Toward a Design Language for Data Physicalization

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Abstract— The use of physical representations to facilitate communication, analysis, teaching, and research is as old as humanity. However, it is only in the past decade that data physicalization is being discussed as a dedicated form of research and design practice primarily concerned with the design of physical artefacts "*whose geometry or material properties encode data*" [10] to facilitate sensemaking and communication. For visualization, as the dominant form of data representation, established principles and taxonomies exist to guide designers. However, an equivalent design vocabulary has yet to be established for data physicalization. The aim of this workshop is to draw together practitioners and researchers from the visualization, HCI, and design communities in order to discuss different approaches toward a design language for data physicalization. Through a series of invited talks alternating with hands-on discussions of existing physicalization examples, the workshop will start to consolidate different efforts of characterizing and evaluating the core properties or "variables" that drive data physicalization, and to define a research agenda in this area.

1 Motivation

In the past years, data physicalization has been established as the practice of designing physical artifacts "whose geometry or material properties encode data" [10]. It is being actively explored as an alternative way to represent data for analysis and sensemaking in a variety of contexts, including design [13], architecture [4], (visualization) education [6, 8], personal analytics [12], and from a perceptual perspective [11]. Similarly, a large variety of practices exist when it comes to creating data physicalizations, ranging from the manual assemblage of analog materials such as simple tangible tokens [8], Lego [5], beads or plasticine [17], to the digital fabrication of physical data-driven artifacts [15], to accentuated interactive physical data displays [16].

However, despite of the large variety of case studies in this area, a principled way of encoding data into physical artifacts has yet to be established—as already highlighted by Jansen et al. in 2015 [10]. The process of visualization—as the dominant approach to representing data—is defined by mapping data to marks and their *visual variables* or *channels* (e.g., position, size, shape, or color) [1, 14], based on the type of data attributes. The set of core visual variables is concise and well researched from a perceptual perspective, and as such, these variables greatly facilitate not only visualization design practices but also teaching the practice of visualizing data to novices. While defining an equivalent set of *physical variables* to facilitate the process of data physicalization seems a natural next step, it is not trivial. This is due to the fact that data physicalizations are multisensory in nature—they address not only the visual senses, but also the tactile, kinesthetic, and, in some cases, the auditory sense. Furthermore, other aspects such as material choices, scale, physical/social context [18], and physical affordances, while not directly part of the data encoding, influence sense making and experience, and therefore significantly shape the design space for data physicalization.

Researchers from the fields of visualization, HCI, and design have started to define and characterize this design space, focusing, for example, on the multisensory aspects of physicalizations [2], semiological perspectives on physical data encodings [13], (physical) data context [18], and, general benefits and open challenges in the area of data physicalization [10]. Furthermore, empirical research has been conducted to start characterizing the effectiveness of physical in contrast to visual data encodings [9], for example, focusing on specific properties such as size [11]. We also see data physicalization explored as a design process [8] to teach the data encoding in a hands-on and creative way. Along these lines, various works have discussed the design of physicalization toolkits [3, 6, 7, 17] to engage in particular novices in the practice of data representation.

All of these approaches inform the practice of data physicalization in unique ways, but they are scattered across different methods, foci, and even research communities. The aim of this workshop is therefore to bring together researchers from different research communities (in particular visualization, HCI, and design) to discuss approaches toward a unified design language for data physicalization. Through a series of invited talks, alternating with small-group discussions, the workshop will start to consolidate different efforts of characterizing and evaluating the core properties or "variables" that drive data physicalization, and to define a research agenda in this area. Discussions will be fueled by hands-on sessions where all workshop participants will actively engage in classifying the properties of existing physicalization examples. In this way we hope to foster active and diverse discussions from different perspectives from within and beyond the visualization community

2 Workshop Goals

This workshop will stand in line with a number of data physialization workshops that have been organized at different conferences, starting at IEEE VIS'14 in Paris[1] with a workshop on the "*Death of the Desktop: Envisioning Visualization without Desktop Computing*", followed by a CHI'15 workshop[2] that explored the challenges of "*making data physical*" to define a research agenda in the area. Two more design-oriented hands-on data physicalization workshops followed at TEI'16[3]

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[1]http://dataphys.org/workshops/vis14/
[2]http://jasonalexander.kiwi/workshops/physicaldata2015/
[3]http://dataphys.org/workshops/tei16/

and DRS'17[4]. The latest workshop in this series took place at DIS'17 and focused on the pedagogical aspects of data physicalization[5].

This workshop will take a new perspective from these prior workshops by focusing discussions within and across research communities on a principled way of encoding data into physical artifacts. The workshop has two primary goals:

1. To bring together researchers and practitioners from the visualization, HCI, and design communities (and beyond) to share previous and ongoing efforts and results of how to characterize data physicalizations and their individual properties.

2. To start an interdisciplinary discussion on the general design language for data physicalization, identifying areas of agreement and controversy.

We do not intend to end the workshop with a concise set of "physical variables" equivalent to the well established and agreed upon "visual variables" in visualization. What we hope to achieve in this workshop is to identify current approaches in this area that spans different research communities, as well as intersecting and complementary perspectives in order to shape a research agenda in this area.

We believe that IEEE VIS is the perfect venue for such a workshop as it will help bring together (1) researchers and practitioners directly focusing on data physicalization specifically from a design or empirical perspective, as well as (2) those who are familiar with and/or interested in the process of encoding data within different application scenarios and contexts (e.g., cognitive psychology, pedagogy, visual analytics, or art).

3 Workshop Format & Planned Activities

We would like to apply for a **half-day** workshop, which will involve two main activities: two invited workshop paper presentation sessions and two discussion-based classification exercises. In order to create an atmosphere that engages workshop participants with a core expertise and interest in data physicalization, those with a more peripheral interest, and researchers and practitioners that are new to this fascinating topic, we will intertwine invited workshop talks with hands-on activities that will guide discussions around physicalization as a design space, how to classify properties of physicalization and what would define a design language in this field.

3.1 Invited Paper Talks

We will publish a call for workshop papers well in advance (see Timeline below in Section 4.2) that will invite for paper submissions that describe both nascent and mature research in the area of data physicalization. Topics of workshop papers will include but are not limited to the following themes:

- The design space of data physicalization
- Translating visual variables into physical data encodings
- Studies of physical properties from a perceptual perspective
- Data physicalization as a design practice
- Teaching data Mappings through physicalization
- Considering material choices and/or digital fabrication for physicalization
- The influence of physical environment, usage scenarios, and interaction models on physicalization design
- Physical encodings in the context of data/visualization literacy

Submissions will present original research ideas or results as they relate to exploring a design language for data physicalization. Submissions should be 4-pages long (in the two column VGTC format) and should clearly state their specific contribution to this growing field of research. Submissions should highlight emerging physicalization research, report work in progress, or describe empirical results or case studies that support more high-level design consideration or guidelines.

Authors of accepted papers will be invited for a 10-minute oral presentation (plus 3 minutes for questions). For a half-day workshop, we plan on accepting 7 papers, which will be presented over 2 paper sessions.

The call for participation will be made public on our workshop website[6] and distributed via mailing lists across the visualization, HCI, design and tangible interaction communities, and through professional networks. Submissions will be peer reviewed by and least two reviewers who will be members of the organizing committee and/or the invited program committee (find a tentative list below). Authors will receive detailed reviews on submissions. Accepted papers will receive additional time for editing before the camera ready deadline. Camera-ready papers will be provided to IEEE VIS organizers for inclusion on the VIS conference USB drive, and they will also published on the workshop website.

3.2 Discussion-based Classification Activity

The invited paper presentations will alternate with two more hands-on classification activities that will invite all workshop participants to critically engage with existing data physicalizations (made available at the workshop, in form of photos and/or videos). As part of these sessions, participants will explore and critique the design choices evident in a selection of example data physicalization and to extract and discuss the different encoding strategies in use. Each session will have four discrete phases.

Introduction Phase. Each session will commence with the organizers providing an overview of the activity and dividing participants small groups (6–8 people, depending on the number of participants).

Classification Phase. This phase will involve each group selecting three cards, each containing an image and brief information on a data physicalization. Based on these cards groups are asked extract the design choices that are evident, these may include: physical variables, design patterns, physical or material properties, physical data encoding, physical/social context etc... The group will collect the characteristics of their physicalizations on a large sheet of paper using post-it notes and markers. We expect these activities to be accompanied by heavy discussions. Groups will be asked to try to consolidate their classifications as best as they can.

Presentation Phase. Each group will be given 2 minute to briefly present their findings from the activity. In this way, differences in approaches and controversial topics will become visible as well as areas of agreement.

A final ***discussion session*** will conclude the workshop. We will write up a brief report summarizing the activities and discussions that occurred during the workshop and make this available on the workshop website, alongside participants' classification outcomes. Again, the workshop will help to identify current efforts and perspectives on establishing principled ways of encoding data in physical artifacts, and to bring together researchers and practitioners working and interested in this area. This type of topic requires not the work of a small group of experts, but it requires input from a critical mass, and we hope to promote and facilitate such discussions through our workshop at the VIS conference.

4 Intended Schedule

In the following we have outlined a tentative schedule for the workshop, if it would take place in the afternoon (of course, a morning workshop would also be possible).

- 14:00 —14:05 (5 mins) **Opening**
- 14:05 —15:00 (55 mins) **Paper Session I**
  4 speakers (10 mins. presentations; 3 min. questions)

[4]http://dataphys.org/workshops/drs16/

[5]http://dataphys.org/workshops/dis17/

[6]http://dataphys.org/workshops/vis18/

- 15:00 —15:40 (40 mins) **Design Critique Session I + Discussion**
- 15:40 —16:15 **Coffee Break**
- 16:15 —17:00 (45 mins) **Paper Session II**
  3 speakers (10 mins. presentations; 3 min. questions)
- 17:10 —17:40 (40 mins) **Design Critique Session II**
- 17:40 —18:00 (20 mins) **Final Discussion & Closing**
- 19:00 **Workshop Dinner**

We will require a standard conference session room to fit 80 people, and audio/visual equipment. We would also require a table to exhibit a selection of example Data Physicalizations on.

The timeline for the workshop organization (CfP, paper deadlines, etc...) is as follows:

- April 4, 2018: **Call for Participation**
- July 4, 2018: **Paper Deadline**
- July 25, 2018: **Reviews Submitted**
- August 3, 2018: **Author Notification**
- August 17, 2018: **Camera Ready Deadline**

5 Organization & Participation

Trevor Hogan, Trevor.Hogan@cit.ie
(http://tactiledata.net/)
Trevor Hogan is a lecturer at the Cork Institute of Technology, Ireland, in the Human-data Interaction group. He received his PhD from the Bauhaus-Universitt Weimar, Germany. The aim of his research is to describe and better understand how embodiment influences and augments an audiences experience of data representation. His research has been presented and published at academic conferences and periodicals in fields such as HCI, Visualization, and Design. His work is strongly interdisciplinary and may be situated in the field of Design, but at the intersection of tangible computing, HCI, interactive design, information visualization, and psychology.

Uta Hinrichs, uh3@st-andrews.ac.uk
(http://utahinrichs.de/)
Uta Hinrichs is a Lecturer at the School of Computer Science at the University of St Andrews, Scotland, specializing in visualization and HCI. She received her PhD in Computer Science with specialization in Computational Media Design from the University of Calgary, Canada. Heavily drawing form fields outside of Computer Science (e.g., Design, Literary Studies, and Information Sciences), Utas research is driven by the question of how to facilitate insightful, pleasurable and critical interactions with information in physical and digital spaces, both as part of professional activities and everyday life. As a visualization researcher Uta has been involved in number of collaborations with artists, historians, and literary scholars which have fueled her interest in the role of visualization as part of humanities research and practice. Her research has been presented and published at academic venues spanning the fields of Visualization, HCI, Literary Studies, and Digital Humanities.

Jason Alexander, j.alexander@lancaster.ac.uk
(http://www.jasonalexander.kiwi)
Jason Alexander is a Senior Lecturer in the School of Computing and Communications at Lancaster University, UK. His primary research area is Human-Computer Interaction, with a particular interest in developing novel interactive systems to bridge the physical-digital divide. His recent work focuses on the development of shape-changing interfacessurfaces that can dynamically change their geometry based on digital content or user input. Jason's work on Data Physicalizations uses shape-changing interfaces to explore the use and understanding around dynamic physical data.

Samuel Huron, samuel.huron@cybunk.com
(http://www.cybunk.com/)
Samuel Huron is an associate professor in Design and ICT at Telecom Paris Tech. His research focuses on creating and studying new tools to democratize dynamic information visualization authoring and by studying design methods apply to research. For his work on "Constructive Visualization" he received the 2015 best doctoral dissertation award from IEEE VGTC Pioneer Group. Before, he was the lead designer of the Institute of Research and Innovation of the Pompidou Center. Samual co-organized previous workshop on data physicalization at ACM DIS 2017 and DRS 2016. He has written about pedagogy, visual representation construction, and using sketching for visualization.

Sheelagh Carpendale, sheelagh@ucalgary.ca
(http://innovis.cpsc.ucalgary.ca/)
Sheelagh Carpendale is a Professor in Computer Science at the University of Calgary where she holds a Canada Research Chair in Information Visualization and NSERC/AITF/SMART Technologies Industrial Research Chair in Interactive Technologies. She is a member of the ACM CHI Academy and has received many other awards including the E.W.R. NSERC STEACIE Fellowship; a BAFTA (British Academy of Film & Television Arts Interactive Awards); an ASTech Innovations in Technology award; and the CHCCS Achievement Award. She leads the Innovations in Visualization (InnoVis) research group and initiated the interdisciplinary graduate program, Computational Media Design. Her research focuses on information visualization, interaction design, and qualitative empirical work. By studying how people interact with information, images, technology and each other, she seeks to design and develop interactive technologies that support the everyday practices of people.

Eva Hornecker, eva@ehornecker.de
(http://ehornecker.de/)
Eva Hornecker is a Professor in Human-Computer Interaction at the Bauhaus-Universität Weimar, Germany. Her research investigates user experience and social interactions with tangible and embodied interaction, and novel application areas for these interaction styles, such as public displays and museum installations. Her work is interdisciplinary and connects technology, social sciences, arts, and design.

Program Committee Candidates

- Stephen Barrass, University of Canberra
- Pierre Dragicevic, Inria
- Fanny Chevalier, University of Torronto
- Nathalie Henry Riche, Microsoft
- Benjamin Bach, University of Edingburgh
- Bruno Dumas, University of Namur
- Jason Dykes, University of London
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- Alice Thudt, University of Calgary
- Andrew Vande Moere, KU Leuven
- Wesley Willett, University of Calgary

6 Conclusion

Data Physicalization is a fast emerging area of research, and while there have been many important developments over the last decade, one aspect that has receive little attention is the establishment of a specific design language that is critical to inform and guide the design of future Data Physicalizations. We envision this workshop as a first step in addressing this shortfall. By drawing together practitioners and researchers from the visualization community to discuss, critique and articulate different approaches toward a design language for Data Physicalization. We expect that the output to the workshop itself will represent an important contribution to the physicalization and wider visualization community, and so will be publicly archived on the workshop website `http://dataphys.org/workshops/vis18/`.

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