Pixels and Bandwidth: On Imaginaries of Travel in Data

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The image of an incomplete message

An imaginary attempt to read an incomplete message can illustrate the interplay between aesthetic, semantic and epistemic concerns for interdisciplinarity. French classical author Jules Verne wrote a novel about the adventure of rescuing a captain of a sunken ship. Verne's novel *In Search of the Castaways* (*Les enfants du Capitaine Grant*) begins with the protagonists, future rescuers of the captain, considering how to read a message that reached them on a damaged piece of paper. The message was packed in a bottle, swallowed by a "balance-fish," and subsequently recovered by a small group of wealthy Englishmen on a yacht. The "balance-fish" is a hammer-headed shark found worldwide in warm waters. This detail speaks of the impossibility of tracing the bottle back to its origin: it could come from any sea at any longitude. Three sheets of paper in the bottle preserve parts of a message translated into English, French and German. Most of the letters are erased, and it is impossible to make sense of the text using any of the sheets individually. The three sheets complement each other to some degree of certainty to give possible directions

for search. Jules Verne presents three different readings, determined by additional constraining factors of departure time, complemented with their travel worldwide. Each of these readings takes the passengers of the rescue ship to a different location and enables Verne to englobe the planet and tell stories about the wonders of travel and adventure. The rescue team, including the captain's two children, sails to Patagonia, then to Australia, before successfully locating the lost captain at the Tabor Island, a phantom reef in South Pacific.

This opening vignette speaks of the challenge of interpreting incomplete messages and the different places an interpretation can take us, literally. The story's protagonists fill in the missing letters with those most likely to make sense, according to some known determinants, such as the departure time, destination, and a possible route the ship could have taken. They rely on their knowledge of geography, sailing and navigation, lines of international trade, and proficiency in different languages. Verne's story suggests thinking of travelling and navigation as an empirical method for exploring hypotheses. French philosopher Michel Serres, an avid reader of Verne, offered navigation as a metaphor to expound the problem of interdisciplinarity more broadly. In his fifth book on communication, *Hermes V*, *Le Passage de Nord-Ouest,* Serres portrayed the shipping passage in northern Canada, which connects the Atlantic and the Pacific, as an image of instability and risk in passing between the natural sciences and the humanities.[1] The Northwest Passage changes with freezing water and melting ice every year and must always be discovered anew. It is equally challenging to find or invent methods for passing between different domains of inquiry and knowledge, according to Serres.

Interdisciplinarity is a concern inherent to Science and Technology Studies (STS). From the volume that became the first handbook of STS, *Science, Technology, and Society: A Cross-disciplinary Perspective,*[2] through

1 Michel Serres, *Le Passage Du Nord-Ouest. Hermès V*, Collection "Critique" 5 (Paris: Editions de Minuit, 1980).

2 Ina Spiegel-Roesing and Derek de Solla Price, *Science, Technology, and Society: A Cross-Disciplinary Perspective* (Beverly Hills, CA US: SAGE Publications, 1977), https://www.osti.gov/biblio/6890751.

subsequent handbook volumes and articles concerned with characterising the field,[3] the concern for interdisciplinarity is mentioned in the first page, paragraph or sentence. This chapter engages with travelling as an imaginary interdisciplinarity trip: a way to articulate multiple perspectives when interpreting data, their relations across datasets and the disciplinary knowledge they draw upon. An approach to visual data exploration is introduced, inspired by the reading of Jules Verne's literary images of search and ambiguity. This approach is applied to a digital archive on radio signals within a research project, *Architectonic Studies of Radio*.[4] The search for meaning is at the core of this research endeavour, aspiring to demonstrate multiple ways of sense-making. Furthermore, following Haraway's attention to the embodied, positioned subject who, when perceiving and understanding the world, has a partial view and perspective,[5] this research locates concerns about telecommunications and its digital traces in a complex interplay between data, navigation and imaginaries of visualization.

This work with radio signal datasets forms a complex relationship with several specific fields of inquiry. It is rooted partly in digital humanities research methods for working with digital tools and large datasets, partly in media-theoretical concerns for communication technologies, and partly in feminist intersectionality. With interest in the materiality of radio telecommunications and digital technologies, the

3 Sheila Jasanoff et al., eds., *Handbook of Science and Technology Studies*, Rev. ed (Thousand Oaks, Calif: Sage Publications, 1995); Edward J. Hackett et al., eds., *The Handbook of Science and Technology Studies*, 3rd ed (Cambridge, Massachusetts: MIT Press: Published in cooperation with the Society for the Social Studies of Science, 2008); Knut Holtan Sørensen, "Disciplined Interdisciplinarity? A Brief Account of STS in Norway," *Tecnoscienza, Italian Journal of Science & Technology Studies*, 2012, 49–61; Ulrike Felt, ed., *The Handbook of Science and Technology Studies* (Cambridge, Massachusetts: MIT Press, 2017).

4 For more on the research project *Architectonic Explorations of Radio*, see the project archive: https://radioexplorations.ch/ (accessed on 07.02.2022).

5 Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies* 14, no. 3 (1988): 575, https://doi.org/10.2307/3178066.

approach taken in this research demonstrates the importance of an interdisciplinary and intersectional perspective on radio signals and technical artefacts more generally.

Seeing and moving across data

At the end of the 20th century, before the massification of computational power and data processing, science fiction authors imagined gifted persons with visual faculties capable of reading patterns in data, making sense of relations that appeared (or were) meaningless. William Gibson, for example, explored this idea with the character of Colin Laney. The latter, in Gibson's words, "had a peculiar knack with data-collection architectures, and a medically documented concentration-deficit that he could toggle, under certain conditions, into a state of pathological hyperfocus."[6] This capability enabled Colin Laney to intuitively spot patterns of information in vast 'floes' of abstract, undifferentiated data. Laney's skill was not explainable: it represented implicit knowledge Laney was inclined to acquire through careful and persistent practice.

Visibility haunts our idea of knowledge and has found particularly fruitful ground in empiricism. If knowledge arrives at the mind through sensory experience, what we see, we know. Philosopher Susanne Langer observed in the late 1950s how evidence derived from sense-dominated natural sciences.[7] The argument has a basis on observed and identified facts. We believe what we see. At the same time, Langer continued, the observation space in laboratory experiments has shifted from direct experiences accessible to our senses to phenomena that are increasingly mediated by visualization and assessed with different measuring instruments. We can observe objects that have never been experienced through instruments and devices that give access to the space of the experiment

6 William Gibson, *Idoru*, Berkley Novel (New York, NY: Berkley Books, 1996), p 30.

7 Susanne K. Langer, *Philosophy in a New Key: A Study in the Symbolism of Reason, Rite and Art*, 3. ed (Cambridge, Mass.: Harvard Univ. Press, 1993).

or dataset, which is too small and too dynamic to be observed by human eyes.

A universally objective position implies the rule of having access to everywhere equally. Donna Haraway called this "the God trick of seeing everything from nowhere."[8] To counter this myth, she claimed it is necessary to embrace the idea that having a body means having a finite and partial point of view which determines and enables our freedom. This view embodies what, for a universalist, objective position would be the disqualifying and polluting bias. In laying out tensions between the two movements that challenged such 'inexplicable scientific objectivity', Haraway disagreed with the relativism that informed both the social constructionists' and feminist empiricists' critique of objectivity.

On the one hand, Haraway challenged the strong social constructionist argument in STS that painted the scientific method as primarily ideological and saw the drawing of knowledge boundaries as moves towards power rather than truth. On the other hand, standpoint theories, together with 'feminist empiricism', remained focused on legitimate meanings of objectivity. Haraway also criticised feminist literature and writing in History and Philosophy of Science for exhibiting a special kind of essentialism, which divides 'them' and 'us' and entraps two poles of a tempting dichotomy regarding objectivity (one either is objective or is not). Against all this, Haraway sought a way to go beyond simply exposing the existing bias in science. She theorized vision to avoid binary oppositions such as being either biased or objective. Instruments of vision always mediate vision, including our own eyes and the 'eyes' of modern technologies like photographs, space probes, and microscopes. Their embodied nature can address varying scales and contexts. It would be useful to extend Haraway's insistence on the importance and persistence of vision in matters of objectivity to the interdisciplinarity of vision and the imaginary of navigation to trace the movement across disciplinary knowledges in a non-reductive way.

Vision is about making phenomena publicly visible and taking responsibility for drawing boundaries of public knowledge. Since vi-

8 Haraway, "Situated Knowledges," p 581.

sualization as an idea and practice emerged in the 19th century in the work of literary criticism by Samuel Taylor Coleridge,[9] scientists and designers maintained the interest in the capacity of graphical analysis to offer a more efficient evidence base to observe data than abstract calculations would do. In writing a history of co-construction of vision and cognition, historian of science Orit Halpern traced the transformation of ideas of mechanical objectivity, questioning the transformation of knowledge formation from discovery to analysis.[10] She focused on cybernetics, with interest in its resonance with 'governance' through the etymological origin of the term and post WWII projects of technological fixes. Visualization is a term derived from the concern for observation and vision, for rendering visible that which is not available to sight, by using machines, scientific instruments and numeric measures and making new relationships, new objects and spaces of action appear.[11] Halpern pointed to the aspirations of mathematician and cybernetician Norbert Wiener to render the world into an accumulation of records, with nothing left 'unknown' and only new degrees of comprehension left to achieve. With this, cybernetics proposed an end to the discovery of the world, and we could thus say the end of travel. The way screens and digital interfaces are used today hinders our desire to explore the world, as Halpern and others noted. Nevertheless, we could consider how different kinds of exploration enabled by these same digital interfaces could promote a sustained interest in the world in re-reading and re-interpreting records and articulating new perspectives. Such explorations are based on reprograming the information processing and display, which is the starting point for the studies of radio signals

9 The Online Etymology Dictionary documents the first recorded use of the term and suggests that Coleridge coined or first used it in the sense close to how we talk about visualizing data https://www.etymonline.com/word/visualize#etymonline_v_30876 (accessed on 17.02.2022)

10 Orit Halpern, *Beautiful Data: A History of Vision and Reason since 1945* (Durham: Duke University Press, 2014).

11 Halpern, p 21.

discussed later in this text, and the development of experimental tools to reorganize and navigate data.

As in the travels that Jules Verne wrote so extensively about, moving the point of view includes being accountable for this movement. It means assuming intentionality and keeping a record of it. The power of sight and the violence implied in visualizing practices sustain the heritage of the conquering, wandering Western eye and its' travelling lens. Science and optics are closely connected: optical metaphors such as 'reflection' or 'diffraction' serve as models of scientific practice. The former relates to Western philosophy and classical critical practice. At the same time, the latter emerged in feminist materialist circles, which included Haraway and Karen Barad, who wrote extensively on diffractive science and sought "an optical metaphor for the effort to make a difference in the world."[12] Earlier, in *Situated Knowledges*, Haraway generalized optics as a politics of positioning, "the key practice in grounding knowledge organised around the imagery of vision."[13] Positioning is not only optical. As the opening vignette about Jules Verne's lost captain illustrates, interpretation and translation take us to different places. Can we aspire to develop visual systems that would be legible to people without the talent of Gibson's Colin Laney? How might we consider information that circulates in pixels? The following text will offer partial answers to these questions.

Data observatories: following patterns in data

To illustrate possible ways of travelling in data, we will take a brief detour to consider the concept and experimental design of *data observatories* developed within the research project *Negentropic Explorations of Radio*. Conceived as an intuitive tool for orienting and navigating datasets, a *data observatory* is a computational instrument that provides measurements

12 Donna Haraway, *Modest_Witness@Second_Millennium. FemaleMan_Meets_OncoMouse: Feminism and Technoscience* (New York; London: Routledge, 1997), p 16.

13 Haraway, "Situated Knowledges," p 587.

of similarities among data points and enables multiple perspectives on data. The development of *data observatories* contributed ways to re-organize the digital archive on radio signals collected by radio enthusiasts and available online as Signal Identification Guide (SIGID) wiki.[14] This database documents the listening practices of the community of radio amateurs and enthusiasts. The archive's primary purpose is identification: radio amateurs and enthusiasts compare a signal they recorded to the archive of known signals, searching for a match. In addition to radio amateurs, recordings of radio signals 'in the wild' capture the interest of telecommunications engineers and media archaeologists, data scientists, ecologists, and historians of science and technology. *Data observatories* enable the navigating of radio signals datasets from a specific point of view of a disciplinary, interdisciplinary, other kind of interest.

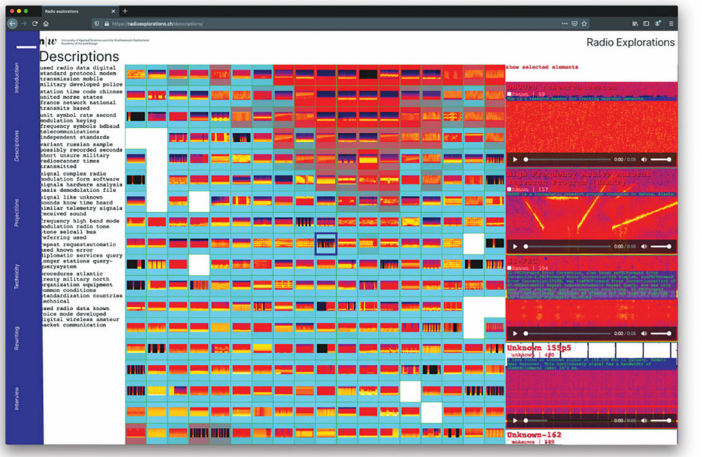
A data observatory is a navigation apparatus that can orient oneself in the vast landscape of data on radio transmissions based on computable similarity. The development of *data observatories* as optical instruments is part of the method and ambition to organize data on radio signals according to the dataset's properties. The data itself means very little in human communication: it consists of demodulated recordings of radio transmissions about the document and the protocols rather than the content of transmitted messages. A self-organizing map (SOM) machine learning algorithm encoded signals in specific properties to render them comparable or commensurable. These were: the probability of silence, the level of noise in the audio sample, or an audio identification technique called fingerprinting.[15] Networks of machine learning algorithms

14 Signal Identification Guide wiki is available at http://sigidwiki.com (accessed on 17.02.2022).

15 Fingerprints are a condensed digital summary of an audio signal, based on peak points in the spectrogram, representing higher energy content. The technique is known for its use in Shazam music identification applications. It was introduced by Avery Wang, as discussed in his invited lecture at the 4th International Conference on Music Information Retrieval in 2003 and the accompanying unpublished paper referenced here, available to download from https://zenodo.org/records/1416340, as well as a Shazam github repository: https://github.com/bmoquist/Shazam, and also from the Columbia University reposi-

train on each of these property sets and produce an organized space – a grid of 'codebook vectors.'[16] – that can be navigated and explored in three dimensions: according to the proximity of codebook cells (horizontally and vertically) and according to the content of one cell (depth). The database gets an informational face, a different one for each property (see Figure 1).

Figure 1: A data observatory interface. The 'informational face' of the radio signal digital archive: Descriptions overview with detailed view of one cell (middle, highlighted).



Courtesy of Selena Savić

tory of Dan Ellis, https://www.ee.columbia.edu/~dpwe/papers/Wang03-shazam.pdf

16 A codebook vector is a list of numbers with the same input and output attributes as the training data.

We previously explored how data observatories can be used to establish radio signals' identities and trace digital information's materiality.[17] The focus here is on how such explorations constitute an act of travelling, which is not unproblematic, and which suggests a way to unfold the interplay between images (i.e. of a radio signal spectrum or a *data observatory* informational face) and navigational imaginaries as a form of scientific communication.

Travelling across data

The *data observatories* enable complex, mediated observation of radio signals through web-based interfaces.[18] We will discuss the travel across textual descriptions of radio signals written by contributors to the SIGID wiki (Figure 1). Data on radio signals are organized according to how we talk about the signals. One moves across the dataset by clicking and accessing information in a browser, observing pixels on a screen that represent relations extracted from radio signals recorded 'in the wild'. We can orient ourselves in this organized space according to specific terms and characteristics of 'clusters' of descriptions that we could call 'topics'. For example, a topic could be determined by the list of words:

> 'data', 'digital', 'standard', 'protocol', 'modem', 'mobile', military', 'developed', 'police'

Or:

> 'variant', 'Russian', 'possibly', 'unsure', 'military', 'radioscanner'

17 Selena Savić, "Articulating Nomadic Identities of Radio Signals," *Matter: Journal of New Materialist Research* 3, no. 1 (February 2022): 56–81, https://doi.org/10.1344/jnmr.v3i1.38959.

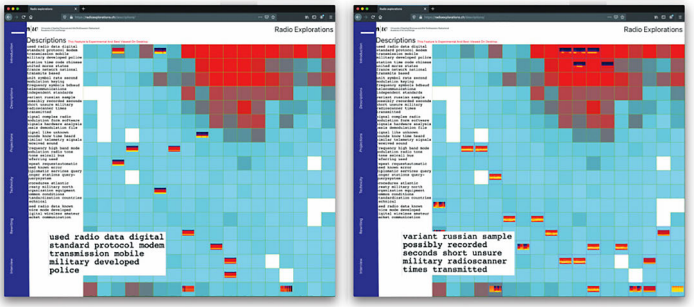
18 The two *data observatories* developed in this project are available online as *Descriptions* https://radioexplorations.ch/descriptions/ and *Projections* https://radioexplorations.ch/projections/.

Or:

'complex', 'modulation', 'form', 'software', 'hardware', 'analysis'

These words direct us towards different imaginaries. The first one speaks of digitality ('data', 'digital') and mediation techniques ('modem', 'mobile'). The second one resonates with international intelligence concerns ('Russian', 'variant'), probably including signals used by military and diplomacy for jamming and spying ('radio scanner, 'unsure'). The third topic resonates with listening techniques, tools and activities for signal analysis. A topic is characteristic or characterized by a group of signals (see Figure 2 for the two topics discussed here), organized on the map of the *data observatory*. This organization is based on similarity across all signals regarding a specific signal property – for example, signal fingerprints. Within a map, signals get 'highlighted' by a topic. In each cell, segments of signals of equal duration are grouped when they exhibit close similarity. Making visual and sonic comparisons of signals in a cell is the endpoint of a movement across the map. The figurative 'depth' of a cell (number of signal segments present) relates to the noisiness of a place. Exploring the overlapping visual and sonic segments informs us of the character of a cell, similar to the way we can experience a location. It also suggests unique connections across cells. For example, different segments of an exciting signal can be found in neighbouring or very distant cells (Figure 1, right vertical area), inverting the informational face of the library, encoded in terms of a signal and directing movement across the dataset. One can choose to visit other cells that host the exciting signal. Exploring one cell in-depth extracts relationships and the essence of a place. This 'essence' can be interpreted further in the topic that highlighted the initial exploration.

Figure 2: Two informational faces of the dataset according to Descriptions, each representing a topic.



Courtesy of Selena Savić

Imaginary, narrative: encoding, decoding and practicing interdisciplinarity

Travel is directly related to privilege: to travel is to have the ability and resources to navigate the world, like Marco Polo or Christopher Columbus did on their trips to extend colonial relations to the 'unknown' world: a world unknown to them while home to others. However, ending exploration and discovery suggests an even more problematic form of appropriation of the world. The movement across the dataset described above is a form of discovery informed by computational measurement of similarity in data points. It is equally accessible to a scholar in political sciences and a communications engineer. This cross-disciplinary access, however, is not enough to constitute interdisciplinarity. Knut Sørensen made this observation in his overview of STS in Norway, using interdisciplinarity as an accounting device to question what is meant by "interdisciplinarity" in STS and to propose four (or more) ways of understanding STS as an interdisciplinary effort.[19] The combination of con-

19 Sørensen, "Disciplined Interdisciplinarity?"

cerns preserved in the digital 'shadows' cast by radio signals transmissions in the form of recordings stored in a digital archive brings together the different disciplinary concerns, including engineering, politics, history, and sociology of technology. The imaginary of travel offers consistency to the interaction between these different fields of expertise. The travel articulates techniques of passage between topics as an interdisciplinary challenge.

Data observatories are based on the SOM algorithm: the artificial neural network introduced by the Finnish professor Teuvo Kohonen in the 1980s as a cybernetic approach to unsupervised machine learning, inspired by biological neural networks.[20] Artificial neural networks of the SOM extract whatever can be essential information from the data, but they do not give us any *reason* for it: reason itself stays in a kind of a black box. The outputs of these computational processes are often used to explain how the world *is* or *will be* (as in predictions), in policymaking, and data-powered business models such as online marketing or surveillance. However, reasoning *with* ML algorithms becomes interesting for humanities when we take its outputs as an incentive to do another translation, to raise new questions through careful interpretation of patterns and clusters observed in data. This is not suggesting that ML algorithms are inefficient in making probabilistic predictions, such as which books one might want to buy, or which advertisement is most effective for a specific user profile. However, we are interested in exploring the possibilities of working with machine learning 'humanistically' without delegating the human responsibilities of reasoning and making sense of data to algorithms. The network topology (the two-dimensional distribution of network nodes) is an invitation to rethink the way to talk about radio transmissions.

Digital data, such as pixels, embody specific logic and lend themselves to the computational processing logic. The main argument in this

20 Teuvo Kohonen, "Self-Organized Formation of Topologically Correct Feature Maps," *Biological Cybernetics* 43, no. 1 (January 1982): 59–69, https://doi.org/10.1007/BF00337288

chapter suggests that travel and vision constitute methodical tools to unfold disciplinary concerns starting from something specific, such as a radio signal recording or a group of pixels, favouring interactional expertise. In working with computation to preserve, rather than suspend richness in interpretations, such an observation describes a concrete imaginary of interdisciplinarity.

Conclusions

Radio signals cannot be known through engineering knowledge alone or a single disciplinary perspective. Signals are made by broadcasting equipment, but they are also part of the natural environment: energy transmissions and material.[21] They are technical artefacts but are also information. The data on radio signals collected in the SIGID database, even if mainly intended to circulate among communication engineers and amateurs, illustrates how these aspects are entangled.

This chapter documents a method to work with this database, while preserving the complexity and entanglement of information. Similar to Gibson's character Colin Laney, neural networks of the SOM algorithm identify patterns in the data on radio signals, but they do not give us any reason for it: reason itself stays in a kind of a black box. However, we do not seek to open this box but acquire digital literacy to play with it like an instrument. Digital literacy is about practising intentionality: articulating ways to index data in meaningful and deliberate ways. With such a multiplicity of relationships comes potentiality and responsibility to follow ensuing narratives.

The dataset that we worked with is not just simply a database. It testifies to a knowledge community that has developed around the technical literacy of telecommunications.

The outputs of this project aim to facilitate speculation on the connection between signal representation and technical communication

21 Douglas Kahn, *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts* (Berkeley: University of California Press, 2013).

protocols by shifting criteria of similarity from taxonomical and instrumental (e.g. used in the military) or physical (e.g. high or low frequency) to properties shared across all signals – such as the probability of silence or noise in the signal. It remains clear that the SOM is simply sorting high dimensional data in the space of possibilities that are always/already encoded. Nevertheless, in the interaction with this information, we should look for ways to articulate interdisciplinary knowledge.