

Indexicality and Visualization: Exploring Analogies with Art, Cinema and Photography

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ABSTRACT

In this paper we offer a critical discussion of data visualization by adapting theories of indexicality as discussed in semiotics and art history. An indexical statement is broadly one whose meaning is dependent on context. We examine how indexicality has informed practices in cinema, photography, and contemporary art and make comparisons with data visualization. Specifically, we explore how these analogies can result in generative concepts that can inform the design and study of data visualization.

Author Keywords

Data visualization; data; photography; cinema; semiotics.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors; design; theory; experimentation.

INTRODUCTION

The digital transformations largely initiated by the personal computer and the Internet have given rise to the emergence of new types of representation collectively known as data visualization. With foundations in statistics, cartography, perceptual psychology, computer graphics, and human-computer interaction, data visualization is increasingly becoming a tool of journalism and artistic practice. Visualization researchers and practitioners propose that the impending ‘data deluge’ can be addressed by utilising human visual capabilities to interpret trends and patterns in large amounts of data. Applications of information visualization range from the analysis of statistical data in disciplines in science (including bioinformatics) and to social relationships in the social sciences (from public health to sociology and human geography). Recently there

has also been growing interest in visualization within the humanities with the rise of ‘Cultural Analytics’ [35]. This shift from the use of visualization in the sciences to the humanities has also seen a change in the subject of visualization from a method for the representation of numbers and statistics to a role in increasingly interpretive and qualitative sources. Where other aspects of visual culture have come under forensic scrutiny, data visualization has, as yet, been little understood in its broader cultural context in terms of issues discussed at length in other heterogeneous fields including photography, journalism, and media art. Among such issues are indexicality and performativity. This lack of scrutiny is partly due to the relative novelty of these new types of representation and, in part, because of their technical complexity. Even as they reveal meanings hidden deep into a data set they hide the process of analysis through procedures, which flatten, simplify, and transform non-spatial information in order to spatialise it.

Our contribution is to examine the concept of indexicality, founded in semiotics, and investigate to what degree it may be useful in providing alternative views on data visualization design and experience. Put simply, indexicality describes relationships of contiguity in the representation of phenomena. Our motivation is that indexicality has proved to be a useful and critical tool in more established forms of representation such as photography, cinema, and other visual arts. We first provide an overview of different concepts around and implications of indexicality across these fields. We then offer a short discussion of how indexicality and other concepts from semiotics have been employed to discuss visualization in the past. We continue with an analysis of how we can apply concepts from past studies in photography, cinema, and art to identify indexical aspects of visualization and then describe some ways how this can inform design. In the final sections we consider some limitations of this concept and discuss future work.

This paper takes a deliberately speculative and explorative approach to the topic in the hope that by doing so we can provoke interest among practitioners and theorists in this potentially productive area. In doing so we adhere to

conceptions of both descriptive and generative theories of design [6]. The following argument and discussion we see as having most relevance to visualization in art, design and the humanities as its identity as a cultural medium develops and matures.

INDEXICALITY IN ART AND SEMIOTICS

Indexicality is a concept developed in semiotics, which has also found value in the visual arts. Charles Sanders Peirce proposed a taxonomy of signs comprising three types: icons, indices and symbols.

“... I had observed that the most frequently useful division of signs is by trichotomy into firstly Likenesses, or, as I prefer to say, Icons, which serve to represent their objects only in so far as they resemble them in themselves; secondly, Indices, which represent their objects independently of any resemblance to them, only by virtue of real connections with them, and thirdly Symbols, which represent their objects, independently alike of any resemblance or any real connection, because dispositions or factitious habits of their interpreters insure their being so understood” [42]

Peirce defines indexicality first as a trace or imprint of the physical, a direct contiguity. He points to a footprint (as index to presence) and lightning (as index to storm). A second definition is that of the ‘pointing finger’. There is a strongly bifurcated aspect to Peirce’s definition, which is somewhat confusing: The former example refers to traces, physical imprints from one item to another. The latter has an important nuance that includes not necessarily physically contiguous references. Doane described [15] how, for Peirce, pronouns such as ‘I’ or ‘this’ are indexical. Such terms, known as ‘shifters’ have meaning only because they refer to the time and place of speaking. Her account highlights that the act of pointing has a capacity to constitute as well as refer to knowledge. Such discussions highlight the fact that such actions of pointing or referral are not simply reflective but are in fact stative, i.e., they are making statements. By putting two things in opposition or comparison, we are generating new standpoints.

One obvious significance of the advent of photography was that it constituted the apogee of mimesis (accurate representation of the real world). Since the Renaissance (and before that in the classical world) capturing the world had been a dominant preoccupation of the visual arts and painting in particular [3]. Photography’s claim to indexicality is firstly drawn from the physical continuity from light reflecting from the physical world to the photosensitive crystals on photographic film and thence, through an enlarger, on to paper. Photography’s appeal was partly in presenting an indubitable record of the real world. 1970s discourses in the art world [33,46], of course, problematised this view, highlighting photographic norms of framing, exposure, and other such mediating processes.

One prevailing concern has been the way that indexicality can be invoked to recall presence or action. Some accounts have described the effect of a ‘reproducible intimacy’:

“Both the intimacy of that relation to a unique and contingent reality and the detachability and circulation of its representation have had enormous cultural consequences” [14].

The knowledge that at some point there was physical collocation or contiguity has implications in terms of viewer experiences of connectedness with artworks. Indexicality is therefore bound up with deixis (meaning through context) and performativity. Indexicality has a performative function, because the mere idea or knowledge that a representation may be indexical introduces a focus on the act itself of photography [22]. This power of the index to provide strong associations of presence has been leveraged for artistic intentions. Metz has pointed out how the indexical quality of cinema has been employed as a ‘realist guarantee for the unreal’ [37]. The sense of familiarity afforded by indexicality in cinema allows filmmakers to introduce elements of fantasy without them being immediately rejected. Manovich [36] similarly asserts that the mere suggestion, perception or even simulation of indexicality in cinema is a powerfully persuasive tool for audiences and points to a cine-historical fetishism with the ‘faithful’ representation of natural phenomena such as whirlwinds, smoke, and waves in this medium.

Isolation and Selection

Meanwhile, outside the realm of cinema, Rosalind Krauss has pointed to Marcel Duchamp’s use of the readymade as an index [33].



Figure 1. Fountain by Marcel Duchamp, 1917

In this case the presence of everyday physical objects in the gallery served a dual purpose. On the one hand, it was a critical tool for thinking about semiotics: The readymade pointed to a reality outside the gallery and had further iconic and symbolic purposes by dint of the particular context of a gallery, in which there is a history of study and problematisation of representation. On the other hand, Duchamp’s readymades (such as the urinal shown in Figure 1) have been invoked to reject later modernist art practices, which deliberately deny reference to the external

world by focusing on style [e.g.,18]. Krauss' account emphasises the temporal and spatial isolation or selection of an object in much the same way that others have described the photographic act. Such works derive their meaning by framing a particular instant in the world's passing by.

Departure from Previous Accounts

There is a formal sense in which selection or isolation function differently between photography/cinema and visualization, which we can relate to historical ways of seeing. Accounts from the German school of media scholarship described as media archaeology have suggested strong relationships between the development of instruments such as proto-cinematic devices and cultural understandings of perception [23,31]. Examples of such ways of seeing include a cultural preoccupation with speed, which began with the railways and influenced the development of cinema [17]. Muybridge's photographic experiments for example have been evidenced for a fascination with capturing rapidness and locomotion [51], photographs which went on to influence Duchamp's work such as 'Nude Descending a Staircase'. What this approach suggests is that the public's actual capacity to imagine is dependent on the development of technologies to assist and expand what can be imagined. In the age of photography the fascination with 'reproducible intimacy' [14] could be linked conceptually to the new possibility of a kind of limited tele-presence brought about by the roughly concurrent invention of the telegraph. The new technological possibility of finding oneself in connection with a place somewhere out of sight implied a different cultural understanding of space. Both the telegraph (and later of course the telephone) and the photograph share this quality of connecting two spaces.

From Performance to Performativity

Semiotic accounts have described indexicality as Peirce's attempt to "find an analytically rigorous means by which to overcome the sign-world dichotomy" [28] an unfortunate Cartesian dualism which has been described as "one of [Saussure's] most durable legacies" [25]. The suggestion is that Saussurian linguistics perpetuated a strong divide between language and the world that was comparable to the mind/body divide in Descartes's philosophy [13].

The dissatisfaction with the duality of representation versus reality had further implications for the development of 20th century art. The desire to blend signification with the world to which it refers echoes 1960s art practices, particularly happenings, which 'flowed over' into their surroundings [27]. Kaprow's action collage recalled earlier synthetic cubist practices of incorporating 'real' elements such as newspaper cuttings into the painting surface. In Kaprow's work materials were not confined to a painting but extended across every surface and it was, in fact, the obstacle of the gallery back wall which gave the artist the impetus to 'blur' the edges of his art practice beyond the gallery [29].

The subsequent explosion of art practices including performance art and interactive media art owe much to the legacy of Kaprow and his contemporaries. Principal to our interest here was a focus on 'performativity'. Arguably the main contribution of this period was a focus on formal ways in which art could be said to act rather than represent. In earlier forms of art action was envisaged as a result of art, not a quality within it and in this sense was not in the same way performative. For example, the power of Russian Constructivist painting to "actively promote egalitarian socialist culture" [30] recognises the influence of art to promote action. The innovation in Kaprow was to radically alter the forms as well as the messages of art.

Performativity in linguistics begins with the recognition that language has not only a descriptive but also a constitutive facet. Words (and crucially for us, pictures) do things as well as describe them. This function has been invoked to problematise the very foundations of representation [4]. Barad proposes a metaphysics of representation based on phenomena rather than subject-object dualisms, i.e., a real-world subject of representation and its representational object. She proposes that a phenomenon-based view implies firstly that instruments constitute 'dynamic (re)configurings of the world' which are practices or performances and question the boundaries of representation. She highlights the part we play in 'practices of knowing' and the socially constructed nature of knowledge echoing Butler's description of the performativity of gendered bodies. Butler sees gender as;

"a corporeal style, an 'act,' as it were, which is both intentional and performative, where 'performative' itself carries the double-meaning of 'dramatic' and 'non-referential'." [11]

Performativity here has an iterative, temporal dimension where identity and, by analogy, knowledge are produced in dialogue with or in reflection to cultural context.

This short overview has identified a number of ways in which indexicality has the potential to bring fresh insights to data visualization practice. In the next section we will examine some previous work, which has applied ideas from semiotics to visualization.

SEMIOTIC CONSIDERATIONS IN VISUALIZATION

Indexicality has been employed to support notions of artistic or journalistic integrity, craftsmanship, and photographic fidelity. In photography the most frequently discussed example is the gradual replacement of analogue techniques of direct exposure of film or paper to light with digital methods. This caused some commentators to perceive an increased degree of abstraction as the translation of light 'directly' to light sensitive film and then to paper gave way to intermediate layers of symbolic abstraction through programming and digital manipulation. This perspective though has been questioned [21] as both naive and ahistorical. Avant-guard photo and cinema

practices such as montage in Dada art broke any form of 1:1 relationship between world and representation. Indeed the authors suggest that the most apparently indexical photographs (such as in photo journalism) are often those, which enjoy the least critical success. The closer to life a photograph is, the less ‘artistic’.

The continued attraction of indexical as opposed to iconic or symbolic representation is the promise of a ‘truthful’ relationship to the world, unfiltered by language or culture, artistic intention, or rhetoric,. A semiotic discussion of visualization by Hullman and Diakopoulos [24] considered the rhetorical techniques employed in narrative visualizations and their interpretation by viewers. Using a layered framework of rhetorical techniques in visualization, they show how omission, emphasis, and ambiguity can be introduced at various stages of the design process, from data and representation to annotation and interaction.

Related to the rhetorical effects on the interpretation of data, the power of data visualization comes in part from an aspiration of truthful representation. This perspective though is, of course, in conflict with the many decisions taken in visualization design about the data set, dimensions, visual encodings, and interaction techniques. In fact, the design process itself can be characterised as a process of refiguring this indexicality into a coherent message. Data drawn from real world processes such as sensors, algorithms, or studies is combined, remixed, and filtered through processes of data mining, sorting, and representation. Both photographic and visualization practices maintain a reflective and sometimes reflexive relationship with the world based on representations which mix symbolic, iconic, and indexical elements. The previous descriptions of indexicality in photography and in particular its function as a ‘realist guarantee for the unreal’ [37] suggest that a degree of the persuasive power of visualization is drawn from a perception of indexicality to the real world. Despite the obvious ways in which data is mediated, filtered, and transformed, there is a desire to see the presence of physical connections to things we know.

Vande Moere [48] takes Peirce’s definitions of the icon, index, and symbol and applies them to a body of his students’ work on data sculptures. Taking various data sets, the students were asked to materialise data through the creation of a sculpture, which would act as both an artwork and an illustration of the data values. Vande Moere uses examples of these student works to categorise each data sculpture as indexical, symbolic, iconic or a combination of two categories. For example Vande Moere classifies a set of sculptures as follows:

“Some student design strategies initiated from an indexical representation by starting from the object depicted by the data itself. [...] one student conveyed the usage of individual keys of a computer keyboard by deforming the components of an existing keyboard (i.e. indexical), here

raising the keys to exact heights to reflect the frequency of their use (i.e. symbolic).” [48]

While this approach is interesting as a design exercise, we wish to broaden the scope somewhat and ask in more fundamental terms what indexicality can bring to visualization.

INDEXICALITY AND DATA VISUALIZATION

We have discussed both the implications of indexicality in art and cinema and some previous attempts to apply its concepts directly to visualization practices. We would now like to ask what the previous discourse around indexicality in the arts can bring when applied to visualization as a tool for criticism and design. Our suggestion is that there are two broad directions to pursue:

- Examine how indexicality may have functioned in visualization as a ‘realist guarantee for the unreal’. What is an appropriate analogy for the photographic referent in the context of visual representations of data?
- Explore how visualization can echo photography’s capacity to recall and distribute acts taking place in specific times and spaces. What are the temporal, spatial, and cultural specificities, which data visualizations can recall in viewers’ experience?

Each of these points above aim to query how indexicality’s capacity to overcome the dichotomy between sign and world might be useful in a discussion of the practices of data gathering, analysis, filtering, and representation, which make up the visualization pipeline [12].

Guarantees for the Unreal

In the above discussion we have cited the discourse in cinema and conceptual art where reference to a contiguous relationship with the physical world has served to first support the suspension of disbelief in cinema and secondly to interrupt norms of representation in artworks. It is particularly interesting that the same faculty is employed in these examples to what are essentially opposite ends, those of questioning and reinforcing reference to the world outside representation.

Identifying the Index

Our first task to make an analogy with photography and cinema is to assess to what degree we can identify the ‘footprint’ in visualization. Are there, in fact contiguous relationships between the physical world, the collected data, and generated representations and if so, how can we characterise the relationships between them?

To identify such footprints we must first ask which, if any, visualizations refer to a physical contiguity with reality. The clearest examples are perhaps those based on sensor data. Suspending for a moment questions of representation, we can find strong parallels between sensor data and photography. Such parallels have precedence in debates on photographic visualization, which surfaced with the adoption of digital techniques in photography.

Commentators have pointed out that contrary to popular perception, making strong processual distinctions between digital and analogue photography or cinema is problematic [19]. Responses focus on a centre ground in which manipulation of digital images results in a loss of indexical to merely iconic representation [21]. Our position is that, given the previous discussion of disruptive production techniques, such as montage, for even analogue photography, such distinctions are largely questions of degree. All such footprints are mediated to a greater or lesser degree. Even if such contiguities at times enter the realm of the symbolic through software our direction in this paper is not principally a metaphysical one. There is of course, an ontological distinction between a footprint and a digital photograph but the space we wish to explore is of a more epistemological order. That is to say, we are interested in the extent to which we can use indexicality to tell us something about user experience and knowledge construction. To clarify then, we consider as our index first that which has contiguity to the physical world or is at least perceived to have. In this we remain faithful to Peirce's original definition [42].

Situatedness

Krauss characterises Duchamp's readymades as involving

"the physical transposition of an object from the continuum of reality into the fixed condition of the art-image by a moment of isolation, or selection." [33]

The performative sense of indexicality is where the presence of an indexical sign makes a statement as a representation that is tied to a reality. Alongside this is an understanding that such tie-ins invoke a selection from a continuum in space/time. Sensor data is isolated by polling the sensor at specified intervals in space and time. Network visualizations are selected by a reduction of their complexity to a number of relationships. Such 'moments' of isolation are significant because of their potential to evoke understanding in the user, as in photography, by "the sheer fact that it was taken" [22] that this visualization is imbricated with some reality. And this sensation may imply an increased sense of trust, as described in cinema [37] and serve to support engagement. This is illustrated by visualizations, which rely on 'live data'. The sense of connection to the physical world is strongly supported by the viewer's understanding that this is happening, somewhere in the world, right now.

In Narratives 2.0 [14] music is subjected to a fast fourier transform analysis which breaks the complicated sound waves into simple individual ones. The individual sounds are visualized with meandering lines, which change direction and colour as they change frequency. The visualization has a strong sense of connection to the original data due to the live translation from music to visuals. Hearing pitch changes, the viewer/auditor is able to examine the behaviour of the animation. The 'footprint' in this visualization is strongly mediated through, first, a

translation from the auditory to the visual, and then through the design choices in terms of colour scheme and spatial mappings that have taken place. Despite these mediations one perceives a strong sense of continuity between the data and the visual effects. This sense, we suggest, is not present in the still images of the visualization provided on the project's website and this suggests that temporality has a strong capacity to imply indexicality.

Performativity

As discussed in an earlier section, performativity has been used to critique such diverse issues as gender identity and the linguistic turn in philosophy [4]. We now consider what the notion of performativity offers to visualization.

Representationalism

Most visualization criticism focuses on the manner of representation [32,47]. In the related field of cartography, entire books have spelled out in exhaustive detail the socio-political power expressed by the strongly partial typologies present in map making [38,54]. Such partialities include bias from political, gendered, colonial, or economic standpoints. While we contend that such discourses have as yet been underplayed in visualization, there is another critical consideration implied by indexicality and performativity, which we wish to introduce in this context. We have described how Barad has proposed a phenomenal and performative perspective on our relationship to events in the world. She suggests that

"The move toward performative alternatives to representationalism shifts the focus from questions of correspondence between descriptions and reality (e.g., do they mirror nature or culture?) to matters of practices/ doings/actions." [4]

This perspective reshapes our design space as creators of visualization. Where previous approaches to visualization have focused on the effective use of representational techniques to provide, for example, aggregate views of data for analysis, performativity implies a reformulation of visualization's task towards a constitutive act of knowledge making. This is to suggest that the aim to 'accurately' or 'impartially' represent things in the world is not only a quixotic aspiration but also one, which ignores the historical, social, and epistemological circumstances in which the data visualization is situated. In accordance with an understanding of visualization as a process rather than artifact [12], the design space shifts from concerns of fidelity, transparency, or accuracy of visualization artifacts to the consideration of generative, productive, and discursive qualities of visualization use.

Perception and Experience

We will now examine a short example to investigate how indexicality functions first as a 'guarantee for the un-real' and second to suggest a sense of situatedness in data gathering processes.

From Index to Indexicality

Wind Map [50] is an animated visualization of air movement over the United States during the winter months of 2011/12 (see Figure 2). The data is taken from the National Digital Forecast Database [40], but it is not specified how it is gathered (i.e. satellite or ground station).

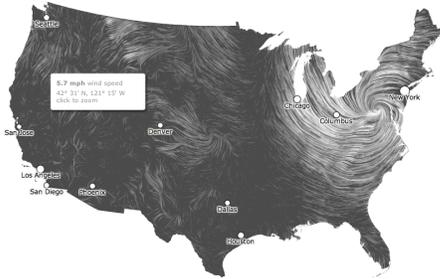


Figure 2. Wind Map by Viegas and Wattenberg [50]

The project was produced as a personal art project by the two artists, Fernanda Viegas and Martin Wattenberg, who are also visualization researchers and engineers in their day jobs. In their Eyeo Festival talk [49] they are at pains to stress that it was not conceived as a prediction tool but describe how user feedback focused on this application. In their talk the artists, go into candid detail about the difficulties involved in producing a visualization that would produce a satisfying wind-like feel but in many ways the final aesthetic is satisfying to people only because of a perceived capacity for it to show local, geographic specifics. The artists retell how a schoolteacher had contacted them to report how his or her class had predicted tornadoes. The near-real-time aspect of the data gathering had the potential to form a strong sense of connection to the events visualized. We would question whether the visualization would have been as popular if it showed, for example, patterns in wind over time. Interestingly Wattenberg concludes the presentation by in many ways echoing our point, albeit in different terms:

“if you identify a data set that has that kind of causal power then you do something that is true to the data it will be useful.” [49]

Wattenberg relates the success of the visualization to the powerful physical world connection in the visualization even though we would characterise that connection as very highly mediated by the many design decisions that the artists describe. Indeed reactions to the piece focus specifically on the capacity of the visualization to evoke a sense of place; “I can almost feel the chilly breeze coming off the water” [53], with little discussion of the design itself. Here is an example where indexicality functions as a ‘guarantee for the unreal’. The design process is obfuscated by an appeal to a viewer’s sense of place. The title of the Wired article ‘Google Wind Visualization Lets You See the Unseen’ [55] evokes earlier discussions of photography and cinema’s ability to detach and circulate reality [15].

CREATING INDEXICAL VISUALIZATIONS

So far we introduced the notion of indexicality as a semiotic concept developed to critique photography, film, and visual art, and put it into relation with data visualization. We now explore how the consideration of indexicality can inform and inspire the design of new data visualizations. We are particularly interested in harnessing the indexicality of visualizations in their contiguity with and situatedness in the real world. In the following, we explore design ideas to increase the perceived indexicality of visualizations.

Making Visualizations Contiguous With the World

Our assumption is that imbuing digital visualizations with imprints from the physical world can give viewers a better sense of how data is transformed into a visual representation. In fact, the physical world already holds a wide range of data visualizations. All activities in the world leave physical traces, some more visible than others. Footprints in the sand, crowds in front of good restaurants, and leaves below trees during autumn—all tell stories of past and present activity. This notion of traces to represent activity has already been used in the context of social navigation to support document navigation and collaborative editing [e.g., 52]. Depending on the type of data being represented, the natural world can serve as an inspiration for how contiguity might be introduced into the representations of visualization.

On a literal level, a visualization designer may ask how the data was collected and whether there is a viable physical manifestation of this activity. For example, the lending popularity of a book in a library is actually already manifested in the (possibly invisible) fingermarks on the cover and pages. If there is no obvious physical trace, it might still be useful to consider what a physical visualization of the data would look like. Even more so, a ‘physicalisation’ that uses material artefacts that resemble the represented entities can ease the perceived linkage between the represented and real.

The notion of footprints carries a spatial connotation that a visualization designer can harness by using spatial representations. Viewers can draw from their experiences with maps and their associations with familiar places in the real world. Considering indexicality as opposed to just spatiality here allows a designer to concentrate on places as phenomena, not just places but situations in which we have found ourselves. Just as art and photography practices blurred representation with experience, indexicality offers a way of thinking for designers to evoke feelings of presence and familiarity in users. Drawing on familiarity requires an understanding of cultural associations. For example, the previously discussed wind map, conveys an indexical impression of wind by drawing from our familiarity with seeing movements of air and water in this way.

If the represented data set contains visual characteristics such as colour it can be fruitful to retain these visual aspects to ease the translation when viewing a visualization. For

example, when representing paintings or photos their visual qualities can be exposed in the visualization [20]. Even when aggregated or re-arranged, the visual resemblance with the represented can give viewers a sense of trust and interest. An indexical approach to visualization design that literally includes such visual details differs from one that simply references them for example by choosing a similar palette. Indexicality emphasises the relationship to the real world and implies that these details have relevance to the subject under observation.

Regardless whether or not the data has any spatial or visual aspects, a visualization can provide direct access to the underlying data points and the way they were gathered, generated, or interpolated. Using detail-on-demand interactivity to see details about graphical elements the viewer may invoke a provenance inspector. Similar to how browsers allow the viewer to inspect an element on a webpage with regards to its markup and styling, it might be useful to think of what an inspector could bring in a data visualization. For this functionality to become possible, the visualization has to be created with provenance in mind. The transformation steps along the visualization pipeline [12] would need to be made transparent to the viewer. This may include both styling rules (e.g., colour mappings) as well as transformation logic (e.g., layouts).

Increasing the Situatedness of Visualizations

The second aspect of indexicality refers to the situatedness of data visualization that can provide powerful framing for understanding the representation in its spatial, temporal, and cultural context. While not necessarily conveying a sense of physical contiguity, situated visualizations refer to moments by using reference points in time and space.

The primary way to convey the situated quality of a visualization is to accompany the visualization with a narrative that is formulated by or with the visualization creators themselves. This narrative is commonly done in journalistic visualizations accompanying news stories that put the visualization into context of current affairs [45]. Besides time, place, and the news story in question, the visualization designer may want to include a description of how data were collected and represented.

In addition to the narrative provided by the visualization creators, the visualization can be framed in multiple ways by its viewers through commenting and annotation. Bringing in additional voices allows the visualization to be situated into different possibly competing or contradicting contexts. For example, a visualization of budget cuts may be accompanied by the stories of people affected providing various contexts for better understanding the visualization.

Visualizations can also be accompanied by other visualizations representing the same data from different perspectives or representing other related data sets. A series of visualizations with a thematic relationship can provide a richer and deeper impression on a subject area.

A particularly powerful way of situating a visualization is to place it into the ‘here and now’. For example, it is possible to visualize the tweets posted around a large-scale event such as an election or soccer game as it occurs in the present [16]. The appeal of visualizing live data lies in the sensation of being to some degree a physically present witness of a distributed event. While the data may come from remote locations, data visualization can bring these places together in the form of visual aggregation.

We discussed how Kaprow’s art sought to ‘blur the edges between art and life’ [27]. By physically situating visualization in context we associate it with not only a place but a social situation. In the above example of the soccer game, a visualization physically hosted at the game would be engaging because it would expand the social sphere of the game outside the stadium and connect it with people world wide. The visualization becomes a nexus point for discussion. Similarly the web based Twitter interactions benefit from the context that they will be manifested at the site of the game. Here a ‘pointing index’ is set up where meaning is created and underlined by the relationship between two different spaces.

In the context of visualization we can consider how visualization is increasingly designed for mobile platforms; tablets and smart phones. Apple iPhones, for instance, have visualization elements built natively into the interface. ‘Notification Center’ is effectively a data dashboard where alerts exist alongside visualization widgets. Presence in the Notification Center gives the ‘Stocks’ app [2] visibility as users check their other alerts but also adds to a sense of liveness afforded by a context where only the most up to date information is shown.

DISCUSSION

We have described, in the preceding pages, how indexicality has informed discussion in photography, art and cinema, where we might locate indexical aspects in visualization and included some short notes on how this can inform the design of data visualizations. We would like now to discuss some limitations and open questions.

Limitations of our Analogies

There are three main aspects of data visualization that may be seen to be standing in opposition to the indexicality of photography and film:

- the distributed character of data gathering,
- the highly aggregated representation in visualization, and
- the translation into the visual modality.

Arguably, the contiguous relationship between the physical world and representation in photography and film is much more direct as there is a depiction that refers to a moment and resembles our own visual perception of the world. Both moment and modality are to some degree maintained between subject and object. In contrast, data visualization is based on an abstraction of the world, which then results in a

seemingly coherent, yet highly abstract visual image. The created image seldom contains literal aspects of the world as perceived by the eye. In fact, the aspects that are visualized may not be experienced in the same way; for example, visualizations of noise levels require a modality translation from the auditory to the visual sense. Furthermore, there is no obvious resemblance of the real world embedded in most data visualizations.

We discussed in an earlier section how photography and cinema select and isolate moments in time and space. Visualization however describes a different order of isolation and selection. Consider the situation of a visualization of wind data reliant on a network of sensors at intervals across a country. In this instance there is an analogy with photography where the visual sensors are also separating out a ‘snapshot’ from a continuum. Where the photograph ‘frames’ an instant in time and space the data sensors ‘poll’ at intervals and have a purely temporal dimension. Unlike photography, however, the spaces invoked by such a snapshot in time are distributed, taking place in many places at the same time. To return to the earlier point concerning the technical enabling the imaginary, we suggest that this kind of distributed tele-presence has meaning for us precisely because we have been culturally prepared for this spatial formation by technology. We are comfortable with the possibility of making sense of a one-to-many perspective only because network technologies have enabled a new way of thinking about our spatial relationship to the world.

While these challenges may exacerbate the practical consideration of indexicality in data visualization design, they also point to the difficulties that visualization pose with regard to their interpretation.

Non-Indexical visualizations?

Because of the strong sense that indexicality represents a connection between the physical world and the sign it is difficult to imagine how the concept may be applied to visualizations, which are not based on some kind of sensors. For instance information visualization seeks to represent an extremely heterogeneous range of digital resources. To seek the same character of physical contiguity in all such visualizations can result in frustration. We have discussed an example of a music visualization, which appears to have indexical qualities despite no real physical contiguity and wish to add another example, also musical to provide further avenues for discussion.

AlgoRhythmic Sorting is an “epistemic experiment” by Shintaro Miyazaki and Michel Chinnen [38]. Sorting algorithms are small pieces of computer code, which by different sets of rules arrange sequences into order. AlgoRhythmic Sorting applies different varieties of sort, for example. “Bubble Sort”, “Heap Sort”, “Merge Sort” and others to a series of simple sine wave tones. The audience experiences the sonification as a series of initially jumbled, and then increasingly ordered tones as the sort progresses

live. We propose that AlgoRhythmic Sorting sonifies the sorting algorithms in a way which is strongly analogous to Peirce’s definition of the footprint but which has, nonetheless an extremely convoluted form of contiguity. When we listen to the tones being sorted, we are hearing the effect of the sorting algorithm not the algorithm itself. Those algorithms are defined by rules in symbolic code but are nonetheless implemented in the physical world in silicon gates or switches. There is a physically contiguous relationship between the rule set and the resulting tones.

This example implies that there are visualizations, which are indexical in ways that are not described here or in previous definitions of indexicality. That implies that either the definition of indexicality in this context needs to be broadened or another term should be found to imply a sense of causality in representations of data.

Difficulties for Design?

We have outlined a number of ways to suggest indexicality in design by for instance, adopting stylistic cues from the origin of the data, e.g., flowing graphics for wind visualizations, or using the visual variables such as colour, which have associations with that origin. We also suggested increasing situatedness by considering the context in which visualizations appear and suggesting closer relationships with the indexical referent by using interactive techniques to ‘get closer’ to the data. We believe that these suggestions have value but suggest them only as tentative starting points. Our recommendations are mostly gauged to improving user experience but we feel that the performative character of visualization has critical potential to inform discussions of visualization’s purpose.

To expand this notion we point to the example of the role of news outlets over the course of the 20th century. The BBC was born in the 1920s with a mission to ‘inform, educate and entertain’ and by their own account provided this as a model for world broadcasting [5]. The first two items of the list, ‘inform’ and ‘educate’ while related, imply very different functions for the news. The later, in particular implies a performative quality, a recognition that the news has agency to act in the world. The performative function of the news has also been demonstrated by, for example, the capacity of investigative journalism to instigate political change. In fact, several accounts [8,9,44] have noted the importance of the social context of communication:

“Performative utterances are after all only considered true when the person who utters them is authorized to do so and their authority is recognized by others.” [9]

In visualization there is a strong sense in which representations are supported by their social or academic context. Even the most subjective data visualization shares many stylistic elements with a history of visualizations from analytic science, which lends an air of legitimacy. Further to this we suggest that viewers of visualizations are inclined to contextualise them in a history of representation

which includes not only the varieties of visual representation described earlier but also other primarily non-visual practices such as journalism. This is reinforced by the current popularity of data journalism where visualization is leveraged to tell 'great data stories' [43]. In such 'stories' indices to the real world such as population statistics perform a situating role, 'tying' the story/representation for example, to particular locations.

Our discussion suggests that there is an opportunity for further research into the performative role in visualization and particularly the way that previous practices in journalism inform audiences' understanding of that performativity.

CONCLUSIONS

This paper has provided an overview of approaches to indexicality from a number of disciplines and discusses their application to visualization. We consider that indexicality and the related area of performativity has the potential to contribute to a productive discussion about visualization's agency in new fields. This discussion is particularly important at a time when visualization is transcending its original disciplinary boundaries into areas where it assumes new kinds of agency in political and social realms. With this transition, visualizations are increasingly made by researchers who bring new theoretical perspectives from their respective disciplines, and these perspectives will, we hope, bring diversity as well as rigour to the field.

The diversity of contexts in which visualization finds itself brings differing expectations for researchers, designers, and viewers alike. With this in mind we suggest that to design data visualization is to design for context. This implies a wider look at visualization practices, which focus not only on the language of representation but also its situatedness in discourse.

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