Sonification as a Composition Technique and Means of Artistic Expression

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Abstract

Despite of the ever-expanding variety of technological means accessible to composers, performers, orchestrators, music producers, and music pedagogues of our time, the essence of music composing has mostly remained the same for centuries: the key question is, how to form an artistically innovative core idea of a musical piece and to find the most ideal instruments for it? This paper discusses composers' explorations on establishing their individual voices, as well as finding and selecting the tools and techniques that would best serve their artistic goals in today's complex and pluralistic network of aesthetics. To facilitate this, various software solutions have surfaced to enable a wider palette of sounds to be used as musical "raw material". Rather than using pre-composed music based on the rhythms and pitches organised by the composer, we will focus on how to translate other kinds of data into "notes", or more largely "sound events", and how to use it in an artistically meaningful manner, resulting into musical compositions in their own right. To do this, we will present compositional case studies based on sonification, realised by various methods and technologies. These include, for example, the application of the software "Orchidea" [9] in artistic practice. We will showcase Maria Kallionpaa's environmentally themed work "El Canto del Mar Infinito" (2020) and her composition "The Reef" (2023), which uses sounds recorded from a coral reef. Furthermore, we will discuss how Olga

Neuwirth incorporated seismic data from the Sumatran area into her work "Kloing!" which was influenced by the 2004 tsunami disaster.

Sonification techniques do not produce musically utilisable aesthetics per se. This raises the question for the creative domains in which composers engage when involving sonification techniques in their process. These domains include:

- the choice of the data or subject being sonified,
- the preprocessing of this data (e.g. the quantization of a series of floating-point values to integer pitch values and metronomic timings),
- a specifically musical design of the sonification method, i.e. the transformation or mapping of the data to sound structures, and
- a purposeful work with the parameters of the sonification.

The TouchNoise system (2014-2017), developed by Axel Berndt, Nadia Al-Kassab, and Raimund Dachselt, explored a further approach. It is a sonification of a particle simulation. The compositional domain here is primarily spanned by a palette of interaction techniques with a particles field, including direct manipulations of the particle distribution as well as flow field and flocking algorithms. We will discuss the aesthetics that this approach evokes.

Introduction

Since the beginning of music history, composers have been ambitious in composing music that would bring out the highest abilities of their performers. Simultaneously, instrument developers have been anxious to respond to their call by designing tools that would enable increasingly technically elaborated musical performances [1]. The evolution of computer-based systems to expand the contemporary composers´ technical “toolkit” can be seen as a continuation of the same pursuit. As rigid forms of classical music (such as the sonata form and specific expectations of harmonic progressions in its context) lose on relevance in the creative process, the prospects of experimentation on musical forms seem endless. This paper focuses on the potential outlook of these liberated forms towards new avenues for sonification as a composition tool.

The modern-day pluralistic music aesthetics and technologies allow for a wider scope of consideration on what to regard as musical material. However, the key question remains: how to form an artistically innovative core idea of a musical composition and its instrumentation? The case-studies discussed below utilise computer-generated, non-musical data as a form of “raw material” only. Creating notated or orchestrated materials using computer-based analysis doesn't absolve the composer of artistic responsibility or authorship. Instead, the composer oversees organising their work into an artistically meaningful unity.

Indeed, drawing inspiration from non-musical data material is not a novel approach per se. A plethora of historical composers have attempted to replicate, for example, patterns that are exhibited in nature. Composers during the Romanticism and Impressionism eras often imitated water patterns and movements in their music. For example, Franz Liszt, Maurice Ravel, and Claude Debussy composed many pieces inspired by water, fountains, and the sea. Early modern composers, including Oliver

Messiaen, were similarly inspired by nature, such as birdsong (c.f. “Catalogue d'oiseaux”, 1956-1958). The composer was also known for attempting to notate the noises made by birds.

Previously, pen and paper were used for analysis and notation, but modern signal processing methods give rise to much higher data resolution that sometimes remain elusive to the attentional bandwidth of human cognition. With the case studies below, we’d like to demonstrate the complexities of translating overwhelming amounts of information into easily understandable stimuli in artistic contexts.

Sonification as Inspiration: “Kloing” by Olga Neuwirth

Like their predecessors, contemporary composers draw inspiration from nature, too. The rigorous ways of measuring data and the means of translating it into other forms of information provide the artists of today rich possibilities of using aspects of natural phenomena as part of their selection of techniques and expressive vocabulary. For example, the novelty of Olga Neuwirth´s work “Kloing!” (2008) for computer controlled piano, live-video, and pianist lies in its original use of sonification as part its compositional structure. The music is partly based on the seismic data collected in the Sumatran area during the tsunami disaster of 2004. Using mathematical modeling, Peter Plessas transformed this data into audible form, including rhythms and pitches. Rather than being a subtle side element of the musical material, the seismic outbursts are present both audibly and visibly when experiencing the work in a concert setting. The rapid computer-generated movements of the piano keys give an impression of natural forces beyond human control. Specifically composed for a Bösendorfer CEUS grand piano featuring a dynamic resolution of 1000 velocity layers per key, the human pianist plays with and against an overwhelming machine (the musical part of which is based on the sonified data), that slowly takes over the part of the human performer.

Composition Case Studies: The Reef (2023) and El Canto del Mar Infinito (2020) by Maria Kallionpää

Musical creation should prioritize a strong core idea and suitable instruments, rather than any technical means. In this vein, data sonification only partially informed the notated material to “The Reef” and “El Canto del Mar Infinito”. Both pieces share a similar theme (protecting the ocean environments), but differ significantly in their approach and instrumentation. While “El Canto del Mar Infinito” is a large-scale chamber music work for seven performers and a conductor, “The Reef” is an interdisciplinary duo for two pianos and a live video artwork created by the visual artist Andre Veloux.

"El Canto del Mar Infinito" was created with the theme of "Nature" in mind for the 2020 Tampere Biennale festival. Kallionpää had previously written sea-themed works, making it a good fit to that years’ thematic direction of the commissioning music festival. The question was how to tackle the topic in a fresh way, given that the Impressionist and Romantic era composers have already covered it thoroughly. Sonification of underwater sounds seemed like an organic solution to this problem, as part of the creation of the work would be handed over to the ocean itself.

To start composing, suitable underwater sounds were sought out. An ideal sample

would not have too many overlapping sound signals, as that could make the notated result of the computer-based analysis garbled. Conversely, too limited sound signals would not offer enough characteristic features for the sonic material to be divided between seven performers. To ensure the composer's control over their material (and by this to keep the overall composition texturally and aesthetically coherent), only a selected number of distinctive samples were selected, and then analysed by the computer-assisted orchestration tool Orchidea [9]. The goal of the analysis was to generate notated pitch material that the composer would then interpret into music. The resulting computer-generated notated excerpts were not regarded as music in their own right, nor were the listeners expected to associate them to the concrete sounds originally used. The intention was to put together a musical composition with a dramatic arch and narrative, which called for further compositional work. To ensure continuity, the formulated motifs were elaborated into a complete musical texture, while expanding or tightening the time values of the formed pitch material, and structuring the timing and proportions of the dramatic events.

At the beginning of the composition project “The Reef”, a similar challenge was faced to that of “El Canto del Mar Infinito”. However, the selection process of the original sounds, and their transformation into rhythms and pitches followed a different rationale. Instead of using multiple short sound clips, "The Reef" only used one big sample from Thailand's Mu Koh Lanta National Marine Park. Being somewhat limited in its spectral composition, this sample consisted of a swimmer proceeding towards a coral reef. Furthermore, the sample’s procedural structure would lend itself as the dramatic arch of the composition. Upon finishing the composition process, a MIDI rendition served as reference for the video artwork created by the visual artist Andre Veloux. Its abstract visual surfaces follow the music in a detailed manner: on top of serving as a structure of the musical composition, the timing of the original sound recording also informed the structure of the live visuals.

Like “El Canto del Mar Infinito”, also “The Reef” required a lot of processing of the computer-generated notated material. Although the software helped to translate the natural sounds into a MusicXML file consisting of notated pitches and rhythms, in its original state, the results seemed to unstructured and entropic for meaningful sonic renditions. As with the human mind, a composition necessitates an organic entity with internal rules and organised timing. These musical events and their proportions cannot simply be drawn from the raw recording of a sonic environment consisting of seemingly random signals. It is the task of the human composer to gather and organise the material by empathically communicate to audiences a coherent and meaningful representation of said data points.

Data-driven vs. musically satisfying

As demonstrated by the examples above, deriving musical structures from extra-musical sources is a well-known compositional concept. It can be observed early on, for instance, in program music. These structures, however, are mostly based on the composers’ intuition and abilities to rather freely translate an observation into musical aesthetics and gestures. With the primary aim of a musically satisfying result the composers

can treat their “inspirational material” and its translation to music rather liberally, even to the point where listeners will hardly recognize the link anymore.

Sonification, by contrast, being subject to its purpose of communicating information about the data it is fed, seems all too restricting or “naturalistic” for use in artistic contexts – at first glance. According to Kramer et al. „sonification is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation. “ [2] Sonification techniques do not necessarily (have to) produce musically utilizable aesthetics.

Nonetheless, composers seem to be attracted by sonification methods and started adopting them in their creative work as soon as the technology became available. In fact, sonification methods offer a range of domains to interact with that are not only compositionally utilizable but open fresh approaches to the creation of musical structures. The following list is intended less as a conclusive inventory and more as creative food for thought. This is contextualized with the question for artistic freedom between the two poles of the data-driven, pragmatic nature of sonifications on one side and the aim for musically satisfactory results on the other.

Probably the most obvious creative domain in which composers engage is the *choice of the data or subject* being sonified. Barrass and Vickers [3] report of several artistic works that involve a deliberate selection process of data that features inherent aesthetic qualities and translates well to musically satisfying results.

While the selection of aesthetically interesting data is already a clear decision against an “uncensored” objectivity of scientific sonifications, it stands to reason that the data itself also does not have to be of untouched nature. Just as a photographer arranges his/her motif, the input data of a sonification can be deliberately *arranged*. In the case of real-time sonification the composer might even *interact in the input domain*. The input domain effectively becomes a kind of user interface to the sonification, which then serves as a synthesizer. Input domain and sonification combine to create a musical instrument and make the composer a performer at the same time.

An example for this is the TouchNoise system by Berndt et al. [4]. It is a sonification of a particle simulation. Each of up to several hundred particles is sonified by a sine wave. Particles move on a 2d plane with the vertical axis being mapped to the sine wave’s frequency and the horizontal axis being mapped to its position in the stereo panorama. The particles’ default behaviour is Brownian motion. The creative domain of TouchNoise is spanned primarily by a palette of multitouch interaction techniques with the particle field, including direct manipulations of the particle distribution as well as flow field and flocking algorithms that the user applies to the field in order to exert an influence on the particles’ motion characteristics, see figure 1. Consequently, the sound aesthetics of TouchNoise are defined by the particle dynamics, i.e. the distribution of the particles on the 2d (frequency and stereo panning) plane and how it evolves according to the movement speed and influences on the direction.

Figure 1: The TouchNoise system sonifies a particle system. Particle motion is influenced by multitouch interaction.

The input data of a sonification can be further conditioned before it is mapped to sound. Such *preprocessing* can make the data more music compliant, e.g. by quantization of floating point values to integer values, transposition of the values into musical pitch ranges, or sampling of (quasi-)continuous data to metronomic timings. Preprocessing can involve information loss. Thus, it is important to make sure that this loss does not affect the data properties that are meant to form the basis of the musical structure.

If the data does not sufficiently establish a musical structure it may also be defined by the composer. Spondike [5] describes that he first collected sonifications, took away those that were musically unsatisfactory and arranged the remaining ones in a *collage*-like fashion.

A core challenge of sonification is the *mapping*, i.e. to define which data properties are to be sonified by which sound properties. Two major conceptual frameworks to develop such mappings are Parameter Mapping Sonification and Model-Based Sonification. Both allow a specifically musical design. Most software tools for sonification can, thus, be regarded as tools for creative experimentation with different mappings and mapping strategies, thereby, becoming compositional tools. An example for such a creative tool is SUM [6] which Adhitya and Kuuskankare use to transform images to music. In [7] the authors demonstrate SUM sonifying so-called “visual music” paintings by Kandinsky and Mondrian and further use it to “recompose” music from a graphical score of Ligeti’s Artikulation by Rainer Wehinger. Sonification has the mapping problem in common with the development of NIMEs (New Interfaces for Musical Expression) and computer music in general [8]. In fact, input data can also be interpreted as gestural data from a musical performance. Hence, it is worth seeking for inspiration also from mappings found in the NIME field.

Once a mapping is found, the parameters of the sonification are set. But they do not have to remain static. The composer is free to *modulate the parameters* over the course of a musical piece, thus, adding to the expressive gesture of the input data a second expressive layer. This layer might, e.g., represent a personal statement. It might be used to emphasize certain aspects or even act in a contrapuntal fashion. But it should also be clear that this method will obscure the link between input data and sounding result. It will hardly serve an objective information transmission any longer.

To move even further away from a pragmatic concept of sonification, the input data can even act as *seed for more complex generative processes*. These will likely involve substantial transformations of the material. The sound output will carry the data-inherent information in an encrypted fashion. With this approach, the input data are rather to be seen as a first inspiration or idea, which can be

subjected to a liberal artistic treatment and expanded into an idiosyncratic musical work.

Towards a Psycho-Aesthetic Design Paradigm of Agency in the Arts

This paper has only but touched on the difficulties arising in preparing 'machine data' for human perception, that is, aesthetic experience. Indeed, the original meaning of the term *aísthēsis* (ancient greek αἴσθησις) refers to the human condition of perception by intellect and the senses, rather than a particular artistic or romantic idea of experience [10]. It is thus even more remarkable that the original meaning finds its return within its respective academic quarters. The plethora of data, as presented by the 'machine' or its recordings, reminds us of Plato's allegory of the cave, where not only the question of constructivism but also the inconceivability of the sheer number of perceptual stimuli of physical reality is being raised. By nature, humans will remain within the confines of the cave and experience reality as shadows reflected onto its walls. In a similar vein, composers face the challenge of interpreting the 'recording' (i.e. *linear* abstractions of reality, such as, but not restricted to, audio or even notation), that is, a comprehensive artifact limited only by its linear depth and frequency of data points, for an audience that utilize processing mechanisms that are all but linear. Thus, while musicians have always been confronted with the daunting task of translating meaning for audiences, it is in this day and age that they find themselves in the role of a cognitive-affective interpreter more than ever before. The composer applies implicit and explicit rules of stimuli organization to match mechanisms of perceptual grouping for creating an abstraction of the world as the artifact presents it. This involves the selection, processing, but also the functional integration and representation of the artifact as part of the composition.

Looking at the artifact, as previously exemplified by audio samples, we recognize additional challenges for modern composers. Were composers of romanticism impressionistically inspired by their subjective representations of perceptual memory, so are composers of the present concerned with the detailed presentation of materialistic features of the artifact (i.e. an audio recording). However, rather than relying onto a subjective component of the materialistic percept of the artifact, the discussed case studies showcase techniques to contextualize the raw material within a social *relevance* of external reality (i.e. the subjective world outside of introspection; such as the impact of the environment on *us*).

In contrast, data sonification, while also restricted to external/physical reality, strives for abstraction towards perceptually critical data points that enable its audience to grasp the materialistic properties of the artifact rather than its social/cultural context. In the scientific application of data sonification, there is no relevance given to the artifact outside its underlying inquiry/research question (, which, ironically, remains human-determined in nature). Nevertheless, the act of data sonification aims to interpret materialistic properties and its consequences for the purposes of enabling intentionality of the agent. It is, thus, a goal-oriented, utilitarian process and preconceives and prepares cognitive processing towards a specific action (i.e. decision-making). This element of agency entails its translational relevance akin to a feedback function. It

serves as a vehicle of improving our understanding of the external world by perceptually grouping and setting up expectations towards the relationship of its constituent parts for the consequence of our actions. Accordingly, we speak of a level of agency that is introrelational as it has utilitarian relevance for the actions undertaken by the perceiving subject only. Armed with these expectations, perceptual cognition can foresee and more easily adapt to the challenges of processing complex data streams [11].

It may seem that this poses a challenge as rigid and complex that it may not apply to any kind of indulging, artistic experience. Indeed, our experience of artistic intent is fueled by the same ingredients of agency but rather than focusing onto the immediate actionable affordances of sonification, the main purpose of its artistic interpretation serves the interrelatedness of the addressee. Thus, artistic experience, whether through the eyes or ears of the creator or the audience, will inherently act as a reductionistic, abstract communiqué between humans. Its relevance can be pinned down to the interrelational aspects of agency (i.e. how do we relate to, perceive, and, most importantly, interpret other agents). The artist's task is to treat the material to make it compatible for social discourse. Amongst others, it is a task of translation by selection, empathy by alteration, and reflection by presentation. It is art.

The Bottom Line

Ultimately, the present paper tries to achieve the impossible within the limited space that is allotted to this format. It illuminates the dynamic intersection of technology and music composition, with a focus on sonification as a potent tool for artistic expression. It underscores the enduring challenge faced by composers: How to forge innovative core ideas and choose optimal instruments amidst a technologically rich yet complex musical landscape.

The discussed case studies, ranging from Olga Neuwirth's seismic data-inspired work to Maria Kallionpaa's environmental compositions to Touch Noise's intuitive interface, showcase the diverse ways in which sonification can be integrated into the compositional process. The exploration of creative domains, including data selection, preprocessing, and parameter modulation, highlights the nuanced decisions composers make to transform raw data into cohesive musical pieces. The authors encourage a departure from a rigid dichotomy between data-driven pragmatism and musically satisfying results. Instead, we advocate for a fluid and creative engagement with sonification techniques, allowing composers to navigate a spectrum that spans from objective information transmission to liberal artistic treatment. Ultimately, we argue that, in this era of technological advancements, the composer's artistic responsibility remains paramount in shaping and organizing computer-generated material into meaningful and impactful musical compositions.

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