Towards Recognizing the Tacit Qualities of Physical Data Visualization

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Abstract
The physical visualization of more complex datasets often mimic traditional and display-centric information visualization techniques, ranging from tangible pie charts to human-scale renditions parallel coordinates graphs. However, our physical world inherently carries and affords for the communication of much richer, multi-faceted and interpretative meanings than just quantitative values. This short paper therefore makes a call to incorporate the qualitative and tacit aspects of our physical environment in future physical visualization research efforts. We believe a physical visualization should not only facilitate data analytical tasks in comprehensible ways, but also exploit natural physical affordances by way of appropriate iconic and indexical data mapping, to make the sense-making process more multifaceted and interpretative.

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physical visualization, design, physicalization, infovis.

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

Introduction
The physical representation of data is not a recent idea. Various cultures have implemented physical

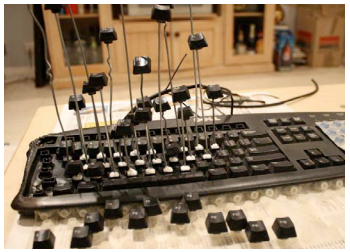
Figure 1. Graph-like symbolic (top), iconic (middle) and indexical data sculptures [13].

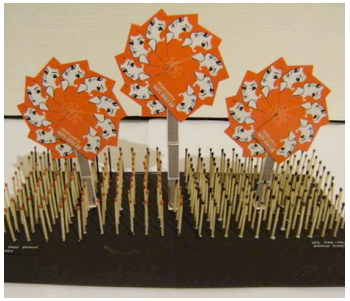
contraptions to capture and convey information in tangible – and therefore also visible – ways. Ranging from simple mercury thermometers to sophisticated pieces of electronically enhanced data art (i.e. see [1]), a rich practice now exists that – based on current media, cultural and artistic interest – demonstrates the compelling nature of simultaneously seeing, feeling and tangibly interacting with abstract information. In recent years, however, interest from human-computer interaction (HCI) and information visualization (infovis) research in this topic has increased (e.g. [7]). Similarly to how infovis aims to augment our human visual cognition, current research in physical visualization strives to augment our other senses to facilitate and support the analysis, exploration and communication of data. In addition, it is expected that the accessible and compelling nature of tangibles [4] could also unlock and engage new audiences for the creation and use of information visualization [3]. In a technological context, physical visualization research has also been spurred by how advances in electronics (e.g. sensing, actuation) and rapid prototyping (e.g. 3D printing, laser cutting) have become increasingly accessible, affordable, and versatile. Moreover, recent accomplishments in mechatronics has now made it finally possible to dynamically alter some primary characteristics of matter, such as altering the surface of a table [2], or the shape [10] and the weight [9] of individual objects.

The concept of 'data physicalization' has recently been coined as the tangible equivalent of 'data visualization'. Here, it is expected that the use of interactive, computer-supported physical renditions of data will further augment our human cognitive capabilities during its analysis, exploration and communication. Similar to the current research interests in infovis, much attention is paid to conveying [6] or constructing [5] comprehensible representations of complex, quantitative datasets.

Quantitative datasets that typically consist of numerical facts, statistical distributions or pair-wise correlations can be relatively easily mapped (or 'embodied' [14]) unto specific physical affordances, like – but not limited to – size, color, shape, weight, or the spatial arrangement thereof. As a result, many existing physical visualizations of more complex data still resemble traditional, display-centric, information visualization techniques, such as bar graphs, area charts and their small multiples, to even network graphs or human-scale renditions of parallel coordinates. However, our physical world does not necessarily resemble that of a (info)graph, as tangible objects and their context inherently carry and afford for much richer and multi-faceted meanings than the discreteness of facts, statistics or numbers. Is it not the primary challenge, then, how to match the challenging 'complexity' of data to our natural ability to almost effortlessly experience and understand the 'multifacetedness' of our physical world? Should we not look for new ways how to embody [14] the 'size', 'multi-dimensionality' and 'time-varying' nature of complex data to that of our 'wide', 'multimodal' and 'dynamic' experience of the world?

As a small yet provocative counterweight, this short paper therefore wishes to make a call to incorporate the rich, qualitative and tacit aspects of physical visualization in future research efforts. A few recent studies (e.g. [8, 12]) that explored the potential application of physical visualization as a persuasive feedback medium have already indicated its often





compelling and widely interpretive qualities. While, admittedly, these particular applications were not meant to convey complex data or facilitate deep insights, they still demonstrated how traditional usability and evaluation metrics might not accurately capture how we can potentially understand, or interact with, physical visualization. For instance, among many other valuable insights, these studies reported observations that related to more subjective aspects like *aesthetics*, *cherishment*, *expression*, *playfulness*, and *sustainability*, all concepts that are still relatively underexplored in the field of information visualization.

In our previous work [13] [14], we recognized several physical qualities that potentially characterize the tangible rendition of data, including: *embodiment*, *metaphorical distance*, *multi-modality*, *interaction*, *affordance* and *physicality*. While this list of concepts was not exhaustive, it still highlights the scope and diversity of the creative design dimensions that reach beyond the direct mapping of abstract information into physical form. Moreover, based on the analysis of the design strategies adopted by more than 140 bachelor interaction design students who each implemented a data sculpture, we proposed a semiotic design model based on three categories – *symbolic*, *indexical*, and *iconic*. While this simple model confirms the usefulness of physical representations to represent data in more traditional, symbolic ways (the deterministic, often direct, mapping of data that can be reversed from shape to data), it also revealed the still largely untapped potential of iconic (metaphorical translations of data that incorporate some meaning) and indexical (having some direct relationship, either physically or causally, with the data) approaches.

We thus propose that both iconic and indexical ways of data mapping (or data embodiment) could be explored to carry the values, the meanings or the functionalities that are useful for data analysis, exploration and communication. We believe a good physical visualization should not only exploit its physical characteristics to convey data in a comprehensible way, but also exploit its tacit, physical affordances to facilitate ways of making sense of the data, much like narrative visualization [11] steers the information discovery process in providing supporting evidence or related details. These affordances could potentially be controlled by mechatronics or other electronic means, but could also be embodied by deliberately steering its iconic and indexical properties. In short, by designing physical visualizations that are comprehensible on multiple levels of human understanding and human interpretation, maybe the complexity and meaning of data could be better tamed.

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