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Guest Editors' Introduction

DATA PHYSICALIZATION

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The practise of representing data in physical form has existed for thousands of years, yet it has only become an area of investigation and exploration for scientists, designers and artists much more recently [3]. Advances in areas such as digital fabrication, actuated tangible interfaces, and shape-changing displays have spurred an emerging area of research now called Data Physicalization [1]. This special issue of IEEE Computer Graphics and Applications presents five articles spanning a wide breadth of current Data Physicalization research, from theory to practise.

Today we are surrounded by data representations in our work, home and social lives, yet the way we experience these remains almost exclusively through our eyes. Imagine for a moment, instead of viewing or reading a graph (Data Visualization) we are presented with a representation of data that we can touch, feel, or hold (Data Physicalization). Now imagine how the experience and understanding of the data may change for you as you interrogate it through a different sensory modality. This is Data Physicalization. Or more specifically, Data Physicalization is a physical artifact whose geometry or material properties encode data [1]. Data Physicalization has gained in popularity over the last few years, and it has grown outwards to include a broad spectrum of fields, including Computer Scientists, Artists, Designers, Psychologists, and practitioners in Human-Computer Interaction and Information Visualisation. A demonstration of the breadth of the Data Physicalization field can be seen in the series of workshops that have been held over the last six years at conferences such as IEEE VIS, ACM CHI, ACM TEI, DRS and at Dagstuhl (for more information on these see Dataphys Wiki [2]). Such diversity has had a positive impact on the field, through rich collaborations and cross-domain exposure of concepts, approaches, and methodologies.

A fundamental question that is often posed about the value of Data Physicalization is why we should go through the often complex process of making data physical. While we would argue that there are many perceived benefits, arguably the main one is that physical data representations allow to study research questions difficult to approach with purely digital/virtual representations. The physicality of such representations supports direct interaction with data in tangible ways, which in turn opens up opportunities for potential cognitive benefits that are not accessible with a digital counterpart. This is not a new notion. For many years scientists used physical props to help explain difficult to grasp concepts. Take for example the many props used to explain thermodynamics, and those used to introduce and explain the double helix of the gene and the structure of haemoglobin. All of these concepts and discoveries were made easier to understand through the use of physical models. Other fields also use similar strategies, including the use of scale models in architecture and teaching aids such as an

abacus in math education (see also dataphys
gallery for more examples [3]).

The community has explored the perceived
benefits of Data Physicalization in the recent
past and through this the popularity of the
field has grown. We therefore believe it is
timely to draw together some of the most
current research on Data Physicalization in this
SI. In doing so we aim to bring further attention
to this field as it matures and, hopefully, it will
inspire new researchers to join the community
and attempt to answer the many open
questions and challenges.

IN THIS ISSUE
In this issue, you will find five research articles.
First, "What we talk about when we talk about
data physicality” critically reflects on the
notion of “data” in the context of data
physicalization. He introduces a conceptual
framework (design space) that can help to
characterize the different ways in which data
physicalizations relate to data ("epistemological" vs. "ontological" and
"representational" vs. "relational"). The
dimensions of this design space are discussed
illustrated with existing example
physicalizations.

Second, in “Thinking with Things: Landscapes,
Connections, Performances as modes of
Building Shared Understanding”, the authors
describe the use of physicalizations to support
the elicitation of how designers and academics
imagine and understand interdisciplinary
systems. The paper describes three workshop
modes, “deploying elements of landscape,
emphasizing connective tissue, and exploring
dynamic performance”, and focuses on the
qualitative aspects of the experiences from the
perspective of how people think through
material manipulation.

Next, “Data Badges: Making an Academic Profile
through a DIY wearable physicalization”
describes the design process and results of the
data physicalizations “data badges” – personal
wearable visualizations to facilitate networking
and social interactions during professional
events such as academic conferences. These
Data Badges were used as part of the Dagstuhl
seminar on Data Physicalization, which was
held in October 2018 [4].

Then, "Move&Find: The value of kinesthetic
experience in a casual data representation"
presents a study where participants pedaled
on a bicycle to exert the energy required to
power a search on Google’s servers. The
authors explore how the bodily experience of
that data, the power required, may affect how
the "viewer" experiences and reflects on the
data.

Finally, "Data Clothing and BigBarChart:
designing physical data reports on indoor
pollutants for individuals and communities"
brought data physicalizations into the field by
using physical data representations to
communicate data about in-door pollutants to
the participants in the Green Housing Study.
Their article reports on how the
physicalizations were received by diverse
audiences.

FUTURE DIRECTIONS
The last decades have brought many advances
in digital fabrication, actuated tangible
interfaces, and shape-changing displays, yet
many technical challenges remain to
implement and support data physicalizations
which can compete in meaningful ways with
the automation capabilities offered by digital
visualizations. However, instead of focusing on
current limitations, we believe it is important
to develop techniques that combine the best of
both worlds (physicalization and visualization).
The large space of combining bits and atoms to
represent data remains largely unexplored, and
designing and evaluating techniques for such
mixed representations will be paramount to
shape future interaction with data.

While there are powerful tools to create a
diverse range of visualizations there are
currently no similar tools available for physicalizations. Some examples exist to create rather specific types of physicalization both to for the creation of actuated physicalizations (Zooids [5], ShapeClips [6]) as well as free-form toolkits for manual assembly and manipulation (Constructive Vis [7]), but there are currently no comparable tools to what D3.js or Tableau offer the visualization world.

Beyond physicalization construction, it is often postulated that data physicalizations may increase the accessibility of data representations for people with visual impairments. What can we learn about designing data representations for this group? Or, should we go one step further and explore whether data physicalizations may be an approach to achieve universal, inclusive data representation regardless of viewer ability?

The vibrant activity in the physicalization community opens future directions, including concrete research questions to pursue, potential applications to explore, and technical challenges to solve.

REFERENCES


ABOUT THE AUTHORS

Trevor Hogan is a Lecturer in Design at the Munster Technical University (formally known as CIT), Ireland, where he also leads the Human-Data Interaction Group. He received his Ph.D degree from the Bauhaus-Universität Weimar in 2016. His current research is concerned describing and better understanding how embodiment influences and augments people’s experience of data representations. His work is strongly interdisciplinary and may be situated in the field of Interactive Design, at the intersection of Tangible Computing, Human-Computer Interaction, Data Physicalization and
Psychology. He is the corresponding author of this special issue. Contact him at trevor.hogan@cit.ie

**Uta Hinrichs** is a lecturer at the University of St Andrews in Scotland. Uta's research is driven by the question of how to utilize and teach visualization and interface design to facilitate insightful, pleasurable and critical interactions with information. She has applied data physicalization especially in interdisciplinary contexts to teach data-driven thinking to audiences ranging from children to adult professionals. Uta's research draws heavily from fields outside of computer science and has been presented at a range of academic venues spanning the fields of visualization, HCI, literary studies, design and digital humanities, as well as museums, libraries, and art galleries.

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**Samuel Huron** is an associate professor in Design of Information Technologies inside the Social and Economical Science Department of Telecom Paris school at the Institut Polytechnique de Paris, and part of the CNRS Institut Interdisciplinaire de innovation. His research is focused on democratizing data visualization to every one. This focus led him to explore different themes such as data physicalization authoring processes, design processes and methods of visualization, and data physicalization workshop. You can contact him at samuel.huron@telecom-paris.fr

**Jason Alexander** is a Professor in Human-Computer Interaction in the Department of Computer Science at the University of Bath. 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 interfaces—surfaces that can dynamically change their geometry based on digital content or user input. He has employed these in several examples of dynamic data physicalization. Alexander's other work has investigated novel interaction techniques using eye-gaze, haptic feedback, and gestural interaction. You can contact him at jma73@bath.ac.uk.

**Yvonne Jansen** is a permanent Research Scientist at the Centre National de Recherche Scientifique (CNRS) since 2016. She received her doctoral degree from Université Paris Sud in 2014. Her research interests include data physicalization, situated and embedded data visualization, and methods and techniques to facilitate the transparent reporting of research outcomes. Contact her at yvonne.jansen@sorbonne-universite.fr