Deepening Presence

Probing the hidden artefacts of everyday soundscapes

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ABSTRACT

Sound penetrates our outdoor spaces. Much of it we ignore amidst our fast passage from place to place, its qualities may be too quiet or fleeting to pay heed to above the bustle of our own thoughts, or we may experience the sounds as an annoyance. Manoeuvring our listening to be excited by its features is not so easy.

This paper presents new artistic research that probes the hidden artefacts of everyday soundscapes - the sounds and details which we ignore or fail to engage - and draws them into a new audible reality. The work focuses on the affordances of spatial information in a novel combination of art and technology: site-specific composition and the ways of listening established by Schaeffer and his successors are combined with the technology of beam-forming from high resolution (Eigenmike) Ambisonics recordings, Ambisonics sound-field synthesis and the deployment of a new prototype loudspeaker. Underlying the artistic and scientific research is the hypothesis that spatially distributed information offers new opportunities to explore, isolate and musically develop features of interest, and that composition should address the same degree of spatiality as the real landscape. The work is part of the 'Reconfiguring the Landscape' project investigating how 3-D electroacoustic composition and sound-art can incite a new awareness of outdoor sound environments.

CCS CONCEPTS

- Applied computing → Arts and humanities → Sound and music computing / Media arts.
- Computing methodologies → Modelling and simulation → Simulation types and techniques → Real-time simulation / Interactive simulation.

KEYWORDS

Higher-order Ambisonics, soundscapes, feature extraction, composition, sonification, acoustic ecology, loudspeaker technology, acoustics.

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1 Introduction

Sound outdoors generally comprises of the by-products from human activity and machines, sounds created by animals (predominantly birds and a small selection of domestic animals), running water, resonances produced by wind and rain, and acoustic reflections. Whether in a cityscape or in the transition zone between urban, rural, coastal or forest, familiar sounds, especially the by-products of human activity are rarely of interest and rather accepted as unavoidable. Yet amongst the noise exists a great deal of information bearing intriguing insights about how the ordinary may tempt a passer-by to linger a while longer. This information is hidden from us either by way of acoustic masking or because it is an artefact of a clearer action. To illustrate with a simple example, consider the sound of footsteps: more than artefacts of passage, they tell us about the person's gait, their shoes, their haste and their trajectory and the surface under their feet. The sound reflections inform us of the surrounding structures in a way that vision fails to do. Composers and musicians may find rhythm and groove, sensations and emotions.

These listening complexities are a central topic of sound- and music-theory. Schaeffer's famous modes of objective, subjective, abstract and concrete listening [1] are influential to composers exploring the meaning of sound in their work, and Chion's variation of the topic [2] as causal, semantic and reduced listening are also embraced in today's artistic practice. Beyond listening itself, how we interact with the environment as elaborated by Ingold [3] plays its part in our understanding of the sound landscape, as do acoustic features such as sound propagation, reflection, resonance, absorption and auditory perception. Schafer, as a central figure throughout the era of soundscape studies [4] also suggested that the perception of the soundscape involves the integration of low-level psychoacoustic cues and higher-level perceptual cues from the

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environment. Rather than regard Schaeffer and Schafer as opposites, we can instead weld together their ideas to encapsulate intrinsic listening - or the musical nature of the sound in itself - and the extra-musical nature of sound and landscape-body interaction, all within a single act of apprehension. More recently, the notion of enhancing experiential qualities in soundscapes has become a popular topic in studies on landscape architecture. Cerwén's design tool that he calls 'Soundscape Actions' is notable in this respect. The tool takes an analytical approach addressing three sound landscape categories: localisation of functions, the reduction of unwanted sounds and the introduction of wanted sounds. 23 Soundscape Actions are divided amongst these three categories [5]. The tool aims to increase understanding and guide an autoethnographic approach to the design of our sound spaces.

This paper documents the first phase of my work aimed at encouraging a 'listening-in' or conscious eavesdropping on ordinary sound landscapes in a way that is engaged and dynamic. The work demonstrates the potential to awake a new awareness of the sound landscape in time and space, connecting acoustics, technology, art and aesthetics. Rather than rely singularly on an autoethnographic approach exploring anecdotal and personal experiences of sound landscapes as suggested in Cerwén's work, my approach incorporates a quasi-computational analytical phase designed to reveal information that we may be slightly aware of, but are unable to expound or concretise.

Previous work applying an analytical approach to soundscapes has been described in [6]. The analysis section of their work involves a separation of 'atmospheres', 'events' and 'subjects'. This separation is inappropriate in my work due to an overlap between these categories that changes depending on the moment and location of listening. Their study also notes that although we identify a soundscape from the sum of many sources and acoustic features, it is often not possible to discretise sounds either by ear or by computer processing. Here I demonstrate how we can clarify events or create focus from what may be regarded as a background atmosphere and frame this information as the subject of primary attention.

This paper is accompanied by binaural sound examples decoded with Harpex [7] using the KU100 HRTF set, and 4th / 7th order higher-order Ambisonics (HOA) in the ANC format. HOA examples use the Spat coordinate system (+Y pointing forward, +X towards right, which will result in 90-degree rotation if listening to the recordings with a non-Spat Ambisonic decoder). A download link to the sound examples is at [8].

2 Sound landscapes of interest

The study addressed ten contrasting soundscapes relevant to the research aims. The sites chosen lacked obviously exotic sources and features of potential interest were partly consumed in background noise or were too fleeting to be understood in real-time listening. Some sites were located in zones of passage rather than in zones of rest, and many contained sounds that could be regarded as annoying or easily shut out from listening attention. Recordings were made during the winter months in Norway when the sounds of summer's nature and human recreation are generally absent. During the winter the acoustics are also emphasised: sound propagates unhindered by vegetation and the crust of ice and snow emphasises distant sound and the reflective properties of surrounding surfaces. The soundscapes were as follows:

- Two Oslo city locations, tucked away from direct traffic noise, which instead filtered around buildings to penetrate these quieter city spaces.
- Three transition zones between urban and forest, where urban sounds were distant and forest sounds were close, made in varying weather conditions.
- One transition zone between the Inner Oslo Fjord and a trafficked motorway into Oslo.
- One from the depths of inner Norway featuring wind and snow.
- Three semi-rural garden recordings made in varying weather conditions.

3 Addressing the sound-field

Real soundscapes can be thought of as 'long play'. Although some sounds are persistent - the world is rarely silent - interesting events are often intermittent and distributed many minutes or hours apart. Composers aware of these temporal features may concertina field recordings, shortening the time between events to ensure a stream of information with which to hold the listener active (as famously demonstrated in Ferrari's Presque Rien No. 1 'Le Lever du jour au bord de la mer (1970) [9]).

For a 'dweller', information accumulates over time and space to collapse into a familiar memory and set of expectations: we know how the landscape sounded on average last week and how it will likely sound tomorrow. In music, electroacoustic composers often apply a technique where sound-scape information is gradually revealed, and after a period of time the complete picture is grasped during the flow of listening 'in the moment'. More recent research into our qualitative judgements of the soundscape suggests that preconscious processing is involved, where we address global characteristics without semantic processing of specific sources [10].

The real soundscape is also incredibly spatial where any one listening position may reveal a new understanding of the scene, or a gust of wind may carry sounds towards or away from our ears. The point from which we listen is thus of primary significance.

The chosen sites were approached addressing these temporal, spatial and semantic considerations. The duration of each recording encapsulated as many features as possible while being of a practical duration for analysis. To gain an idea of variance, sites were visited at different times of the day and recorded from two or three locations.

4 Preliminary spatial analysis

Although sound landscapes offer diverse acoustical, associative and interactive experiences, they present similar challenges in analysis: potentially interesting features are spatially distributed and often embedded in noise, or are barely audible. These challenges guided the recording and analysis methods.

4.1 Recording

In previous artistic work [11] I employed an outdoor recording method consisting of a distributed mono microphone array to capture and emphasise specific local sounds. This musically interesting approach however distorts the reality of sound-spatial relationships inappropriately for the current project. Instead, Ambisonics microphones recorded the encapsulated sound-field and the analysis method took advantage of the microphone array's properties.

An mh acoustics Eigenmike® on loan from IRCAM over the Christmas period 2019 was used for most of the recordings. Two synchronised Soundfield SPS200 microphones and a Sound Devices 788T mobile recorder were used for one specific site. Each recording lasted for 10 minutes except for when sub-zero temperatures reduced the effect of the Eigenmike laptop battery.

4.2 Spatial analysis

The analysis and transformation methods needed to service large numbers of long-duration source recordings in a systematic way. The individual treatment of recordings in a digital audio workstation was therefore avoided, and use of production tools deferred until the final stages of composition. Instead, automatic analysis and processing methods incorporated a small selection of interactive controls that allowed for basic calibration during real-time audition. These controls adjust for the individual spectral-temporal qualities of each source.

To analyse the recordings, beamforming, which produces directional signals by combining channels from a microphone array or HOA source was used. Beamforming is commonly applied in spatial decomposition. It's uses include in sound recording focusing on one instrument in an ensemble [12], in audio engineering for sound-field analysis [13], and in systems tracking sound in complex environments [14]. To date there appears to be no published work describing practical application as a means to identify sources in soundscapes or to understand how the source behaves, although [15] showed that by using a spherical microphone array, components in a multi-source noisy environment could be estimated more successfully than when using normal spectral filtering techniques. Some composers including in myself have applied beamforming as one of many compositional techniques without documentation or work analysis.

The Eigenmike recording was first converted to 4th order HOA using IRCAM's `spat5.hoa.em32~` object [16] and encoding method-3 described in the Spat5 reference. The `spat5.hoa.beam~` object was used for processing directional beams in a 4th order hyper-cardioid configuration. Alternatives to IRCAM's beamforming include the shotgun feature in the Harpex VST [7] or the Sparta beamformer in the Sparta VST suite [17]. These achieve similar results but were found to be less easily incorporated into the MaxMSP workflow and incurred a higher CPU overhead.

42 beams spaced in an equal area over a sphere proved to be a good compromise between information capture and the CPU considerations that would later arise in the real-time system. This spatial decomposition was compared to the original source by synthesising the resulting 42 audio channels and their correlating directions into HOA using `spat5.pan~`. The comparison revealed that the W-channel of the latter required a 9.3 dB reduction, and the overall signal a further 23 dB reduction. After this compensation the synthesised version sounded and looked highly similar to the original.[1]

To understand how directional sources are moving in space, a 100 Hz high-pass filter first removes spatially spread low frequency energy. Next, the amplitude (as RMS) and spectral features (as centroid) of the individual 42 beams are compared at a 10 ms temporal resolution - a process that outputs the directional RMS maximum and its correlating centroid as a real-time stream. The data is visualised as a moving source in `spat5.viewer~`. This visualisation reveals that the discrete directions of the 42 beams imposes a spatial sampling, and if a real source direction lays between two beams, the directional extraction flickers between the two closest directions. Increasing the number of beams improves accuracy as far as the resolution of the recording allows, but discrete spatial sampling is still evident. Increasing the number of beams also imposes higher CPU loads which inhibits the real-time system as it expands in processing complexity. Instead, the rolling average of the last n data points averages the information. The directional resolution is then more accurate for when the analysis has identified continuously moving or static sources, and adds no significant extra noise to chaotically moving data. The value of n determines the responsiveness of the analysis. $n=3$ is used as a default.

4.3 Directional information sonification

A sonification of the maximum RMS direction facilitates an aural evaluation of the time-space without semantic source content influencing spatial judgements. The data is sonified in HOA using `spat5.pan~`: direction controls the sonified Ambisonics source and RMS controls volume. Sounds used in the sonification include the W-channel (omni-directional channel) of the HOA source and a sine-tone where frequency is controlled by the spectral centroid of the extracted direction. A real-time, user-controlled threshold parameter, silencing the sonification when the maximum RMS is below a given value, allows background noise to be investigated interactively.

[1] [21] implies that a 42-beam spatial sampling is too sparse to make a precise mathematical comparison but discussion of the topic is outside the scope of this paper.

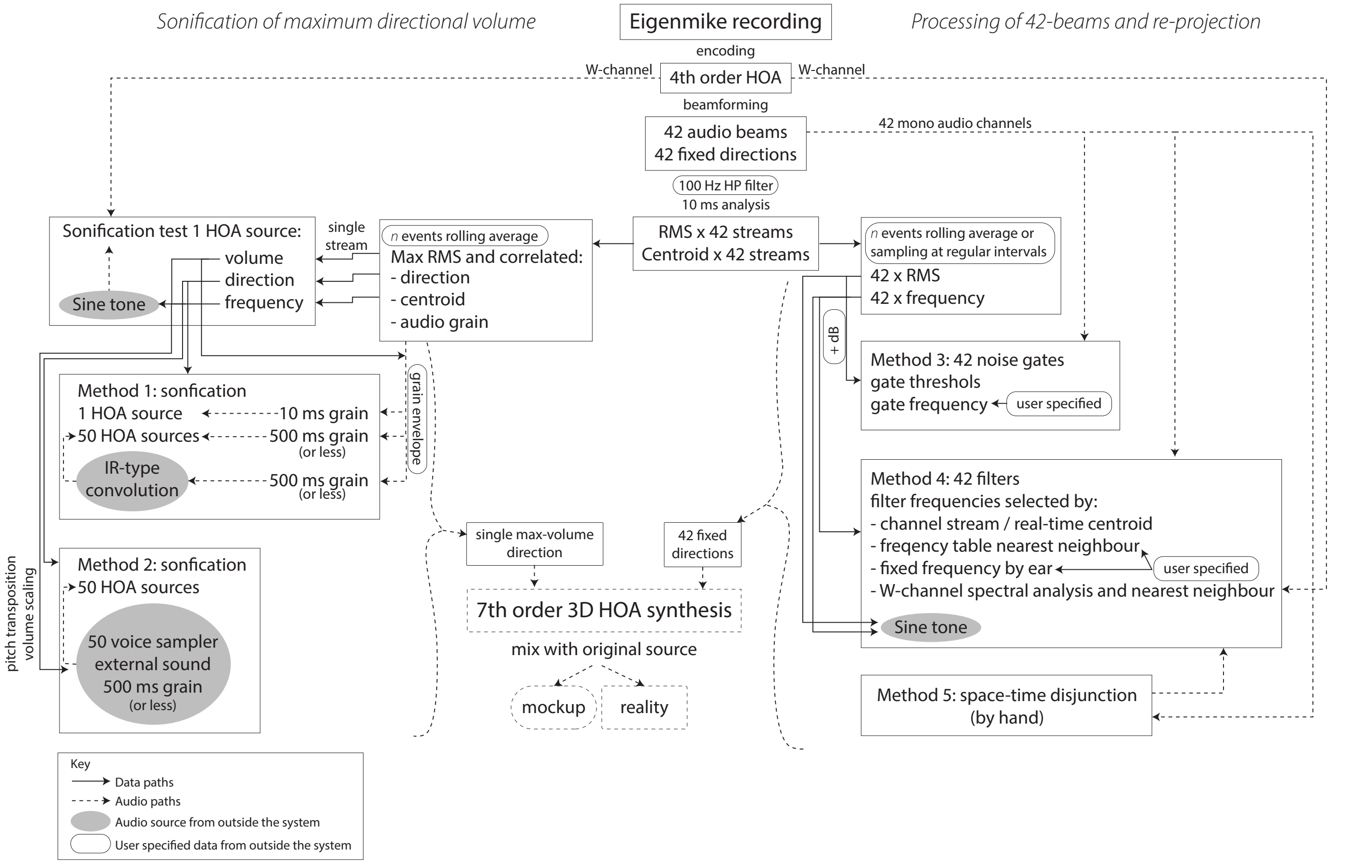

Figure 1. Background method and method branches

5 Method branches

The preliminary spatial analysis decomposes the scene into spatial data and audio stems, and synthesises the information in 7th order HOA. The results indicate that the method of extracting directional and amplitude information over the complete sphere functioned well. The method branches described in the next section concern real-time processes that take place in between the decomposition and re-synthesis stages with four aims: directing spatial listening to different features of the original recording, semantic abstraction of sources in keeping with the spatial investigation, enhancing barely perceptible acoustic resonances, and addressing the integration of temporality and spatiality.

Figure 1 summarises the background method and method branches. Methods applying sonification of the momentary maximum directional volume are on the left, and methods which add audio processing to all 42 directional beams are on the right. The figure shows automatic processing of sound and data, and user control or additional audio entering from outside the system.

5.1 Directing spatial listening

5.1.1 Purpose: This method aims to emphasise the impact of spatial change in listening awareness by focusing exclusively on the information in the single loudest direction.

5.1.2 Method: Rather than sonify the maximum RMS direction with the W-channel (as above), in this method the 10 ms sound fragment from the real-time loudest beam produces a stream of sound consisting of grains 10 ms long. The short grain duration however adds artefacts disguising associative and spectral features of the original recording. The solution is to increase the number of HOA sources whose locations are now updated in turn, maintain the 10 ms read rate, and increase the duration of the sound grain. The maximum duration of each sound fragment is a multiple of the number of HOA sources. The longer grains overlap and smooth the sonified output, preserving sufficient associative and spectral features of the original source. Three real-time controls allow the method to be fine-tuned while listening: grain envelope (effecting density and perceptible granularisation), the high-pass filter frequency applied prior to detecting the maximum RMS (serving to focus the analysis on a frequency region in the source recording even though the sonification uses the full band signal), and the threshold value that silences quieter grains (eliminating spatially chaotic low-level noise).

5.1.3 Audio example: Example 1a is an urban source recording from a blind side road in Oslo. We hear the noise of the city, ventilation systems, some footsteps, and the road and train clearly to the right. Example 1b demonstrates the method: in the start, the road and train are automatically identified as the loudest source direction. When the footsteps appear, the system then switches to this new focus, eliminating other directional information.

5.2 Abstracting sources

5.2.1 Purpose: This method aims to abstract the semantic nature of the source while preserving its spatial behaviour, drawing on how composers often transform sources in composition. The method builds on the spatial sonification approach by adding a polyphonic sampler to replace the spectrum of the original recording.

5.2.2 Method: A 50-voice sampler was built in MaxMSP. When the maximum directional RMS is above a threshold, each value triggers a note-on message in the sampler and the sound is then spatialised. RMS values also scale sample volume and the correlating centroids are mapped to a transposition scale (where the centroid range is mapped to a user specified multiplication range). The locations of each of the 50 sources are updated in turn, as are note parameters in the sampler. Both the threshold and the sample envelope are user controlled.

5.2.3 Example: Using the same recording as example 1a, example 2 illustrates this method using a short sparrow chirp as the triggered sample. The pre-RMS high-pass filter is set to 2000 Hz, biasing the analysis towards the transients. Example 2a applies a transposition range of one octave up and down and a sample envelope of 450 ms. Example 2b uses a 100 ms envelope.

5.3 Direction informed by spectral change

5.3.1 Purpose: For the ear, changes in spectral colour rather than volume may draw attention spatial features. Method 3 aims at revealing directional spectral changes when volume changes are insufficient, where rather than deduce the one maximum direction we instead hear a re-articulation of the sound-field.

5.3.2 Method: A noise-gate side-changed to a band-pass filter is added to each of the 42 beams. Both the filter frequency and the gate threshold determine when the gate opens in the following way: the filter frequency is constantly updated from the mode value of the W-channel centroid, calculated within in a user specified time interval. Each of the 42 beams then pass through individual filters, after which the RMS of these filtered versions determine when the gates open. The original full-band signals then pass through. Further, the gate threshold is continuously recalibrated to follow the dynamic contour of each of the 42 beams with three options. Each option produces slightly different results:

(a) The threshold is updated as an average of the last *n* RMS values of each beam. This is useful for sources containing large variations.

(b) The values are sampled at regular time intervals. This is useful for stable sources where variations are limited in range.

(c) Thresholds are set based on the minimum value so far, with the option of then freezing that value at any time. This is useful to allow most information through the gate system, and the freeze function highlights longer trends.

Other user controls include the duration of the noise-gate attack and decay times, and a value that can be added to the RMS ensuring the gate removes noises hovering around the threshold.

4.3.3 Audio example: Using example 1a as the source, example 3 demonstrates the method applying recalibration option (c). The noise-gates are set with an attack of 5 ms and decay of 1000 ms. The silence in the beginning of the example is due to the filters preventing the gates from opening.

5.4 Enhancing background resonances of the city

5.4.1 Purpose: Noise-based sounds filter around and through structures. Enhancing the barely perceptible resonances from this natural filtering can serve to mask noise or to help us listen.

5.4.2 Method: A resonant filter is added to each beam and the filter frequency is controlled by the real-time centroid of each beam. For most noise-based sounds the centroid is unstable and the update rate of 10 ms results in an unsuitable 'bubbling' frequency. A smoothing function is added that calculates the median centroid frequency from an array of incoming values and interpolates between these medians at a user specified time interval or 'glide time'. Designed to address background resonances which themselves change slowly, the slow response time does not present any musical problems. This filtering method is a compositionally interesting way to abstract the sound-field.

5.4.3 Audio examples: Example 4a is a source recording from the same site as example 1a. Example 4b applies the filtering method using a glide-time of 1000 ms with 4a mixed in for easier comparison. Four variations were then tested:

(i) A frequency table is prepared by the user. The nearest neighbour to the real-time centroid is selected from this table. The density of frequencies in the table will determine the spectral complexity of the output as well as allowing the resonant field to be 'tuned'. In example 4c the filter table imposes a new spectrum while the output follows the dynamic spatial qualities of the original sound.

(ii) A frequency table is prepared with values that reflect the global trend in the recording. Aural decisions are often more successful when deducing global features but are also labour intensive and subject to listening fatigue. Instead, a spectral analysis of the W-channel calculated the 10 loudest frequencies in real-time as 10 data streams. For each stream, the mode frequencies from specified time chunks are appended to a table. After analysing a representative duration of the recording, the table is locked, and as above, the nearest neighbour to the real-time centroid is selected from this table. After listening for a short time, the resonant field may sound 'correct' and the centroid tracking can be disabled, fixing a single filter frequency for each beam. Example 4d illustrates this approach.

(iii) Building on method 4(i) and 4(ii), in 4(iii) the filter frequency is updated only when the noise-gate threshold is exceeded. The result is a compositionally useful abstraction of the sound-field. Example 4e demonstrates this method.

(iv) Filters are replaced by sine-tones, generating spatial additive synthesis. Like method (iii) this creates a compositionally useful abstraction which is illustrated in example 4f.

5.5 Extending time and space

5.5.1 Purpose: In this method, transformations of the sound-field focus on the extension of time and space. Temporality and spatiality are inseparable in the real world and the method addresses a similar integration in the investigation of acoustics and music.

5.5.2 Method-5(i): When beam-forming clearly isolates direct and reflected sound we can then manipulate both temporal and spatial separation. Increasing the time difference alludes to a spatial expansion and highlights the reflective and geometric features of the space. In case study no.2 below, this technique is applied to the crow call and the subsequent transformations heard throughout the second half. The case study also demonstrates other treatments of direct and reflected sound, such as pitch transposition or further processing by one of the methods described above.

5.5.2 Method-5(ii): To prolong momentary information, a post noise-gate delay is added to each beam. Although predictable in stereo, when applied to the spatial field the results are more interesting. Sound example 5 demonstrates the method using same source as in example 1.

6 Case studies and compositions

The following three case-studies illustrate how the above methods probed and emphasised qualities discovered at each site, and how the outputs were shaped into landscape compositions.

6.1 Pathway and the 170-loudspeaker

Reflected sound is a vital component in many of the site recordings. Directional sound projected from a loudspeaker can be used to highlight the acoustic properties of surfaces making them 'speak' - an observation gained during informal investigations using IEM's icosahedral loudspeaker (IKO) [18]. The IKO is however a concert instrument: expensive, bulky and visually dominating. The solution was to scale down the IKO into a more practical construction. In tests, I found that horizontal projection was more important that vertical projection due to indoor spaces tending to feature high ceilings and outdoor spaces rarely presenting interesting canopy surfaces. An eight-channel speaker would be portable and compatible with commonly available audio interfaces. Zotter et. al designed a technical solution that became the 170-loudspeaker [19]. This speaker projects 3rd order horizontal HOA beams and requires an 8-channel audio interface and amplifier. The first prototype was designed for indoor use, although future editions will be modified for outdoor conditions.

Because the project specifically addresses outdoor environments, it was important to find a suitable indoor location for the non-weather-proof 170-speaker that would immediately create an indoor-outdoor connection. The outdoor site was a pedestrian path located along-side a large glass window at the Norwegian Academy for Music in Oslo (figure 2). The inside location for the speaker was directly on the other side of the window (figure 3). Eigenmike source recordings were made between Dec 2019 - Jan 2020 when institutions were partly open but students on Christmas break (extracts from this recording are those used in the above sound examples). The outdoor soundscape consisted of distant sounds from the train and road, closer infrequent sounds of people walking, a few birds and distant voices. Closer sources rebounded off two adjacent buildings and distant sounds were filtered by the city structures. The indoor area was a large alcove featuring the glass window on one side, two red-brick walls, stone floor and some leather covered furniture.

Figure 2. Outdoor site for case study 1

Figure 3. Indoor site for case study 1

Methods 1, 2, 3 and 4 revealed interesting qualities from the original sound landscape and created materials that interacted with the acoustical features of the physical installation location. The results were then composed into a 20-minute work that bridged two real environments - outdoor and indoor - via HOA and beamforming as shown in figure 4. Resonances and transients highlighted the qualities of the indoor space while also connecting to the experience of the outdoor sound landscape. The case study is documented in the project 'Inversion-1' as a 360-video with 360-

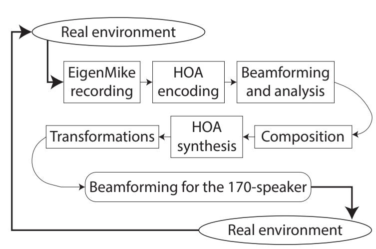

Figure 4. Case study 1 compositional overview

audio rendered in Youtube from first-order Ambisonics (FOA) [20].

6.2 Amphitheatre and small loudspeaker array

The amphitheatre is located behind the Norwegian Academy for Music in Oslo. Eigenmike source recordings were made in the same time-period as case study 1, but unlike the pathway, this site is surrounded by asymmetric high brick buildings, trees and shrubbery (figure 5). The recording revealed a more distant city drone than in case study 1 and nearby noise from ventilation systems. During good weather, visitors frequent the area.

Figure 5. Outdoor site for case study 2

By far the most interesting feature of this area is a flutter echo highlighted by transient sounds, yet it tends to go unnoticed and is furthermore less prominent when the summer vegetation dampens the acoustics. These properties are clearly revealed in the winter recordings when crows pass overhead and the city's transient sounds enter the area. To further investigate the acoustics, 3-D impulse response recordings were made with an SPS200 microphone and a Genelec 1032 loudspeaker. It was then possible to replicate the acoustics in the composition without the transient volume that would be required in the real-world context.

Methods 2, 3 and 5(i) were found to be most relevant. When direction informed by spectral change (method 3) lost interest, method 2 then proved useful in musically developing the semantic information while preserving its spatial function. Method 5 allowed a detailed study of the acoustic features of time and space characteristic of this site.

The final stage of this case study is a site-specific version of the composition played over an outdoor distributed loudspeaker array. The installation date has been delayed by the COVID-19 pandemic and is now planned for the autumn of 2020. The composition process involved a site mock-up, where the original recording was played in the background to the composed materials. This background will be removed when the installation is played outdoors. The mock-up revealed how the composed sound-field changed the mode of listening to the original, and in turn informed how a listener may then experience the combined outdoor environment. 'Sound Landscape Development 5' is a 360-video with 360-audio rendered in Youtube from a FOA version of the composition mock-up [20].

6.3 Expanse, intimacy, near, far, calm, turbulent

This case study uses three Eigenmike recordings from Fyresdal in West Telemark, January 2020: a snowy wind recorded from a porch with windchimes, horses and a donkey feeding in a small stable and chickens feeding inside a small chicken coop. I was particularly interested in the morphology of the sounds and the contrasts of spatial expanse and intimacy. This meant that although all methods yielded interesting results, for compositional purposes I focused on methods 1, 2 and 5(ii). As the recordings were from a private location, this case study is primarily for concert. Aiming to project the experiential sound landscape, a few carefully chosen studio recorded sounds of similar spectral-temporal morphology were added. 'Sound Landscape Development 2' documents the work [20].

7 Conclusions

New methods for processing and composing with high resolution recordings of everyday soundscapes have been developed. These methods aim to reveal and enhance hidden features that may become sources of interest, deepening our sense of presence in everyday sound landscapes. The coupling of technical and artistic approaches draw on higher-order Ambisonics, acoustics and perception, and integrates these with an interpretation of sound and the way we choose to, or are guided to, listen. The methods fall into two categories: the sonification of extracted directional information, and a manipulation of the directionally decomposed audio scene.

During in-situ experiments for the site-specific playback of composed sounds, it became evident that a live microphone would be useful to calibrate the layered (composed) sound to the level of the real-time background. This will be added to future projects.

A continuation of the work with 3D impulses is currently underway, where directional and spectral information is analysed and used to determine further spatial, spectral and temporal compositional decisions.

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