not only build a new kind of living archive, but also have listeners' experiences of that archive one of wonder and sensation, a sonic database that would not only help us to remember and learn about the past, but also to create new experiences within the complexity of changing soundscapes over a period that usually defies our human comprehension. I see this tool being helpful to researchers in many disciplines, and also having a place in libraries, museums, centers, and perhaps "in the field" along paths such as the Santiago's Way, where one could download an audio file from the map online; then listen as they walk back through history.

About the Author

Maile Colbert is an intermedia artist with a concentration on sound and video, living in Lisbon, Portugal and teaching at Faculdade de Belas Artes, Universidade Porto. She spent the last four years collaborating with the organization Binaural/Nodar, and is an ongoing contributor of articles on soundscape ecology and sound studies at "Sounding Out," the award winning sound journal, and has performed and screened widely in Japan, Europe, Australia, and the Americas. More on her and her work can be found at www.mailecolbert.com.

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References

Barthes, Roland. 1985. "Listening." In The Responsibility of Forms: Critical essays on music, art, and representation. Oxford, UK: Oxford Press.

Kolar, Miriam A. 2013. Archaeological Psychoacoustics at Chavín de Huántar, Perú. Ph.D. dissertation, Department of Music. Stanford, CA: Stanford University. https://ccrma.stanford.edu/groups/chavin/current.html).

Krause, Bernie. 2012. The Great Animal Orchestra: Finding the Origins of Music in the World's Wild Place. New York: Little Brown and Company.

Vanclay, F. 2008. "Place matters." In (F. Vanclay, M. Higgins, & A. Blackshaw, eds.) Making Sense of Place. Canberra: National Museum of Australia Press, 2–11.

Machine Listening to Soundscapes: Playful Discovery of Sound Languages

By Iannis Zannos

Abstract

This article looks into the possible repercussions of massive availability of data in Soundscape research and creation. The problem posed by large amounts of sound data is that it becomes no longer possible to review the entire sound collection of a project manually, due to practical time limits. Machine listening techniques can help to search through large sound databases, and to identify those parts of the sounds which have desired properties, or categorize sound segments into groups that share certain characteristics. However, introducing the machine as a quasi-active component in the perception, understanding and manipulation of sound requires a fundamental re-thinking of the way in which sound is perceived. The article traces some of the implications of machine listening from a general philosophical and culture-theoretical view. It identifies concepts, practices and thought movements that foreshadow the idea of machine listening, such as the concept of navigation as a fundamental component of the understanding, interpreting, and constructing of both real and virtual environments. The discussion traces existing connections between pre-historic concepts such as the labyrinth and ideas that appear in the history of technology, leading to the digital computer. It is suggested that examining these ideas in relation to machine listening and contemporary soundscape practices can help both in the understanding and creative application of machine listening techniques.

Introduction

The present article originated from a simple practical question: How can the artist or the researcher deal with the ever growing amounts of recorded sound data? In the early days of soundscape studies, recording technology as well as sound storage media imposed a limit to the total duration of recorded sounds that a project could collect. Today, this limit lies easily beyond the amount of time available to the researcher or artist in a project. Several factors contribute to this situation: first the high capacity and low cost of digital storage media. For example, the total duration of uncompressed stereo sound at 44100 KHz and 24 bit resolution that can be stored on a hard disk of 1 Terabyte (with an approximate cost of less than 100 US dollars) is more than 1,000 hours).

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(((2 ^ 30) * 1000) / (2 * (24/8) * 44100)) / (60 * 60)
= 4057981.2″
= 1127h 13 min 1″
= (140.90213 8-hour days)
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Fig. 1. Total duration of 24 bit stereo audio recordings fitting in 1 Terabyte disk.

At 8 hours of listening per day, it would take more than 4 months to listen once through all the sounds contained in that 1 Terabyte disk. But the actual practical duration limit of useable recorded sound for a research or art project is much shorter than that, if one considers the need to develop familiarity with the sounds through repeated listening, particularly if one were to make meaningful choices or observations, as to be expected. A host of questions arises from this fact, some of which may have profound repercussions on our concept of soundscape as a field of research and creative engagement.

Among these questions are:

- Does the availability and accessibility of large amounts of recorded sound require a fundamental rethinking of work methods and the ontology of soundscapes?
- What are the experiential (psychological, phenomenological) and cultural implications of data overabundance in the audio domain?

What can we learn and use from other research and cultural domains that deal with large amounts of data, such as bioinformatics, experimental physics and astrophysics, and in general from domains that engage in "Big Data" research methods (such as finance and business informatics, meteorology, health care, genomics, and connectomics)? An exploratory "what-if" attitude is adopted here, assuming that we need to incorporate the concept of the 'machine' in our listening process in order to contextualise the radically changed reality of storage and its related ramifications, so to speak. From this perspective, this article will try to outline the possible consequences regarding our understanding of what a soundscape is – as well as the ways in which one works with sound. In some domains, the machine is already central to the loop of sound and therefore humans. Music Information Retrieval (MIR) is a field with well-developed methods and tools based on digital audio signal processing. Many interactive 'media arts' works surrender at least part of the responsibility of assembling and modifying the presentation of sound collages to the machine. The influence of the machine on practice has transformed through various artistic and philosophical stances, such as Surrealism and Dadaism, Concrete Poetry, Oulipo, Letterism, and Situationism. It may not be a coincidence that these movements appear in parallel with the gradual rise of use of machines in modern societies.

A key issue connecting these movements is sense-making, with respect to the delegation of work, action and control to non-humans. In other words, what is the substance of meaning, how does it arise, what is its role, and how do humans make sense of things? The importance of these questions grows proportionately with the degree of delegation to machines, for we need to understand how machines make sense of what we delegate, and how this may relate to our understanding. Hence it is hardly surprising that, faced with the increase of automation and algorithmization of processes in society, cultural attitudes towards meaning tend to break down, with the consequential impact being movements arise as ways for humans to confront or embrace the meaningless or absurd. Research in cognitive science, machine learning and artificial intelligence, as well as various contributions referred to as constructivism (Plask, von Förster, Maturana, Varela) and having their roots in biosemiotics (Uexküll) and cybernetics (Wiener) offer alternative meanings and contexts. The following traces some further implications of this issue, from the perspective of working with sampled sound.

Sampling vs Listening

Sampling, through sensing devices intended to measure data from the environment and store them for later use, represents a new type of interface to the environment. It is fundamentally different from other types of interfaces, in that it delegates both senses and memory to machines instead of relying on human sensory experiences. At the same time it introduces a new layer of mediation. Recorded samples can be regarded as virtual environments mediating our experience of the world over time. Accessing sampled data in any way involves an element of re-interpretation, or reconstruction. Put another way, mediation creates a new object of experience, whose relationship to the environment from which the recorded data originated is subject to re-interpretation and reconstruction.

> "... there is a third approach to sample-data mediation, which involves the living human being as part of the reconstruction process through sensory experience of the data."

Sample-based reconstruction activities fall commonly into two types: (a) rearrangement and editing of the data, using them as building materials in the construction of new experiences and (b) use of data as a source from which to extract a model or hypothesis representing a novel view of the phenomena from which they were obtained. The first type of reconstruction is mostly associated with creative cultural or artistic activities. The second one belongs to the domain of empirical sciences. The author contends that there is a third approach to sampled data mediation, which involves the living human being as part of the reconstruction process through sensory experience of the data. It is possible to understand this approach as resulting from the reversal of the perspectives of the two types of activities above; instead of diverging, they converge to create a new kind of relationship with the sampled data as mediated experiences. This proposed third type of approach to sampled environments is based on the exploration of features revealed within the data through the senses. This is made possible through synthesized auditory (or also visual or tactile) representations of features obtained from analysis of the data. The features are made audible instead of being represented as abstracted numerical or symbolic elements.

Human Experience

Approaches placing the subjectivity of human experience at the center of systematic studies of the environment have existed prior to the digital age. Philosopher Henri Lefebvre developed the concept of rhythmanalysis to refer to the analysis of perceived rhythms in the urban environment. Situationist Guy Debord used the notion of dérive to describe an intentional concept of aimlessly drifting within the urban environment; it is a means toward revealing psychological effects of the environment, as is suggested within the discipline of "psychogeography" put forth by Debord and the Situationist movement. Whereas both of these concepts arose within methodological models that employed plain introspection as a primary method of investigation, the broader context of these models also involved physical measurement as an additional source for the analysis of the geographical, social and functional experiential characteristics of the environment. Revisiting these concepts is thus useful in the new context of recorded soundscapes when searching

for ways to understand the workings of human perception in the temporal unfolding of the navigational experience. Understanding the perceptual mechanisms of rhythm perception and developing a formal system for describing rhythmic structures can guide the structuring of multimedia navigation seen as a kind of performance. Conversely, looking at the navigation within the artificial environment of data from the psychogeographical perspective of dérive can serve as a complementary method for retrieving environmental features from data.

These pre-digital concepts can be reintroduced in the broader epistemological context of soundscapes as mediated environments. Older general theories and concepts that rely on navigation for the exploration of conceptual structures, such as the Labyrinth of Minoan Crete (< 500 BC), Johannes de Sacrobosco's *De Sphaera mundi* (ca. 1230), Ramon Llull's *Ars Generalis Ultima* (1305), and Gottfried Leibnitz's *De Arte Combinatoria* (1666) can be linked to the originating concepts and techniques of the Western Theory of Harmony. These theories use navigational devices to explore relationships of concepts laid out in quasi-virtual spaces, in order to generate new statements and thus new meanings from the combination of concepts. The devices can therefore be regarded as early models of computational intelligence, that is machines that generate thoughts or meanings. In the age of digital computers, theorists such as Peter Gärdenfors (2000) have proposed "geometrical" models of thought. His book, *Conceptual Spaces: The Geometry of Thought*, investigates such models which employ spatial metaphors comparable to their much earlier precursors. In this context, the navigation of the user in a recorded soundscape becomes, in this sense, part of a machine intended to generate meanings and/or experiences.

To close the circle between sensing and thought, or data input and data processing, the movement of the user can also be recorded to form new data which in turn influence the resulting models that filter or map the data as experiences. In this sense, the models or processes that connect 'data' to 'experience' play the role of language. Languages change incrementally in response to input from the actions of the participants in the communication process. This gives rise to the question of model versus processual nature of language; in other words: is language to be understood as a model, or as a process? Another question regards the nature of the models which underlie the construction of navigational machines. Historically, there are one, two or multi-dimensional pitch or pitch-class oriented models derived from modality or tonality as well as cyclically arranged models of metrical stress in the temporal dimension. To these now are added models arising from psychoacoustics and digital signal processing, based mostly on the spectral content of the audio signal. A major part of Music Information Retrieval research is concerned with the effort to create mappings between these two worlds, that is, pre-digital and digital musical sound topologies. The present research proposes a third, quasi-agnostic but psychoacoustically-informed approach which frees itself from the anchor of modal/tonal/metric models and relies on interaction for the creation of languages from recorded interactions with users which form their experience incrementally and interactively.

About the Author

Iannis Zannos has a background in music composition, comparative musicology and computer music with emphasis on interactive performance. He has worked as Director of Music Technology and Documentation at the State Institute for Music Research (S.I.M) in Berlin, Germany, and Research Director at the Center for Research for Electronic Art Technology (CREATE), University of California, Santa Barbara. He has taken part in numerous international collaborative New Media Arts projects and has realized multimedia performances both alone and in cooperation with other artists. He is teaching audio and interactive media arts at the Department of Audiovisual Arts and the postgraduate course in Arts and Technologies of Sound in the Music Department at Ionian University, Corfu.

References

Alpaydin, Ethem. 2010. *Introduction to Machine Learning*. Cambridge, MA: MIT Press.

Bonner, Anthony (ed.). 1985. *Doctor Illuminatus: A Ramon Llull Reader.* Princeton: Princeton University Press.

Collins, Nick. 2012. "Automatic Composition of Electroacoustic Art Music Utilizing Machine Listening," *Computer Music Journal* 36(3), 8–23.

Collins, Nick. 2011. "Trading Faures: Virtual Musicians and Machine Ethics," *Leonardo Music Journal* 21, 35–39.

Couturat, Louis. 1901. *La Logique de Leibniz*. Paris: Felix Alcan.

Fidora, Alexander and Rubio, Josep E. 2008. *Raimundus Lullus, An Introduction to His Life, Works and Thought*. Turnhout: Brepols.

Foucault, Michel. 1986. *Death and the Labyrinth: The World of Raymond Roussel*. New York: Continuum.

Gärdenfors, Peter. 2000. *Conceptual Spaces: The Geometry of Thought*. Cambridge, MA: MIT Press.

Guenon, René. 1931. *Le Symbolisme de la Croix*. Paris: Vega.

Link, David. 2010. "Scrambling T-R-U-T-H: Rotating Letters as a Material Form of Thought" In (Siegfried Zielinski & Eckhard Fürlu, eds.) *Variantology 4: On Deep Time Relations of Arts, Sciences and Technologies in the Arabic-Islamic World.* Cologne: König, 215–266.

Llinares, Armand. 1980. *Références et Influences Arabes dans le Livre de Contemplacio*, Estudios Lulianos 24 (71).

Maturana, Humberto and Poerkesen, Bernhard. 2004. *From Being to Doing, The Origins of the Biology of Cognition*. Heidelberg. Germany: Carl Auer.

Maturana, Humberto and Varela, Francisco. 1979. *Autopoiesis and Cognition: The Realization of the Living* (Boston Studies in the Philosophy of Science, Vol. 42). Dordrecht, Holland: D. Reidel.

Pask, Gordon. 1975. *The Cybernetics of Human Learning and Performance: A Guide to Theory and Research*. London: Hutchinson Educational.

Queneau, Raymond. 1947. *Exercices de Style*. Paris: Gallimard.

Von Förster, Heinz. 2002. *Understanding Understanding: A Volume of von Foerster's Papers*. New York: Springer.