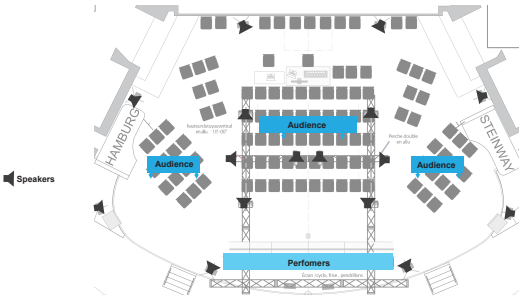

Fig. 3 - Arrangement of audience and performers, *Ultrasons* series University of Montreal, April 2023.

The piece was written for ten Moog Mother 32 semi-modular analog synthesizers[8], eight metal sheets and sound spatialization. In the past, the ensemble used to play simple old analog test equipment oscillators [34], as of 2022, the ensemble plays Moog Mother 32. In addition to the analog synthesizers, I decided to use eight sheets of metal, this was to have acoustic sources and to explore the relationship between the spatialization created by acoustic sources and the spatialization created with speakers.

A score was written, and a notation system was developed for the parts to be played with metal sheets, those to be played with synthesizers, and the movements of the performers. I drew inspiration for the synthesis notation from the model previously adopted by the *Ensemble d'oscillateurs* [34]. This model indicates information regarding the frequency, amplitude, and modulations of these two parameters. In the case of the Moog Mother 32, the parameters are more numerous, so I decided to adopt the following strategy. The performers were provided with a starting patch (Fig. 4).

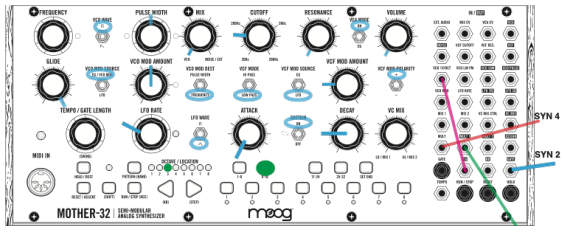

Fig. 4 - Example of a starting patch.

The score indicated actions to be performed on the knobs. Different colours were chosen to highlight the alternation between parameters. Black was chosen for the volume, and grey and green for the other controls, such as modulations and the filter.

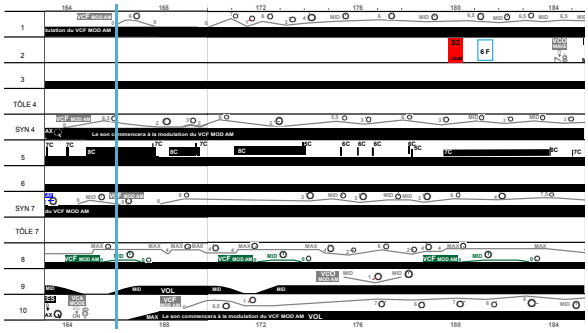

Fig. 5 - Example of the score for the synthesizers.

As for the metal sheets, I tried to note the undulatory movements to be performed.

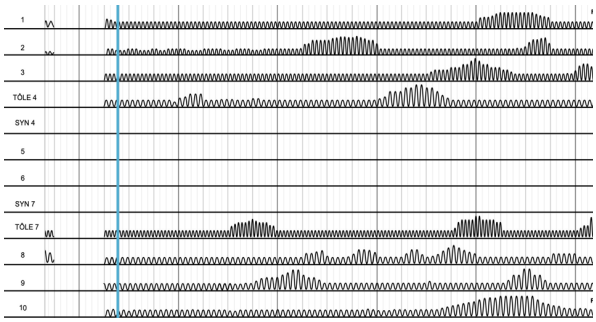

Fig. 6 Example of the score for metal sheets.

For the positions of the performers, I included visual references for them in the score.

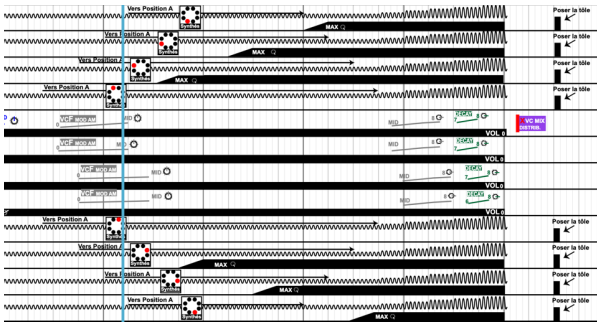

Fig. 7 Example of the score for the positions of the performers.

[6] Charles St-André, Jean-Sébastien Schnubb, Alexandre Sasset-Blouin, Zacharie Perreault-Samson, Antoine Morin, Alexandre Hamel, Antonin Gougeon-Moisan, Gabriel Geneau, Zakary Colello, Emanuel Brie.

[7] A recording of this concert should be available on my website nicolagianni.com during the fall 2023.

[8] In semi-modular synthesizers, some connections between modules are already in place, while others can be made connecting cables through a patch bay panel.

While playing the synthesizers, the performers can see a video score on the screens placed next to the synthesizers.

Fig. 8 - The synthesizers with the video-score screens. Photo by David Piazza.

This video score system, adopted by the *Ensemble d'oscillateurs*, consists of ten connected screens [34]. The performers at the metal sheets, in their initial position (see next section for displacements), can follow a paper score on a music stand. At certain points, when they're on the move and in certain positions, the performers can't see the paper or the video score, so I took charge of the musicians' conduction. On the day of the concert, Bernier and I asked ourselves what the ideal position for this role in an immersive context would be, especially so as not to restrict the audience's view, considering that the audience and performers are at the same height because there is no stage. A non-central position was chosen, next to one of the loudspeakers.

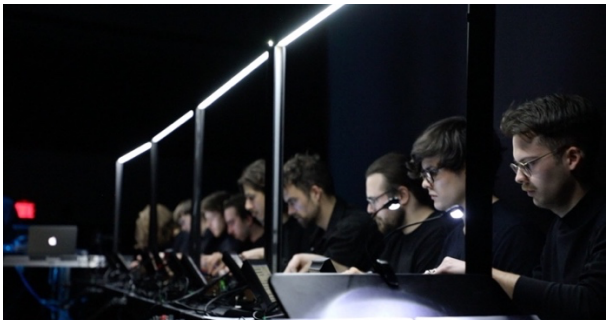

Fig. 9 - A picture of the day of the concert by David Piazza.

The piece was rehearsed with the performers and Bernier every week from February 14 to April 18, 2023. The rehearsals were fundamental to the process of creating the piece and writing/refining the score. Thanks to exchanges with all those involved, I was able to work on the language for notating the synthesis and the metal sheets and on the feasibility of the passages to be played, particularly concerning the transitions between the different synthesis sounds. Although the idea was to create coherent sounds, each section is characterized by a particular palette. In addition, although for most of the piece the materials evolve slowly, at certain points, I decided to articulate more the structure (e.g. the transition between the second and third sections). All this, given the semi-modular nature of the instrument, made it essential to plan the distribution of the parts to take into account the time needed to move from one sound to another through the manipulations on the synthesizers.

IV. Spatialization control

Spatialization was controlled through SpatGRIS, a software developed by the Spatial Immersion Research Group (GRIS), of which I am a member and which is directed by Robert Normandeau. The system consists of a plugin, ControlGRIS, which can be used in any DAW to place sounds in space, and the spatialization engine, SpatGRIS, which is a stand-alone software. The system allows an object-based approach to sound spatialization. Audio data is accompanied by OSC data that describes the position of the sound sources in the space. This makes it possible that the spatialization is independent of a specific speaker configuration [35], so the same spatialization can be used with different speakers' configurations. SpatGRIS offers two modes of spatialization. For this work, I decided to use the DOME mode, which is based on the Vbap algorithm. I decided to use this algorithm as it makes it possible to localize sounds quite precisely, which I thought was a good strategy, considering that the Claude Champagne Hall is highly reverberant. In the case of the concert, the audio outputs of the synthesizers were connected to an Allen Heat SQ5 mixer. This mixer was connected through the Dante protocol to the hall sound system and my computer.

Synthesizer sounds have a fixed position for each section. These positions change with each section through the use of presets in ControlGRIS. For reasons of spatial mapping, I decided to place the sound materials according to the position of the musicians creating them. This choice was also made to allow the performers to hear the sounds they create. The width and the height of the sound sources were controlled with the Span functions available in ControlGRIS, which allow sound to be spread over the horizontal and vertical axes.

V. Spatial, immersive and musical creation strategies for the composition of the piece

The decision to use analog synthesis in a spatialization context was somewhat of a challenge. Due to their referential character, field recordings can already evoke a space, and in general, the recorded real-world sounds, even if transformed, can have a lively irregular character that can help to localize them in space. Considering this, in some parts of the piece, I tried to evoke certain natural sounds (e.g. wind) or the spectral irregularity of a sound recording through the synthesis patches. In other sections, to foster an immersion sensation and to create a diffused sound field, I used spectral similar and spatially static sounds characterized by slow spectromorphological changes. My aim was also to exploit a specificity of analog synthesis from a spatial perspective. By their nature, sounds obtained with analog synthesizers, even if generated starting from the same patch and instrument model, will always sound slightly different, and this allows for the full exploitation of decorrelation phenomena. So, I decided to take advantage of decorrelation throughout the piece by writing similar parts for some of the performers. Other factors to keep in mind when composing for this kind of ensemble are the number of available sources, in this case ten, and the specificity of the instrument, which requires a certain amount of time to modify a sound for a performer. I also wanted to utilize the connection possibilities between the various semi-modular synthesizers thanks to their patch bays. Starting from the second half of the piece, six and then all ten synthesizers are connected via patch bay cables and the actions of one performer can affect the sound created by the others. In addition, due to the position changes, some performers prepare the patches of the synthesizers that will be played by other musicians. These choices have a musical motivation. For example, the synthesizers are connected because I wanted the rhythm of the devices to be the same at certain parts. At the same time, with these decisions, I wanted to evoke, in a way, a feeling of community, trust and mutual help. Finally, the sometimes unpredictable character of the sonic results of analog synthesis in a live performance context seemed to me to be particularly suitable to evoke the tension between human

beings' will to control and the uncontrollability of natural events.

I decided to use metal sheets for different reasons. Their sound can be reminiscent of that of the wind when it makes the materials it encounters vibrate. They are relatively light devices that can easily be played by moving performers. In addition, having moving acoustic sources allowed sounds to enter the dome of loudspeakers and highlighted the complex relationship that is created between an acoustic sound, the surrounding environment and the listeners [3]. The metal sheets were chosen in different sizes and qualities of metal, to have a variety of timbres and pitches, but with the idea of creating sound materials traceable to a common source, in a perspective of orchestration and decorrelation.

Given the correlation between the spatial, immersive and musical aspects, the creative strategies are presented together according to the different sections of the work. I will also indicate the musical references that influenced the different parts. The piece lasts 15 minutes and can be divided into six sections. The piece begins with eight performers, arranged around the audience in an octophonic configuration (Fig. 10), playing the metal sheets. For most of the initial part, the performers play simultaneously. The sounds of the metal sheets arrive from all directions of the horizontal plane. The idea is to explore the spatial attribute of envelopment through the use of these acoustic sources in a reverberant space such as the Claude Champagne Hall. Some moments are characterized by pauses and sound rotations. The rotations are created by having one performer's musical gesture followed by that of the nearest musician, following the *movement through the repetition of similar materials in different parts of the space* strategy. The other two performers play four synthesizers. Synthesis sounds gradually enter the scene, progressively occupying the front/back and right/left axes and blending in with those of the metal sheets. I chose sounds reminiscent of the wind, filtered white noise with resonant peaks, following the *Soundscape recreation* and the *orchestral metaphor* strategies. The four materials are organized on four different parts of the sound spectrum (low, low-mid, high-mid, and high), thanks to the different cut-off frequencies.

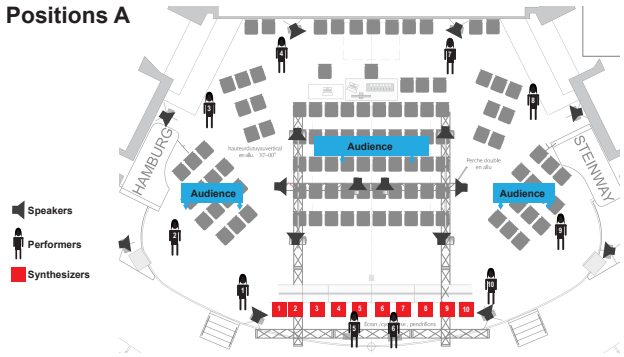

Fig. 10 - Initial arrangement of performers.

Then, the performers, while playing the metal sheets, slowly move towards the synthesizers, crossing the hall and passing by the audience in the aisles created by the chairs, as shown in figure 11. These movements create slow spatial trajectories of the acoustic sources, ending in a frontal choreography in front of the public.

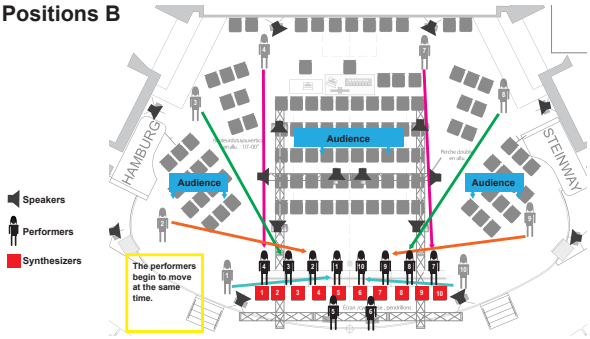

Fig. 11 - Second arrangement of performers.

As stated above, the idea is to occupy the space to shorten the distance between the audience and performers and also to explore the correlation between the spatialization created through the speakers and that created by acoustic sources. As already mentioned, the sound trajectories of the acoustic sources allow depth and distance to be explored because of the performers' displacements. The acoustic sources enter the dome, and an interplay of depth and distance is thus created between the sounds diffused by the speakers and the metal sheets. Once in front of the public, the performers continue to play the metal sheets. The sound diffusion is now frontal. After a crescendo of intensity, the performers place the metal sheets on the floor and then take their places at the synthesizers, one next to the other, forming a line (Fig. 12). To make these movements and positions possible, I requested a special configuration for the audience chairs from the concert organization.

In the second section, I chose to use groups of low and sub-bass sounds, close in frequency, with very soft attacks positioned in the lower part of the speaker's dome. The aim was to create beats and bring into play sound sources that are difficult to locate [21]. The beats of low-pitched sounds, especially at high volumes, can almost foster a physical sensation. I wanted to create a listening experience where it is not so important to understand where the sounds are coming from, as they could seem to be coming from all directions. The idea was to foster envelopment. For this approach, I take inspiration from David Foster Wallace and Paul Taylor's definition of David Lynch's cinema: "This is something the British critic Paul Taylor seems to get at when he says that Lynch's movies are "to be experienced rather than explained"" [36]. After a while, these low-pitched sounds are contrasted with sounds in the middle and high end of the spectrum placed in the upper part of the dome, with the idea of exploring the spatial attribute of engulfment. The upper part of the dome is characterized by a certain degree of spatial clarity due to the nature of the sound materials (high and mid-spectrum recognizable pitch sounds and filtered white noises), while the lower part is characterized by low spatial clarity (low-pitched sounds, long attacks).

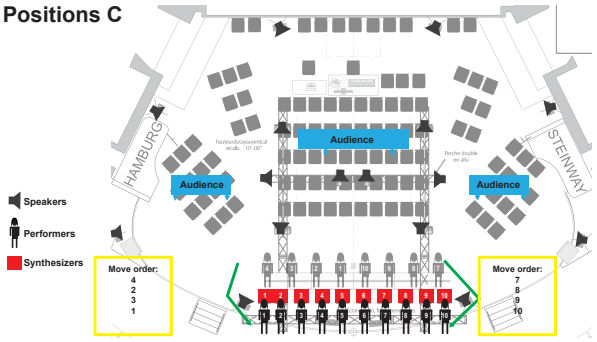

Fig. 12 - Third arrangement of performers.

The section ends with a crescendo in which four voices are added to the scene. These voices are organized in *spatial counterpoint,* and each of them occupies a quarter of the lower ring of loudspeakers. For this part, I created a starting shared sound with a rather unpredictable behaviour, which might recall the wind whistling very loudly, with the idea of evoking a soundscape. I designed the patch taking into account some aspects of the unpredictability of analog synthesis. The filter is modulated by a high-speed LFO, and due to the analog nature of the instrument, the LFO speed can't be exactly the same for all four devices, creating slight unpredictable differences. The rich content of the spectrum and its modulations can make this material easily localizable. Furthermore, although the sounds are similar, they are characterized by different temporal evolutions, aiming to create a *Movement through the repetition of similar materials in different parts of the space* and to envelope the audience. To compose these first two sections, especially concerning the types of materials and their evolutions, their orchestration and the exploration of beats, I was freely inspired by the music of Éliane Radigue, e.g. *Occam Ocean 2* [37] (although in this case, the instrumentation is orchestral) and that of Sarah Davachi, e.g. *Two Sisters* [38].

The third section is characterized by long, smooth sounds, in some ways reminiscent of the beginning of the previous section but intended to evoke a more pronounced sense of loss of spatial references. Here again, the relationship between spatialization and analog synthesis is in evidence. Four voices occupy four segments of the upper part of the dome, playing respectively an F5 and an F5# with a sawtooth wave, and an F5 and an F5# with a pulse wave. The timbre of these materials changes slowly over time due to a filtering action. Low-pitched sinusoid-like sounds are added progressively. Even these sounds are smooth, long-lasting and characterized by slow dynamic envelopes. These materials are initially organized in a hint of melody that develops in space. An area of the dome is dedicated to each note in the perspective of the *orchestral metaphor*. As the section continues, the sounds temporally overlap each other, creating one continuous drone together with the sounds present in the upper part of the dome. Because of the spatial arrangement, the pitch proximity of the notes and the slight pitch variations due to the analog devices, phenomena of decorrelation and beats are again created. In this case, I wanted to explore the spatial attribute of immersion (considering engulfment and envelopment together), thanks to the continuous nature of the sounds that are spread throughout the dome of speakers. The difference between the sounds placed in the lower and upper part of the dome lies in the spectrum, but the dynamic envelope and general temporal behaviour could make them perceived as a single spatial sound object slowly changing over time. The idea was to emphasize timbre and texture slow changes through the orchestration of materials characterized by pitch fluctuations in different parts of the spectrum. To do this, although one probably cannot speak of microtonal composition, I was freely inspired by Ligeti's work on timbre pitch and orchestration, e.g. *Lux Aeterna* [39].

In the fourth section, six synthesizers are connected via patch bay cables. The performers connect their cables all at the same time following a signal from performer 4. The idea was to emphasize this connection through a shared choreographic gesture. Synthesizer number 4 generates the gate signal for the other instruments, determining the rhythm of the created sounds. This rhythm is driven partly by the performer's actions and partly by a random function activated in the instrument. The sound is characterized by the repetition of a percussive element at a progressively increasing speed, evoking the electroacoustic technique called rebound [9]. Thanks to the random function, this progression is often unpredictable. As the speed of repetitions increases, the sound progressively changes from a rhythmic pattern to a continuous texture. The six voices play an E on three adjacent octaves starting from a very low register and are placed in different spatial positions, globally occupying the first half of the dome starting from the bottom. These positions are fixed, and the six voices always play in unison. However, because of the analog character of the instruments, percussive sounds are not always perfectly in sync creating decorrelation phenomena especially when the tempo is fast. The idea was to position listeners within this music scene that aims to evoke the tension between humans' desire for control and nature's uncontrollability through the opposition between the regular rhythm of the rebound figure and the interventions of the random function. I thought that the decorrelation phenomena created among the six very similar synthesis voices could foster an immersion feeling of being inside a process. The other synthesis voices, located at the top, play sharp, smooth, long-lasting materials as opposed to the materials at the bottom in an engulfment perspective. Concerning the rhythmical unpredictable nature of the section, I was inspired by the work on rhythm and textures by Gábor Lázár and Mark Fell, e.g. *The Neurobiology of Moral Decision Making* [40].

The fifth section begins with two synthesizers playing two white noises, which are filtered at different frequencies and positioned at the left and right rear of the dome. The modulation of the filter resonances is used to evoke the howling wind. I have included this material to recall the opening section. Along with this windy sound, in the lower part of the dome, there are three voices held in time playing E0, E1, and E2 respectively, in connection with the previous section. Other voices are progressively added to this content, which, by their iterative rhythmic behaviour and dynamic envelope, could recall the undulatory sounds created with the metal sheets. I tried to explore the attributes of depth and distance through some spectromorphological variations driven by some synthesis parameters. At first, the repetitions of these rhythmic elements are characterized by a gentle attack, a long release and a filtering that cuts off high frequencies. The idea is to simulate a distant sound. The volumes then gradually increase, the attacks and releases become shorter, and the high-frequency filtering is

[9] I use this technique extensively in my piece *Rebonds* [18].

progressively removed to give the impression of an approaching material. The rhythm of these voices is still handled by synthesizer number 4. The undulatory character is achieved by modulating the pitch and dynamic envelope through connections in the patch bay. By removing one of the cables from the patch bay, the performers abruptly remove the pitch modulation, transforming the undulatory sound into one that might remind a palm-muted guitar. This is the main material of the next part of the fifth section, the most melodic and tonal part of the piece. Six voices arranged in the middle and lower part of the dome play the same simple melody spread over five different octaves (one octave is doubled). To write this part, I created a playlist that I listened to often during the composition phase, which grouped shoegaze, indie alternative pop, and new wave tracks[10] characterized by chord progressions and rhythms that I find similar in some ways. From these repeated listens, I have derived a very simple monophonic progression (E D C - C D E). This melody is sometimes played in unison, while sometimes groups of two or three voices anticipate or delay the transitions between the notes of the melody. Thus, some voices deviate temporally from the main melody and then re-synchronize with it. The fact that the voices are arranged at different points in space accentuates these deviations. Is it the different positions in space that highlight the temporal deviation of the voices from the main melody? Or is it the temporal deviation that emphasizes the different positions in space? I guess that the two phenomena exist together influencing each other. One could consider this space composition technique in line with the *orchestral metaphor* strategy. Two additional voices play only some of these anticipated or delayed melodic passages, to further emphasize these deviations. In this part, the intention was also to foster a sense of engulfment. To this end, content that could evoke the wind (filtered white noise) is placed at the top of the dome in opposition to the melodic materials in the lower part. The idea was to create a contrast between two distant materials, both in terms of timbre and temporal evolution, to accentuate the difference between the upper and lower parts of the sound space.

The last section begins with four voices occupying the lower part of the dome, recalling the undulating sound present at the beginning of the previous section played by two performers. In the meantime, the eight performers who played the metal sheets return to play them after having connected all the synthesizers via patch bay cables and having prepared the patch that the performers remaining at the synths will later play. The metal sheet performers first play their instrument in front of the synthesizers (fig. 11), dialoguing with the undulatory-like sounds played by the synthesizers through a series of spatial *call-and-response.* The performers at the metal sheets then slowly make their way back to their initial octophonic arrangement (fig. 10), playing their instruments continuously while crossing the Claude Champagne Hall. As in the first section, slow sound trajectories are created inside the dome. Sounds diffused by loudspeakers blend with acoustic sounds due to the similar undulatory character. The piece ends with a grand crescendo of intensity. The remaining six synthesizers are activated one after the other by the two performers behind the instruments. These synthesis sounds are added to those already present. Considering that each synthesizer is positioned in a different zone, this generates a progressive filling of the sound space in the upper part of the dome. These sound materials still recall the undulatory nature of metal sheet sounds on different spectral registers. Some of these materials are characterized by recognizable pitch content, while others consist of filtered white noise with resonance peaks. The eight performers on the metal sheets play louder and louder until the conductor signals the end of the piece. The metal sheets stop, and one of the two synthesizer performers disconnects the cable that generates the gate signal for all the devices, causing the sound to stop. For the last section, I was not inspired by a particular musical reference (although I probably somehow believe that we are always influenced by the music we listen to), the idea was to explore the relationship between the sound of metal sheets and a synthesis material that could evoke this acoustic sound. The aim was also to create a soundscape with extreme characteristics (evoking a very strong wind) and increasing dramatic tension.

VI. Conclusion and future developments

In this article, I discussed some theoretical and practical aspects of immersion and spatialization in the context of live music with performers through the presentation of a case study. I reflected on the relationship between the initial compositional concept and the composition of space and immersion. I presented the concepts of spatialization and immersion and took up Rebelo's idea of how creating an experience that diminishes the boundaries between audience and performers could foster an immersive experience. I then discussed the relation between sound and space, introducing spatial attributes and some strategies for sound spatialization. I later focused on the writing of the score and the rehearsal period with the ensemble. Finally, I presented strategies for spatial, immersive and musical composition, notably by illustrating techniques that relate the specificity of analog synthesis to the composition of sound space and also strategies that relate the spatialization created by loudspeakers to that created with acoustic sources.

In this article, I proposed a conceptual framework for the composition of live spatialized immersive music with performers. Although I am aware of the uniqueness of each project in this field because of the many variables at play, I believe it can be useful to reflect on this type of creation within a framework and to get to know different composition strategies by composers working in this field.

As for future developments, I plan to work on some aspects regarding spatialization control and rehearsals with performers. The piece will be performed again on November 24, 2023, at McGill University's Multimedia Room (MMR) in Montreal, Canada, for a concert at the Live@CIRMMT series. In this context, a spatialization tool called MapSPAT, developed with Jean-Philippe Jullin, will be used. The device is currently in the prototype stage, and the idea of developing it came about in the context of the composition of *Le vent qui hurle.* “MapSPAT is designed to create real-time spatialization linked to sound characteristics during live concerts. Through an analysis system based on audio descriptors and a mapping system between musical and spatial parameters, MapSPAT makes it possible to spatialize sound automatically without having to write automations in a DAW. Thanks to a matrix interface, users can link sound parameters

[10] This playlist includes songs by Vondelpark, Haelos, New Order, Yeah Yeah Yeah, etc.

with spatial parameters. A variation in sound thus causes a variation in spatialization. For example, an increase in intensity can generate a trajectory from bottom to top [41]". For *Le vent qui hurle*, the device will be used to create sound trajectories for the synthesizers' sounds.

Finally, I realized that it is important to have sufficient rehearsal time with the performers in the concert hall, for example, so that it is possible to work on the movements and the balance between the sounds diffused by the speakers and the sounds created by the performers. This kind of work may require a process of adaptation and tuning in each new presentation context.

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