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Ordnance Survey: Exploring Activity Through Large-scale Topologies and Auditory Mappings

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ABSTRACT This paper describes recent work on a large-scale, distributed audio installation entitled *Ordnance Survey*. It explores problems associated with presenting an overview of large, complex data sets in real-time. This is accomplished through the creation of a spatially separate audio-visual environment in a manner that aims to provide an immersive experience of disparate events in a single locality.

Ordnance Survey consists of an immersive audiovisual environment that is fed by a network of geographically dispersed sensors, these combine to provide an overview of activity from spatially disparate locations. These sensors may be considered as parasitic agents that feed on the activity in their local area—creating audio in relation to the proximity and behavior of festival-goers themselves, the weather, and the festival performers. This audio is transmitted back to a central listening room where it is used in the construction of a multi-speaker soundscape.

The soundscape, therefore, directly relates to the complex interactions that construct the weekend's event; tracking disparate occurrences such as people's movement around the site, audio from concerts and the regularity of toilet visits. In the dimly lit space of the listening room the audience is presented with simultaneous audio-visual experiences that directly relate and convey a detailed yet comprehensible representation of the whole festival. Tracking the flow of the observers and the observed, the installation provides an overview of disparate events all in one place.

INTRODUCTION The installation *Ordnance Survey* represents the social activity of a whole festival site through the presentation of an audiovisual environment. A central aim of the work is to highlight the interconnectivity of the seemingly disparate events that constitute a music festival through the provision of a topographical auditory display. In pursuit of this aim, a system of remote sensors and transmitters capture ambient auditory information and generate audio that relates to activity within the site; relaying this audio back to a central listening room where it is re-presented to a group of listeners—thus creating a sensory experience that relates to the activity of the site.

Ordnance Survey is primarily an artwork designed to produce an aesthetic result, so a true transference of data from the site to the listener is not its main concern. Rather, it strives to present an overview of activity in the site through sensual means. Thus, through its design, it sacrifices a literal transference of data for the creation of an impression, a sensory experience that reflects the events. By completing this work the artists have been engaged with the complementary issues addressed in the fields of auditory display and soundscape composition, as well as the associated issues of auditory scene analysis, data sonification, mapping, and algorithmic composition. This paper will present some of the discussions that relate to the larger aesthetic motivations and problems that informed the development of the piece. Following this, we will present a detailed technical description of the piece as installed at a recent new music festival in Ireland.[1]

INTERPRETING COMPLEXITY

The process of presenting simultaneous auditory streams from multiple locations presents a technical and aesthetic challenge to the artists, a challenge that relates to the limitations of the human perceptual system's ability to interpret and understand simultaneous information from a multitude of locations.

Two differing approaches to considering this problem informed the design of *Ordinance Survey*: firstly, from a perceptual point of view, the field of Auditory Scene Analysis (ASA), and secondly, from a compositional point of view, the field of Soundscape composition. Both these approaches deal with how a person relates to, and interprets, their auditory environment; both fields are complex and in-depth. This article will not attempt to represent the fields in all their detail, but will introduce points that are relevant in that they affected the design decisions of the artists. For further background reading on both these topics the reader is referred to Bregman and Truax.[2]

AUDITORY SCENE ANALYSIS

Albert Bregman's book *Auditory Scene Analysis: The Perceptual Organization of Sound* outlines the principles behind ASA detailing the brain's ability to perceptually organize a complex audio environment.[3] ASA explores the brain's ability to group sounds into distinct packages or objects that have arisen from a single source of sound and is thus concerned with "how many sound sources there are, what the characteristics of each sound are, and where each source is located."[4] To understand how this works it is best to start with an understanding of how the brain perceives sound.

Most sounds found in nature are what are known as complex sounds, sounds that can be described as consisting of a number of different sine waves oscillating at different frequencies with various amplitudes. In harmonic sounds, sounds that have a perceived pitch, these sine waves oscillate at frequencies that are multiples of the lowest frequency, and it is this lowest frequency that determines the pitch. The amplitude and spacing of these higher frequency sound waves affect the sound quality or timbre of the sound. When the brain is presented with a complex auditory scene consisting of a number of simultaneous, different sounds it has to interpret which of the frequency components correspond to one sound, and which correspond to another. Through a process known as sequential integration the brain groups these frequencies into sound objects based on the temporal and intensity relationships between them. Examples of these instances include: do the frequency components start and stop together; do they rise and fall in intensity together; are they near each other in frequency; are they part of the same harmonic series, i.e., do they have a harmonic relationship to each other?

These elements have much in common with the Gestalt psychologists' organization principles of the visual field which are:

- *Similarity:* elements that are similar in physical attributes tend to be grouped
- *Proximity:* elements that are close together in space or time tend to be grouped
- *Continuity:* elements that appear to follow in the same direction tend to be grouped Common Fate: elements that appear to move together tend to be grouped
- *Symmetry & Closure:* elements that form symmetrical and enclosed objects tend to be grouped[5]

The brain's ability to ignore different auditory streams and pick out information from just one is known as the *Cocktail Party Effect*.[6] However, in the case of *Ordnance Survey* we are less interested in the user's ability to pick out a single stream from the information available, than we are by our requirement to present a coherent aesthetic experience. Bregman sheds some light on this when he discusses the application of ASA to music. In a symphony orchestra you have over seventy players all producing "noise," yet these results can be pleasing to the ear and can be listened to without a resulting sense of chaos or sensory overload. Bregman introduces the idea of a chimeric instrument, an instrument that does not belong to any single sound making object; rather, it is created through the superimposition of a number of instruments.

> *Natural hearing tries to avoid chimeric percepts, but music often tries to create them. It may want the listener to accept the simultaneous roll of the drum, clash of the cymbal, and brief pulse of noise from the woodwinds as a single coherent event with its own striking emergent properties. The sound is chimeric in the sense that it does not belong to any single environmental object.*[7]

Musical scene analysis is thus, in some ways, more complex that auditory scene analysis in that we don't necessarily reduce the parts in the piece into distinct auditory objects. Rather, we develop a level of hierarchy in the music, marking out the individual parts as distinct at one level, but existing within a total composition that is distinct at another level.[8] A musical piece can be perceived as a single musical object, or, it can be heard as groupings of solo or ensemble instruments within the musical body. For example, a solo flute part might stand out against the body of an orchestra, or the string section may play in counterpart to the wind section. Most importantly, the sounds of an orchestra are balanced and created by a designer, called a composer, which nicely leads into our second area of interest: soundscape design.

SOUNDSCAPE DESIGN

The field of soundscape design is discussed in several books, one of these is Barry Truax's *Acoustic Communication*. This publication is concerned with how our sonic environment, known as a soundscape, conveys information to a listener situated within it. This (somewhat ecological) account describes the listening process as a search for meaningful information in the incoming auditory data stream. Truax highlights the fact that in this instance the basic unit of information in an auditory stream is difference. For example, continuous sounds, such as simple pure tones, convey little or no information. Such sounds quickly become perceptually uninteresting and are either filtered out by the brain or become annoying. However, for communication to be effective, variety in audio must be balanced by it being understood as meaningful to a listener. If there is too much information, or information is unordered and cannot be patterned, it is as useless to the brain as would be too little information. Truax uses white noise, a sound that has changing energy at all frequency components, as an example of sound that is too complex to convey any useful information to the brain, and thus, may quickly becomes tiring on the ear.[9]

Truax outlines three variables that must be considered to create a functioning soundscape:

> *A variety of different kinds of sound, and variations of particular types of sound, are present and clearly heard. Such sounds may be said to be "rich" in acoustic information.*
>
> *A complexity exists within the sounds themselves and in the types and levels of information they communicate. Listeners who are familiar with the environment are able to decode and interpret subtleties in the sound that the novice does not recognize.*
>
> *A functional balance operates within the environment as a result of spatial, temporal, social and cultural constraints on the system. That is, variety and complexity are constrained by balancing forces that keep the system in a functional equilibrium. However, the system is limited in its ability to reorganize itself when threatened by perturbations and change at the organizational or structural level.*[10]

Natural soundscapes can be assessed using the above criteria. In this definition successful soundscapes have a variety of well balanced sounds that can be clearly distinguished from each other. They have a level of complexity that is simple enough to present information to the novice listener, yet complex enough that through a period of sustained engagement a listener can acquire a more sophisticated and enriched listening experience. A balance exists within the sounds of the environment in terms of spatial, temporal, and timbral organization. Most importantly, the complexity and intelligibility of the environment are balanced to achieve transformation of data whilst maintaining interest.

DESIGNING ORDNANCE SURVEY

The brief overview of ASA and Truax's criteria for a successful soundscape as outlined above provided a framework which guided the design of *Ordnance Survey*. Combined, they present a set of balancing questions and principals to be considered.

SIMILAR AND DIFFERENT

As stated previously, the main aim for the piece was to present an overview of all activity over a festival site in a manner that simultaneously provided for the listener's ability to perceive distinct events while also perceiving the whole as a coherent sonic experience. This desire to create a work that supports a hierarchical mode of listening ties in with Bregman's observations with respect to musical scene analysis. For this to occur there must be complexity and difference, but so too, there must be a level of coherence and similarity that allows for the grouping together of individual sonic events into larger structures.

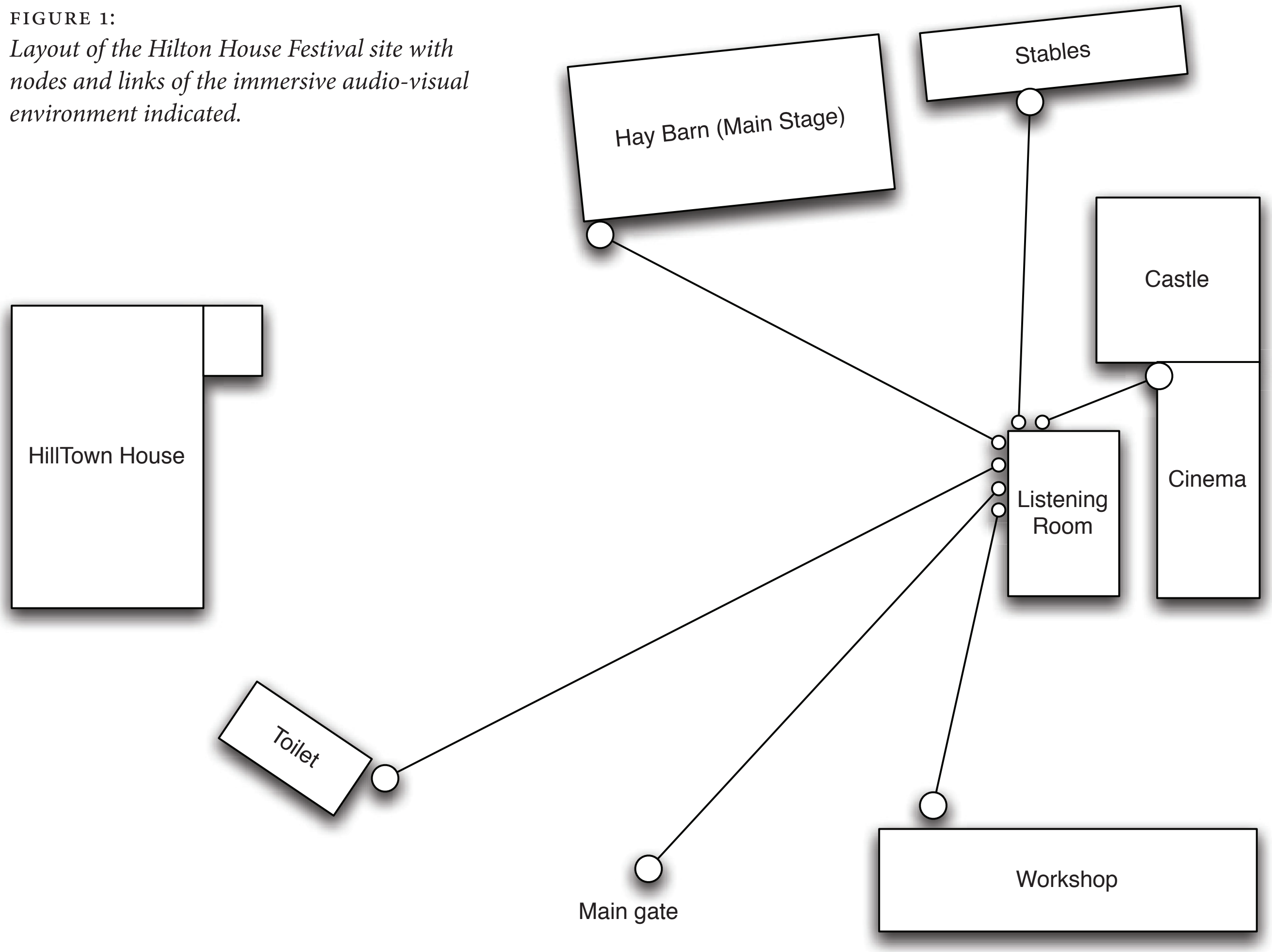
In designing each individual node, this principal of similarity and difference in the sonic palette informed choices. Though each node is composed of similar materials they react to stimulus in different manners. (The details of each node are given below.) Though each node contains a sensor and actuator, these are not solely responsible for the totality of sound transmitted to the listening room. An element of the soundscape is constructed from the conveyance of the local sound at each node along the connecting wires back into the space. For, in traveling along these wires, the sounds are modified by the medium itself to the extent that they sound different, yet are still recognizable. The wire acts as a rather extreme filter with periodic reflections that add a repeating echo. This filtering and reverberation being applied to all sounds aids in the similarity. This simple representation of the transformed sounds helps to focus the ear. All of the sounds, no matter their source, travel along similar piano wires from their source to the listening room and are all colored in a similar way.

This timbral "flattening" effect on the sounds make the sounds seem like they are part of the same composition, thus increasing the likelihood of Bregman's chimeric musical experience. This reduces the sonic complexity for the listener and makes the whole auditory scene more integrated and listenable.

SPATIALLY FLATTENED

By presenting all the distant sounds from across the site in the same space simultaneously, we have, in effect, flattened the spatial aspects of the sound landscape. Sounds that

FIGURE 1:
Layout of the Hilton House Festival site with nodes and links of the immersive audio-visual environment indicated.



were distant now sound as present as those that are close. Such a flattening of the auditory depth of field affects Truax's notion of balance in the soundscape and also can have an affect on the brain's ability to segregate the audio into separate streams. A presentation of simultaneous streams of somewhat disparate auditory information from many sources could lead to the listener suffering from sensory overload, however, a balance is created between the need to distinguish the sounds from each other and the need to create a working composition. This problem is partly solved through the respatialization of the sounds onto separate auditory channels so that each node comes through a separate and distinct speaker. This helps the listener to identify which sounds are coming from which location and this, in turn, allows the listener to identify activity levels around the actual site. Additionally, complexity levels in the installation were managed through the automated mixing process—foregrounding different areas of the site in turn.

LISTEN UP

The most important aspect from a design perspective is the development of a complete sensory experience, an experience which represents the activity of the festival site. With this aim in mind, the listening room is carefully designed to promote mindful contemplation of the sonic landscape. The listening space itself utilizes two main approaches to concentrate the ear of the listener. Firstly, when entering the room the listener enters a darkened space; with a lack of any visual stimulus the channels of auditory information become more prominent, this concentrates the mind on the process of listening.

Secondly, there is dim lighting in the space that responds in brightness to the amplitude of the sound. This light fluctuation is affected by just three of the audio streams. When the user recognizes this they attempt to understand the relationship between sound and light, thus encouraging an even closer attention on the sound.

CONSTRUCTING ORDNANCE SURVEY

FIGURE 1 gives an overview of the festival site at Hilltown House, Castlepollard, Co. Westmeath, Ireland. The individual nodes are marked as circles and the piano wires are indicated as lines connecting back to the listening room.

THE NODES

The nodes are positioned around the site and are connected to the listening room via long lengths of 0.1 mm piano wire. (The nodes are positioned at a height that is sufficiently high enough to avoid any strangulation or trip hazard, generally about two or more meters above the ground.)

Node 1 (Sentinel): This node was positioned at the entrance to the festival. It contained an infrared beam breaker type detector. This enabled it to react each time a person entered or left the festival site. Each time the infrared beam was broken a solenoid tapped the wire connecting the node to the listening room.

Node 2 (The Call of Nature): This node was positioned above the door of the building that housed the toilets. It contained an ultrasonic range finder that could measure the proximity of an object from the door. This proximity measurement controlled the frequency at which a solenoid tapped the wire connected back to the listening room. As a person walked toward the door the solenoid would begin to tap the wire at ever increasing frequency ranging from one tap every minute or so to one tap every second. As the person entered the building the tapping would drop off again.

Node 3 (Ascension): This node was suspended above an outdoor stairway that led up to the listening room. It contained a PIR (Passive InfraRed) sensor that was triggered whenever a human walked beneath it. Again, this node contained a solenoid that plucked the wire repeatedly whenever a person was in range of the PIR.

Node 4 (Ears): This node contained a microphone which picked up the sound from within a space that was used for rehearsal by musicians. (The space also housed a video installation by another artist). The signal from the microphone controlled the spinning of an electric motor such that increasing sound level led to increasing rotational velocity. Attached to the motor's spindle was a pick, picking the wire which connected the node to the listening room once per revolution.

FIGURE 2: *Sentinel (sensor and actuator hidden in can)*

FIGURE 3: *Receiving cans attached to listening room wall*

Node 5 (Telephone): Node 5 was the simplest of all the nodes. It consisted of an empty can suspended above the main stage of the event, it was connected to the listening room by way of a long stretched wire. It acted as a pure bean can telephone—relaying sound from the main stage along the wire to the listening room.

Node 6 (Install): This node combined an ultrasonic range finder with a solenoid in a similar manner to that used in Node 2. The sound from each node was picked up at the receiving end of each piano wire by a compact electric microphone located in a metal can (FIGURE 3). These cans (one for each node) were mounted in a vertical line to the outer wall of the listening room, some twelve feet above the ground. The microphones signal was amplified to line level by a prea mp and fed into the listening room to a motu828 eight channel audio card, which in turn, made each audio stream available within the Max/MSP software.[11]

THE LISTENING ROOM

The listening room was contained in a stone building dating from the seventeenth century. The room was approximately fourteen feet wide and twenty-four feet long. The two windows of the room were completely blacked out and a heavy lightproof curtain hung over the door. Positioned around the darkened were six beanbags. Hanging from the ceiling were three, bare, incandescent light bulbs. Positioned around the periphery of the room were six active speakers on stands. The computer, sound card, and associated electronics were concealed in a plinth in the far corner of the room and away from the door.

FIGURE 4: *The Listening Room (with house lights on for purpose of photographic documentation)*

THE SOFTWARE

The software, written in Max/MSP, was designed to carry out a few simple functions. It assigned each audio stream to an individual speaker. It also monitored the sound level of three of the audio streams and used this value to control the brightness of three light bulbs. This set up an inverse relationship, whereby an increase in sound level led to a decrease in light level.

The software also applied compression and limiting to the sound in order to set a maximum on the possible sound level. Finally, it adjusted the volume of each stream in a slowly moving cycle from a minimum point to a maximum over the course of fifteen minutes or so. This gentle volume adjustment was programmed in such a way as to ensure an evolving relationship was developed between each audio stream over the course of the day. In this way, the volume of each stream as experienced in the listening room, was affected by two things: the actual activity of the corresponding node and the state of the software controlled fade.

CONCLUSION The design and construction of this installation presented a number of challenges to the artists. The overall aim was to create a sensory experience that related in real time to the activity (sonic and otherwise) of the music festival in which the installation was situated. This posed some problems to the artists, most notably issues relating to the brain's ability to perceive simultaneous streams of auditory information. More concern was placed on the creation of an experience that related to activity, rather than a literal transference of data from site to source. This enabled the artists to achieve the perception of an integrated aesthetic experience through the filtering and sculpting of sounds, such that simultaneous, yet distinct streams, were perceived as an aesthetic whole. Research-informed design processes were applied to the data, as well as to the creation of the listening space in order to create a space that promoted contemplative listening as the main activity.

Over the course of the two-day festival the installation was visited by approximately one hundred listeners with many choosing to revisit several times. The dim lighting and immersive sound enticed many visitors to stay for over an hour. Informal interviews with participants indicated they found the piece enjoyable and interesting regardless of the process that was involved in its creation. When informed of the connection between onsite activity and the generated soundscape many chose to revisit the listening room to investigate the relationships aurally.

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BIOGRAPHIES

Tom Davis is a digital artist working mainly in the medium of sound installation. He recently graduated from the Sonic Arts Research Centre in Belfast with a PhD in Sonic Arts. His practice and theory-based research centers on issues of Embodiment, Ecology, and Complexity in Sound Installation. Davis has exhibited work across Europe and has performed at festivals and conferences in Europe and the United States.

Nicholas Ward is a Belfast based interdisciplinary artist. His work is predominantly sonic in nature, exploring notions of mechanism and physicality though installation and performance. Ward is currently studying for a PhD at the Sonic Arts Research Centre at Queens University, Belfast.

NOTES

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