MATTER Journal of New Materialist Research

Universitat de Barcelona
http://revistes.ub.edu/index.php/matter/about

Articulating Nomadic Identities of Radio Signals

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DOI: https://doi.org/10.1344/jnmr.v3i1.38959

Abstract

This article presents a new materialist approach to artificial neural networks, based on experimental research in categorization of data on radio signals. Picking up on Rossi Braidotti's nomadic theory and a number of new materialist perspectives on informatics, the article presents identification of radio signals as a process of articulating identities with data: nomadic identities that are informed by all the others, always established anew. As a resistance to the dominant understanding of data as discreet, the experiments discussed here demonstrate a way to work with a digital archive in a materialist and non-essentialist way. The output of experiments, *data observatories*, shows the capacity of machine learning techniques to challenge fixed dichotomies, such as human/nature, and their role in the way we think of identities. A data observatory is a navigation apparatus which can be used to orient oneself in the vast landscape of data on radio transmissions based on computable similarity. Nomadic identities render materiality of radio signals as digital information.

Keywords

Radio signal; Digital archive; Nomadic theory; Machine reason; Identification.

Introduction

What we know about radio signals spans different domains of human sensibility and legibility. For example, a communication engineer knows how a signal 'sounds' in its demodulated form, or what its spectrogram looks like. More importantly, they know how the signal works, how information is modulated on the carrier wave, and at which frequency it occurs. A perspective from information studies might seek to identify patterns in data on signal properties and organize this knowledge in the archive. A feminist data scientist might problematize these archival practices, looking into the way differences across signals have been (or not) naturalized, land the lack of representation of certain types of transmissions, or certain archivists in the archive (D'Ignazio & Klein, 2020). A media archaeologist interested in media ecology might trace the material history of radio signal transmission technology and its biological-technological codetermination (Parikka, 2010). In this text, I discuss a specific intersection of radio signals onto-epistemology: what the signals are and what we can know about them in connection to engineering, international relations, media theory, and sociology. While this article can claim none of the academic fields it visits as its own, it seeks to frame the problem of the conceptualization of radio signals as an interdisciplinary problem that relates and connects different disciplines, without reducing them to any single dominant view.

New materialist attention to radio signals emphasizes the inadequacy of fixed oppositions (i.e., human/nature), and singular disciplinary perspectives, to host sensorial and cognitive coupling with radio signals. This article suggests no direct access to the materiality of the electromagnetic medium. Instead, new materialist interest is articulated here through an engagement with the digital data on radio signals. The materialist approach is reinforced with one important characteristic of the dataset: it documents real, situated radio signal transmissions. Radio signals are transmitted and received by technical equipment, which is built based on techniques of ideal energy propagation and information encoding. Unlike ideal transmissions, the recordings of signals are shaped by contingencies in the process of propagation through the environment. The transmissions are situated by the virtue of being recorded by specific people, using specific equipment, on specific locations on Earth, and the decision to include them in the database, such as the Signal Identification

Guide [SIGID] wiki[1]. This archive gathers recordings and other information on radio signals heard across the planet, documented by voluntary contributors.

Radio signals matter to the emergent field of new materialist informatics in two distinct ways. First, the origin of radio signals can be natural emissions or human-made transmissions. Hiss, Whistler, Dawn or Auroral chorus[2] are some of the names given to naturally occurring electromagnetic phenomena that can be 'heard' with specific receiving equipment. In *Earth Sound Earth Signal*, Douglas Kahn challenged the distinction of nature and culture in the instrumentalization of radio signals, on the premise that media (as in telecommunications media) do have nature and are underdetermined (Kahn, 2013). Jussi Parikka focused on the joint history of media and nature to tease out senses and rationalities inherent in the logic of life and technic, as in 'bio-logy' or 'techno-logy' (Parikka, 2010). In this parallel between media and nature, Parikka creates room to discuss natural technics in the context of organization and architecture, such as insects-builders or self-organized swarming systems. A new materialist media theory recently proposed by Vera Bühlmann, engaged Michel Serres' philosophy of natural communication to speak of mediality of public knowledge (Bühlmann, 2021). The double articulation of time as/in space, of physics of communication as a communication of physics, requires attending to materiality of time that passes (commutes), to its communicative materiality. In the ways highlighted here, technicity and communicative capacity of radio signals are expressed as nature, but also have nature. Radio is not passive energy waiting to be put to use, but active energy, whose materiality unfolds in time and space.

The second aspect of radio signals that is relevant in new materialist informatics is their inherent technicity: humans can experience radio only with mediation of transmission equipment, and this equipment is increasingly digital. Having no sensorial access to electromagnetic phenomena, we must rely on acoustic and visual representations of signal's frequencies to analyse and identify the transmissions. Communication engineers and people with related expertise can identify patterns, signatures and tonalities in demodulated audio samples and signal spectrograms.

[1] Signal Identification Guide wiki is available at: https://www.sigidwiki.com/ Accessed Jan. 26, 2022.
[2] For an overview of techniques and practices of the reception and study of naturally originating radio signals, see *Radio Nature* by Renato Romero.

The necessity to combine faculties of sonic and visual knowledge, speaks of the spectrality of informational content in radio signals.

The invention of an affordable and accessible system for radio signal reception on a personal computer, RTL-SDR[3], motivated the community around open-source mobile communication to start collecting and sharing techniques for observation and identification of environmental radio transmissions. The practice of radio observation is similar to bird watching or other wildlife observation, with the important difference being in our incapacity to actually perceive wildlife with no or minimal support of technical equipment. Radio signals, as previously mentioned, require sending and receiving equipment to operate under specific conditions in order to capture signals and enable their observation. The combined interest of radio enthusiasts and hardware hackers brought rich digital archives of data on radio signals online. The SIGID archive, which is the basis for computational experiments described in this article, is accessible to anyone with a connection to the internet. While the data is organised in a clear and legible fashion, a non-expert may still find the information on radio signals difficult to navigate.

In addition to exploring effective ways to organise digital data, the research in digital archives of radio signals problematizes what is sometimes referred to as 'digital literacy' (Colman et al., 2018; Vee, 2017), namely how computation and networks work and how we can develop skills in working with them. While the approach to computation in the past fifty years remained techno-solutionist, that is focused on solving whatever problems one was given with technical means, a digital literacy would in principle enable one to articulate different expectations from computing, which are non-essentialist and non-instrumental. I experiment with machine learning algorithms in order to challenge instrumental categorizations of technical artefacts, such as radio signals. Inspired by feminist critiques of technoscience, I propose to work on becoming skilled in using these advanced computational techniques differently, as one possible mode of resistance. This article gestures at possible ways for doing so.

[3] Engineers gathered around open-source mobile communications project (osmocom) found a way to turn small USB dongles, made for digital television (DTV) reception, into computer-based radio scanners. They hacked the driver on the RTL2832U chipset and found a way to access the raw IQ data from the analog to digital converter, which samples the radio frequency space. The tuner on the DTV device can tune in a wide range of frequencies. https://sdr.osmocom.org/trac/wiki/rtl-sdr (accessed 17.02.2022)

This article establishes intersectional connections between the work of machines and people – in terms of knowing and finding patterns. In the text that follows, I discuss the design and engagement with computational artefacts, *data observatories,* which stand for the method and ambition to organise radio signal data according to properties that come from the dataset, for articulating the archive in its own terms. Signals are computationally described and compared in terms of properties that are shared across the entire dataset. By encoding the data in this way, the signals get an informational face, a sort of nomadic identity. This identity is not universal or fixed, but mobile and changing depending on how we are looking at it. These identities tell different stories of connectivity, of its entanglement with computation and archiving. Situating computational identities of radio signals through a programming praxis aims to develop their partialities, not universality, opening up the way to insights which are complex, contradictory, structuring and structured, not from outside but from within.

What is Materialist about Materialist Informatics?

Radio signals which I discuss here manifest as 'weird' materiality when portrayed within the classical human/nature divide. In Parikka's articulation of new materialist concerns as media theory, weird materialities designate that which escapes direct human perception, and is irreducible to categories of 'soft' or 'hard'[4] (Parikka, 2012). Radio signals are 'simply' energy, but they have a material and symbolic importance for human societies, both as environmental radiation and as messages they transmit. I will trace three approaches to the question of informatics in (new) materialist scholarship, through the weird materiality of radio signals.

Iris van der Tuin acknowledged that working in new materialism while "living in networked societies and experiencing ecological changes in our everyday lives revitalizes the question of subjectivity" (Van der Tuin, 2014, p. 233). In her exploration of new materialism with Rick Dolphijn through cartographies and interviews, van der Tuin affirmed new materialism's capacity to challenge the authoritative gesture that

[4] Parikka specifically refers to Serres' distinction onto 'soft' and 'hard' as two polarities which for Serres are indeed in a continuum, contrary to Parikka's reading in the text referenced here (Parikka, 2012). For more on the continuity of 'hard' and 'soft' in Serres see (Bühlmann, 2020). Parikka's interpretation is based more closely on Serres articulation of pollution in *Malfeasance: Appropriation Through Pollution?,* while materiality of communication and communication physics for Serres are based on the irreducibility of communication or physics to hard and soft.

takes apart the material and discursive in an overly confident logic typical for Enlightenment (Dolphijn & Van der Tuin, 2012). Dolphijn and van der Tuin traced the specific approach to materiality at stake in feminist new materialism. New materialism, they assert, is a practical philosophy, which entails the affirmation of the thinking process as material. Such philosophy shows us one possible way to address radio signals as material and discursive artefact at once, to approach their 'weird' materiality.

Haraway's take on materialist informatics pointed to the inevitability of living in relationship to standards and regimes that are not one's own (Nakamura & Haraway, 2003). The dominance of techno-economic systems facilitates propagation of universal categories of 'human' and 'machine', unresolved in her original take on the cyborg, while reinforcing the impossibility of walking away. This is important to recognize so that one can think of other ways of doing life, while remaining "always inside complex material semiotic worlds and not inside these universal categories" (Nakamura & Haraway, 2003). For Haraway, language is material and she is interested in its materiality as specificity. For example, she recounts in the interview with Lisa Nakamura, how she appropriated the term Cyborg from space-race language, in order to infuse the technical imaginaries with that of social reality of women in her influential Manifesto (Haraway, 1987). This act of appropriation demonstrates the power of language to inscribe practices and new matter-realities through concepts. My approach to knowing radio signals is informed by Haraway's and numerous other feminist scholars' refusal of universal categories and insistence on situating oneself within complex webs of knowledge. Precisely by undoing clear, pre-determined distinctions between radio signals and nature, but also across signals themselves, identities can be articulated in informational terms, in terms of the digital archive of radio signals.

For Felicity Colman, materialist informatics should be specially concerned with the image. She develops new materialist considerations for "the image as a mattered aesthetic intra-active affective measure" (Colman, 2014, p. 13) in feminist theory and practice, and following Barad's notion of intra-actions (Barad, 2007) proposes to understand an image as "an aggregated concept […] a material thing that is the result of a series of relational positions, the centre of which is a body" (Colman, 2014, p. 9).

The image is an important mode of communication in the digital field. It can also provide focus. Colman reiterates the concept of identity with the image, with new-materialist feminist attention to naming, predication, and mediation. Such attention to image as identity is precisely opposite of representation, and lends itself well to reimagining the archive of radio signals. Trying to capture materiality of the image through mediation and searching for markers, Colman suggests to look at the body as a platform capable of mediation, a medium and a media. “We can use the discursive matter of feminicity to articulate the living capital body – as image and as a materialized informatics – involving identification of the predication of feminicity and, indeed, of masculinity, unicity and other technicities” (Colman, 2014, p. 13). Colman’s material treatment of the image which captures and focuses (digital) information suggests the possibility to both render and access materiality of digital archives, which will be explored in this article.

Nomadic Identities: Challenging Classification

To question classification is a feminist concern: how are people divided in categories of gender; how is an identity articulated and performed, with regards to its other. With the specific explorations of a radio signal dataset that I practice and discuss here, I strive to challenge conventional dualisms and classification as normative modes of thinking, perpetrating a singular logic of the world: for example, the logic of a radio amateur’s fascination with communication engineering. The current practice for identification of radio signals engages closely with conventional, instrumental classification. A signal is described in terms of its capacity to transmit information in military communication, in navigation, or as part of amateur radio spectrum. To counter this, I propose to pay attention to nomadic identities of radio signals, always made anew through computational comparisons across a database of recordings of different radio transmissions.

Nomadic theory of Rossi Braidotti makes an important proposition that resonates with the materialist concern for radio signals identities that I develop here. To speak of nomadic subjectivity is for Braidotti “an act of resistance against methodological nationalism” (Braidotti, 2011, p. 7), which might be useful to challenge classical mobilization of differences in dialectical opposition and mutual consumption towards an interconnected scheme. Nomadic subject resists “deterritorialization” in Deleuzian terms: the mobilization of difference and estrangement from the familiar or intimate social identity. It engages a rhizomatic logic of zigzagging across interconnections. For Braidotti, being nomadic is clearly “not a glamorous state of jet-setting” (2011, p. 10) but to the contrary, the difficult and strenuous process of critical relocation, of grasping and disclosing one’s situatedness, “speaking from somewhere specific and hence well aware of and accountable for particular locations” (Braidotti, 2011, p. 15). A nomadic subject is a sustainable subject, open to intense flows of desires, almost to the point of breaking (Braidotti, 2006). This sustainable subject position is available to the reader anywhere at any time, or as Katherine Hayles positions Braidotti’s posthumanism: it is a way of being, it is transhistorical and non-technical (Hayles, 2018). This is important when considering its capacity to challenge classical taxonomies and ordering increasingly performed by technical/informatic systems. Could we update Braidotti’s nomadic theory to address materiality of neural networks and classification algorithms?

Databases and digital archives provide lists and system of details that document the lives of plants and animals, natural and social phenomena, behaviours and observations. Everything we encounter appears already categorized in some way, which propagates the presumption that these categories are meaningful in themselves. Tahani Nadim wrote critically of databases as providing more than comprehensive lists. She pointed out how the Fauna Europaea zoological taxonomic index of European animal species: “constructs a naturalized image of Europe (Nature’s supernation, if you will), […] it confirms the continued relevance of natural history collections, and it translates the taxonomic gaze—with all its (colonial) blind spots—into a symbolic calculus (species-as-assets)” (Nadim, 2021, p. 128). Databases, such as the radio signal digital archive are not passive containers of data. They facilitate certain rationalizations while hindering others. They are historically specific, practically different and their context matters. This resonates with contemporary feminist critique of database ontology, its singular logic of representing the world, carefully traced hierarchies and exclusions. The authors of a cultural studies article on tagging noted that: “within databases […] we construct categories of normativity, singular ways of commanding the logic of the world” (Juliano &

Srinivasan, 2012, p. 619). From a related media-theoretical position, Posner and Klein question the meaningfulness of categories in archives and connect to feminist theory (in particular the work of Butler, Haraway and Barad) to “challenge the repressive systems of classification” (Posner & Klein, 2017, p. 4).

Intersectional feminism poses important questions to methods for working with data and classification. In *Data Feminism*, Catherine D’Ignazio and Lauren F. Klein (2020) engage with intersectional analysis of the ways in which systems for counting and classification perpetuate oppression. They recognize an initial impasse: to be put to use, data must be classified in some way. This builds on well-known work of Bowker and Star (2000) who saw classification as essential to any working infrastructure. Once the system works, it becomes ‘naturalized’. Data feminism is concerned with uses and limits of data, informed by direct experience and by intersectional feminist thought and paying attention to power and privilege.

Van der Tuin teased out the unsituatedness of classifications (Van der Tuin, 2015) in her discussion on classification’s underlying, implicit tendency to fix things. Classification is not a neutral mediator, it is “thoroughly entangled with the work that it does” (Van der Tuin, 2015, p. 19). With a focus on Harding and feminist theory as an example of classifying gesture, van der Tuin has shown the many ways in which separating feminism onto three (or any number of) distinct threads, ends up affirming epistemic categories as conflict-based. In her influential book *The Science Question in Feminism*, Harding (1986) presented a classification onto three strands: ‘feminist empiricism’, ‘feminist standpoint theory’, and ‘feminist postmodernism’. Rather than challenging positivism, van der Tuin observed how Harding’s categories stood in competition with each other, as competing feminist epistemologies. Demonstrating ‘sloppiness’ in Harding’s writing on and with Haraway’s ideas, van der Tuin concluded that such classification was unable to fully close off the categories. Taking into account Foucault’s critique of classification and taxonomy, and the emphasis he put on the situatedness of knowledge in classifications, van der Tuin but pointed out that “the situatedness of knowledge cannot be theorized or acted upon” (Van der Tuin, 2015, p. 28). She emphasized the exclusion mechanisms: "Classificatory approaches are founded on the assumption of the ability to logically list categories that mutually exclude one another." (Van der Tuin, 2015, p. 28). It is important to recognize the impasses encountered in feminist efforts to theorize and address differentiation in the effort to situate and identify radio signals. While the discussion on Harding's classification of feminist approaches is not directly relevant to the way radio signals matter in terms of classification, the root problem of classifying gesture remains important to disclose and reject.

A useful work to consult in terms of problematizing classification in the domain of informatics and design of computational artefacts is Roberto Bottazzi's *Digital Architecture Beyond Computers* (2018). Bottazzi traced the genealogies of proof- and search-oriented combinatorics as antithetical potentialities of computation: one can either use combinatorics to prove a hypothesis, or use a generative approach to obtain an abundance of possible solutions. He recounted the case of Ramon Llull's wheels of *Ars Magna*, as a mechanism for disseminating the author's doctrine and religious beliefs. Giulio Camillo's articulation of *L'Idea del Theatro* and Leibniz's *Ars Combinatoria* are discussed as methods of search for new, unseen designs. Aby Warburg's *Mnemosyne Atlas* was a pioneering way to organize large collections by purely visual means. Contemporary design work with machine learning is a culmination of these trends for Bottazzi: a way to investigate datasets in search for patterns or sources of intuitions that can be used in architectural or urban design process, for example. Pursuing this thread further, Bottazzi made a provocative proposal for cryptography as a means to venture into domains beyond human cognition (such as abstract data, or recordings of radio signals) by carefully constructing a system of signs that move in and out of realm of human legibility (encryption and decryption) and moving productively across different domains (Bottazzi, 2019).

In search-oriented cryptographic terms, identification of radio signals would be based on the abundance of digital information, rather than on predefined instrumental categories. Such understanding of identification is inspired by Hayles' proposal for paying attention to the non-conscious information processing of machines and humans. In *Unthought*, Hayles (2017) offered a framework of looking at nonconscious cognition to speak of non-binarized approach to thinking, which is not necessarily human. She aspired to recognize the thinking of non-humans and machines. As part of this argument, Hayles stressed the role of non-conscious cognition for dealing with abundance of information, to keep consciousness from overwhelming and the human subject from becoming psychotic. Incidentally, she described contemporary information processing technology, such as pattern recognition and visual analysis algorithms, traffic control at airports, automated trading algorithms, as examples of non-conscious cognition. Because this form of 'unthought' is a common characteristic of humans and contemporary computation, Hayles asserted, it is important to take technology into account to arrive at the definition of the posthuman. While the focus on the posthuman is not directly relevant to nomadic identities of radio signals, the notion of commonality in human and computational thinking points in the direction of articulating techniques for thinking *with* computation, augmenting the meaning already contained in the Latin term 'computare': to reckon together.

Data Observatories

Data observatories articulate a possible way to think with computation. They are part of the method and ambition to organise data on radio signals according to properties that can be defined as 'intensities' in a Deleuzian sense. This means that a perspective on any of these properties renders the dataset as a *plane of consistency* on which properties circulate as intensities. Appropriating the term used by Deleuze and Guattari in *A Thousand Plateaus* (Deleuze & Guattari, 1987) this notion emphasizes the attention to connectedness through intensities, and a capacity to compare something to something else in abstract terms that are still completely specific to that which is compared. More or less of a property can be identified in each node, each piece of data, and that they could be compared and organized accordingly. This means to articulate an archive in its own terms. I encode signals in terms of properties that are shared across the entire database. One of these properties is the probability of silence, another is the spectral entropy in the audio sample, a third is an audio identification technique called fingerprinting[5].

Data observatories give access to the knowledge of signals in their concrete manifestation: as they were received and recorded. The networks of machine learning

[5] Fingerprints are a condensed digital summary of an audio signal, based on peak points in the spectrogram which represent higher energy content. The technique is known for its use in Shazam music identification application. See (Wang, 2003).

algorithm train on each of these property sets, and produce an organized space – a grid of ‘codebook vectors’[6] – that can be navigated and explored in three dimensions: according to proximity of codebook cells (horizontally and vertically) as well as according to the content of one cell (depth). Combining machine learning tools with design of *data observatories* is a way to challenge taxonomies with processes for organising unstructured data. The neural networks built with the machine learning algorithm operate in this space as mechanisms of differentiation: a way of ordering differences based on probability.

Data observatories give access to this incomplete archive in an organized way, presenting the radio enthusiast as well as researchers interested in information studies, digital humanities or media materiality, with ways to navigate the signal space according to interests and questions we might want to ask it.

Signal Identification Guide Wiki

The Signal Identification Guide (SIGID) wiki is an organized archive of information about radio signals. The SIGID wiki website is a collection of all the information about radio signals that is held among a community of radio amateurs and enthusiasts. Any radio signal that can be received and recorded can be included in the database, either as a sample of an already described radio signal or as an unknown signal yet to be identified. Each signal is characterized by signal type, frequency, bandwidth, modulation type, location, sample audio, spectrogram and a short description. The majority of signals have at least one associated audio sample, and most of the audio samples have been demodulated from raw energy recordings to audio.

The archival strategy of the community gathered around SIGID wiki is contingent on sub-group interests in radio signal application domains, such as the military, amateur radio, commercial, marine, trunked signals, or satellite reception. Signals are divided into two general categories, ‘known’ and ‘unknown’. Unknown signals are recordings of received signals that are yet to be identified. At the time of this writing (September 2021), there are 432 known or identified and 328 non-identified signal pages on the

[6] A codebook vector is a list of numbers that have the same input and output attributes as the training data. For function of codebook vectors in self-organizing maps, see for example: (Pölzlbauer, 2004)

website. Known signals are subdivided into categories based on their application, or rather 'listening communities' – groups of people interested in tracking this particular type of radio telecommunications. All signals are also organized according to signal properties such as analogue or digital information encoding, or frequency band they occupy (very low, low, middle, high).

Transforming Data Relationships in Self-Organized Observatories

The Self-Organizing Map (SOM) machine learning algorithm is the basis for computational experiments because of its' capacity to detect patterns in unlabelled data and facilitate an explorative approach. SOM is an unsupervised machine learning technique introduced in 1980s by a Finnish computer scientist Teuvo Kohonen (Kohonen, 1982). It is known for its ability to classify data in an intuitive manner, emergent from the data. SOM has been widely used in the past forty years, across different fields such as genetics and synthetic biology, ecology but also in numerous engineering applications (Kohonen et al., 1996). More recently, a group of architects and designers explored the potentials of SOM to point at productive convergences between architecture and information technology (Bühlmann, 2013; Hovestadt, 2014). They paid special attention to informational potentiality for traversing the human/nature dichotomy, or the calculability of digital data that circulates through and even determines urban infrastructures and architecture.

Starting from an unordered collection of recordings of different transmissions and their meta-data, I organised radio signals in a rectangular grid. The grid is a way to display the data in two dimensions, by projecting the higher-dimensional onto a low-dimensional space of predetermined size, sort of a map. The relationships that emerge are observed as clusters, filtered through topologies of other data. First, values for a property of all signals – for example, probability of silence or spectral entropy – are computed using a standard feature extraction algorithm on all audio samples. These numerical values are then fed into the networks of SOM which maps alike input values closer to each other, illustrating the similarity relationships between different data items. SOM clusters data points similar to a Voronoi diagram, it arranges the means into a geographic order according to their similarity relations.

SOM brings the data points into a plane of consistency, providing measurements of similarities which circulate on it.

The data observatories provide a way to articulate signals' identities in terms of their own characteristics. I produced two different views on the signal archive, two studies that use the same techniques of differentiation: *Descriptions* and *Projections*. For each study, a web-based interface is developed, enabling navigation of the space of radio signals database according to an observer's interest. The visual language for both studies is based on the previously mentioned 'codebook vectors' grid: chunks of radio signal audio samples are distributed across the cells of the map. The first study, which I titled *Descriptions*, explores radio signal data alone, while the second study, *Projections*, explores projections of the radio signal data on an external dataset which is closer to human experience, such as music, bird songs, urban sounds. I will present here two vignettes on the use of data observatories, and then discuss their implications for articulating nomadic identities of radio signals across the data observatories.

Descriptions

Descriptions are a projection of audio sample data onto textual descriptions of radio signals written by contributors to the SIGID archive. This process establishes a connection between the inaccessible domain of electromagnetic radiations (radio signals) and the accessible domain of language. Radio signals are intended for machine-machine communication and only translated into information upon reception. I work with recordings of radio transmissions, without examining their content. The organisation of this non-intuitive, inaccessible data has to be approached through a different domain, which, in this case is the adjacent domain of textual descriptions, associated with each signal in the database. I used a topic modelling algorithm[7] on these descriptions, to generate lists of the most important. There are words that speak of military use and international relations (spying and jamming); there are technical words that speak of protocols and demodulation; there are groups

[7] I worked with Latent Dirichlet Allocation (LDA) as topic modelling algorithm. LDA is a form of unsupervised learning that processes text as 'bags of words' looking for statistical correlations. Topic modelling or topic detection is a machine learning method to discover human-readable topics in text.

of words that are associated with radio amateurs. Starting from one of the identifies 'topics', the archive unfolds in directions of individual interests, tracing similarities across sometimes completely unrelated signals.

Figure 1. 'Data Observatory: Descriptions' web interface. Red cell in the middle contains a part of the HAARP signal, which resembles 'neon lights' (right pane) discussed in Vignette 1. Visit the web-interface online at https://radioexplorations.ch/descriptions/ (accessed on 17.02.22)

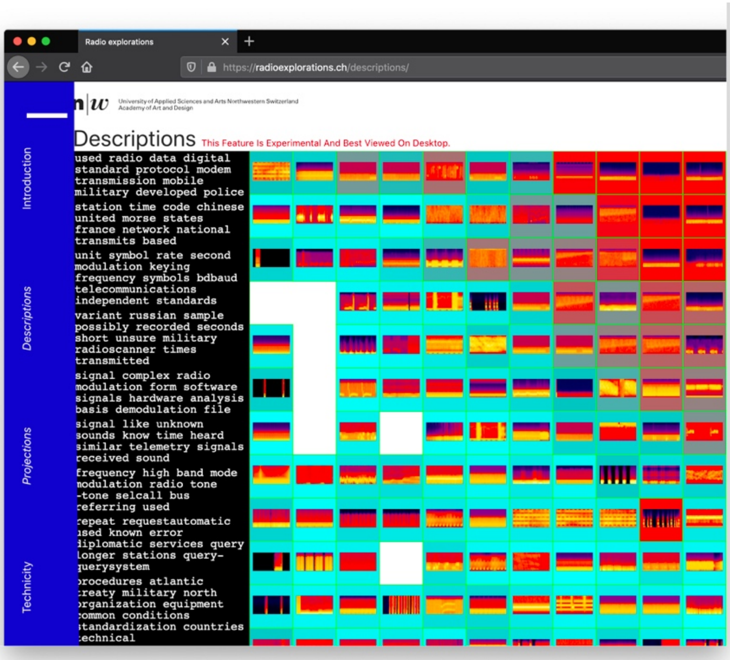

Figure 2. 'Data Observatory: Descriptions' web interface. Zooming in on the nine 'topics' represented here by lists of keywords separated in blocks.

Vignette 1: How to approach an archive without knowing what you are looking for? I take any signal and look at it, for example 'High frequency active auroral *research programme' (see Figure 1) whose samples appear in the center of the map. The signals' spectrogram looks like a photograph of neon lamps in space. But this is not a photograph. It is a time-frequency representation of sound. Its description says it belongs to a research programme studying the properties and behaviour of the Earth's ionosphere. Reading about ionospherics elsewhere, I learned that some climate research uses data on lightnings to measure the degree of climate change. They found, already in 1999, a significant correlation between the increase in temperature and in lightning activity in the northern hemisphere of our planet.*

This is a short observation that can emerge from descriptions of radio signal transmissions. One prominent topic that emerged from topic modelling is relationship between the military and telecommunications (see Figure 3). Is there something new and specific we can learn from this setup? The second vignette suggests some possible stories about this connection.

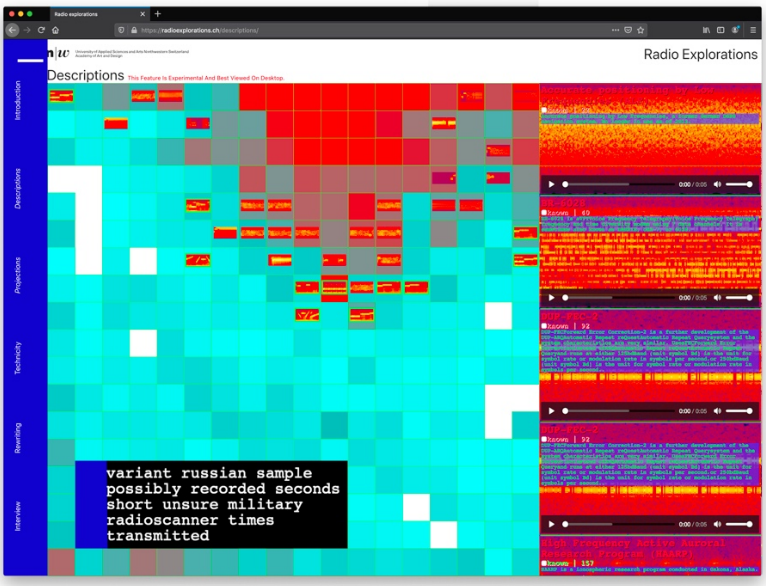

Figure 03. 'Data Observatory: Descriptions'. Highlighted topic (overlay, bottom left) corresponds to the non-empty cells. Among them, highlighted is the HAARP signal.

Vignette 2: I highlight one topic that speaks about military and some related keywords. Interestingly, the signal from previous story is found in one of the cells at the bottom of this area. It is a rhythmical sample that has a similar rhythm and spectral power to DUP-FEC-2. I notice the FEC in the names of other signals.

> *Apparently, FEC stands for "Forward error correction" – an error control method used in situations where retransmissions are impossible. What this cell tells us about military: it is tightly connected with diplomacy and intelligence; impossibility of retransmission is characteristic of military communication.*

To notice the connection between military and intelligence requires little more than common sense. Yet here we have some form of proof, a tangible connection between telecommunication practices and citizen knowledge, engineering and politics, established through the cognitive assemblage of this computational artefact and an active, interested explorer who poses questions. Even more importantly, the example hints at a way to articulate what we know about one signal. The SIGID wiki archive's purpose is to support identification of radio signals found 'in the wild'. Here we encounter a way to approach the identity of a signal as nomadic, to establish a nomadic identity for any signal in the database. Parts of a signal's samples can be found on many different cells (see Figure 3, green highlighted cells of the HAARP signal for example). A signal shares some properties with other signals in the cells it occupies. It zigzags across similarities in the properties that articulate a 'data observatory'. These properties describe qualities of that signal, and at the same time, propose new categories or clusters by which signals could be organized. Nomadic identity is not a subject, but it is open to intense flows of interest and information.

Projections

The second data observatory *Projections* enables the comparison of radio signals by articulating their similarity in terms of an external dataset that illustrates different genres of music. In this data observatory, radio signals are organized through musical genres in the following way: the SOM algorithm does not compare radio to music, but projects radio signals onto a previously computed model that organised songs from the Free Music Archive (FMA) dataset for music analysis[8] and its eight genres (see Figure 4). A pragmatic question to ask is whether this organization can support identification of 'unknown' signals? This would mean to match a signal categorized as

[8] See more about the dataset and access the files archive: https://github.com/mdeff/fma (accessed on 17.02.22).

'unknown' to a 'known' signal from the database. In radio amateur practice, this is done by careful observation of different signal properties by someone who has already 'seen' and 'heard' a large number of signals, and understands patterns left by different communication protocols. I propose to work differently: to find a plane of similarity, in comparison to which I can establish similarities between signals in projections and reflections off of a different kind of data. Now, it becomes relevant how radio signals samples are placed next to each other: a direct similarity between radio signals on the map should reflect their likeness in an aspect that is shared with audible information on music.

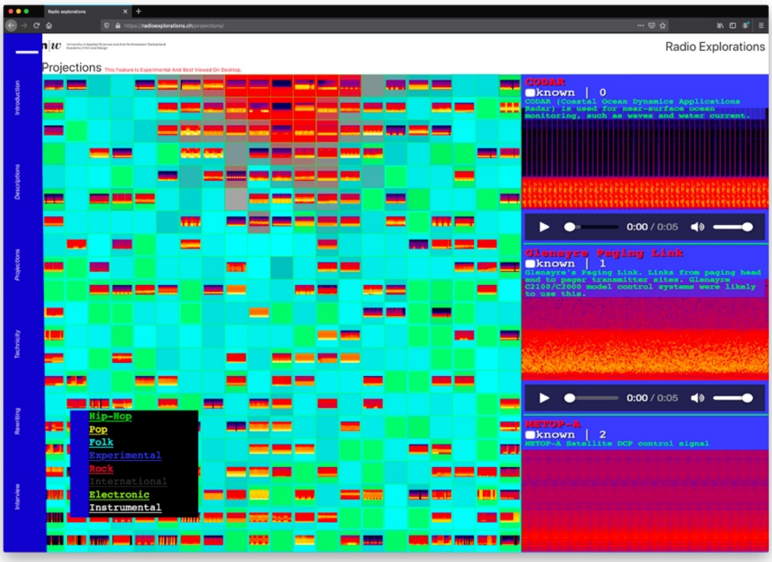

Figure 4. 'Data Observatory: Projections': Signals are 'projected' onto a pre-organized map of musical samples, labelled according to the genre (overlay, bottom left). Each genre 'highlights' some cells among which certain radio signals can be found. Highlighted here is the 'Hip-Hop' genre. Visit the web-interface online https://radioexplorations.ch/projections/ (accessed on 17.02.22).

Together with the administrator of the SIGID website, we identified some interesting groupings of unknown signals. We found out that a lot of the 'similarity' between songs and radio signals comes in as an artefact of recording, listening itself, the fact that these are transmissions in the environment, modulated by the spatial conditions, and equipment operation. This points to the importance of not taking the results of algorithmic processes on data as 'truth about the world'. Data can be very noisy, or is speaking of a different phenomenon altogether. Therefore, it is only interesting to use these algorithms in order to gain multiple perspectives on the data, to articulate careful and specific questions, and then consider doing something about it.

Machine Reason

The articulation of nomadic identities of radio signals discussed in this article demonstrates and problematises the capacity of machine learning techniques to support reasoning about environmental radio transmissions. The digital, argued David M. Berry (2012) in his introduction to *Understanding Digital Humanities*, is the new unifying idea in academia and knowledge. With this new idea, reasoning shifts towards a more conceptual or communicative method, a way of thinking that raises different kinds of questions (e.g., how many times a word repeats in a text) and leads to different kinds of findings. We can observe in the vignettes (*Descriptions* and *Projections*) described above, how machine learning algorithms challenge the way we ask questions: it is not so much about finding correlations – they are abundant; but about constructing meaningful ways to interpret them.

Neural networks extract whatever we decide is the essential information from the data, but they do not give us 'reason' for it. For example, when the proximity of nodes in a recommendation algorithm is interpreted as a prediction that one should buy items whose vectors are closely linked, neural networks are mobilised to provide reason for purchase, or a suggestion of it. I do not want to imply that such recommendation systems do not work well – because they do. Such direct deductions tend to only confirm what we already know. With the exploration of radio signals, on the other hand, I strive to demonstrate the capacity of machine learning processes to articulate nomadic identities of radio signals always anew, always different depending on the perspective. Reasoning with machine learning algorithms therefore is only appropriate if it does not lead to interpretations of the world, but if we take its outputs as an incentive to make another translation, to go to a new place.

Working with machine learning algorithms as a way to articulate identities of radio signals opens up a space of different thinking which is characterized by synthesis instead of analysis. Computers bring together concerns of mathematics and matter, ideal and material. Notions such as synthesis, entanglement and assemblage enable to round out the simplification and abstraction of clean materiality, and embrace continuity in a fleshy, touching, incorporating, and ever-changing sense. New materialist alertness to fixed, predetermined modes of existence is expressed in a related way by Coole and Frost (Coole & Frost, 2010) who challenged the common sense that “real” material world consists of solid, bounded objects with predictable and controllable behaviour. They critiqued the notion of matter as “identifiably discrete” and trace a number of ways this has been problematised by chaos and complexity theory, quantum physics, genetics biology, and biopolitics. In the most general sense, this alertness is addressed at unsettling the human/nature dichotomy, to which radio signals lend themselves well, in the sense that they can exist as natural and human-made phenomena.

This article proposes to consider characterizing things through synthetic differentiation, and through the lens of a carefully considered question. It affirms articulation of differentiating algorithms that preserve flexibility in terms of parameters and enable observations that do not issue from established ontological categories.

Conclusion

Radio signals are hard to categorize and characterize because we have no direct experience of them, but encounter them through technological translations and transformations. By unpacking radio signal identification process as it is conventionally practiced by radio enthusiasts, in this article I discussed ways to establish an organized radio signal space prior to categorization. This de-territorializes, or rather re-territorializes radio signal identity in terms of other radio signals, and avoids looking at signals based on what they ‘do’ (anthropocentric view) and how they exist technically (a form of essentialism). Our techno-life world could benefit from new ways of reading radio, and for that matter, other telecommunication infrastructures and computational technologies. Katherine Hayles suggested thinking about these as cognitive assemblages: more or less loose connections of humans and technical devices through which cognitions, interpretations and meanings circulate (Hayles, 2017). This would mean to recognize the entanglements in functioning of, for example, the airport traffic control and check-in area, prominently described in Rob Kitchin and Martin Dodge's book *Code/Space* (Kitchin & Dodge, 2011). Liveable worlds depend on our capacity to notice and consider entanglements with technology and for that, we have to concentrate on developing tools to gain multiple perspectives on data.

Several ideas for novel ways of reading datasets and archives, in circulation among new materialist and science and technology scholars, are relevant to this argument. Tahani Nadim drew on Arondekar's urge to find "new ways of both mining and undermining the evidence of the archive." (Nadim, 2021). She suggested "encountering the archival trace as a 'recalcitrant event,' a notion borrowed from Shahid Amin that abandons the impetus of 'discovery' in favour of mobilizing traces in and through narration and interpretation." (Nadim, 2021, p. 129). Every archive, database, and archival practice instils a specific set of beliefs and hopes in advancing accuracy and capacity to reason with it.

In a media-archaeological exploration of wireless networks (radio waves) in space, Miyazaki and Howse proposed transduction devices to make sense of network connections by rendering their electromagnetic emissions sonically accessible (Miyazaki, 2013). Sonification of networks acts as an epistemic experimental system which discloses the ongoing algorithmic processes within urban areas. Sound enables one to 'make sense' of electromagnetic activities. I propose a related approach to radio signal archive, to develop a sense of data that is intuitive like sound. The approach discussed in this article enables us to make sense of digital information about radio signals on a level that is different from modernist objectivity, and yet is not purely subjective: we are able to discuss and share experiences of working with data observatories.

The outputs of this project aim to facilitate speculation on the connection between signal representation and technical communication protocols, by shifting criteria of similarity from taxonomical and instrumental (i.e. used in military) or physical (i.e. high or low frequency), to properties shared across all signals – such as the probability of silence or noise in the signal. Neural networks of the SOM algorithm extract whatever we consider as essential information from the data on radio signals. Working with SOM as instrument, enables us to observe affinities and interests as the main driver of these explorations. Data observatories built with SOM as instrument are computational artefacts that provide measurements of similarity between data points, and enable a multiplicity of perspectives on the data.

The dataset I work with, created from the SIGID wiki entries, is something more than a discrete database. It testifies of a knowledge community that forms around the question of technical literacy of telecommunications. One of the collateral outputs of this work is the use of digital observatories as tools to assist the identification process for signals that are currently categorized as unknown.

While machine learning is often discussed in humanities in terms of its biases and problems with optimization, this article stresses the importance of digital literacy when working with digital information. I articulate how identities can be read in machine learning statistical models. It is an experimental method of working with biases, in order to make them legible, countable and accountable. I propose these identification processes as arbitrary, nomadic renderings of reality in the eyes of a machine, affirming inherent instability and flexibility of a signal's identity. By rendering signals commensurable in this way, I propose to take an active stance with regards to machine learning algorithms and expose a research interest from which we can learn and tell stories about signals.

Acknowledgements

The Radio explorations research project was generously supported by the SNF-Spark funding grant number 190310. I am grateful to my collaborator, Yann Patrick Martins for programming the data observatories, and to our research workshops guests: Carl Colena (SIGID wiki), Miro Roman (ETHZ), Simone Conforti (IRCAM), Sarah Grant (Kunsthochschule Kassel) and Roberto Bottazzi (The Bartlett) for their invaluable inputs. Special gratitude goes to Miro Roman for numerous informative discussion on working with SOM and big data, as well as to Carl Colena for his support and discussions on radio signals beyond workshops and interviews.

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