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Published in:
Proceedings of Conference on Human Factors in Computing Systems (CHI23), 2023

Publication date:
2023

Document Version
Accepted author manuscript, peer reviewed version

Data Physicalization: From Theory to Practice

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ACM Reference Format:
Martin V. A. Lindrup and Aksel Biørn-Hansen. 2023. Data Physicalization: From Theory to Practice. In *Proceedings of Conference on Human Factors in Computing Systems (CHI23).* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

Fig. 1. Examples of data physicalisation for sustainability. To the left, a digital and a physical representation of flight data. To the right, a materialisation of CO2 into physical bits and a data physicalisation for sense-making about the impact of food production.

1 DATA PHYSICALISATION AND SUSTAINABILITY

As the workshop proposal details, data physicalisation is not a new area of concern. In Human-Computer Interaction (HCI), researchers have aimed to bring tangible form to data for decades with special interest groups on tangible computing, data art, physical data artefacts, shape changing displays etc. A landmark paper related to data physicalisation is Ishii and Ullmer [12], which introduced the idea of 'tangible bits'. Following this work, terms such as tangible user interfaces (e.g., [11, 19]) and tangible data representations was coined (e.g., inFORM [7], Tangible CityScape [18]). In recent years, due to e.g. the advances in microcomputers and digital fabrications, physical and tangible data representations have emerged as a distinct research area. In their 2015 paper, Jansen et al. [13] define tangible and physical data representation as Data Physicalisation (research area) and data physicalisation (artefact), and discusses a variety of general opportunities and challenges connected to Data Physicalisation.

One area that is heavily informed by data is sustainability and the many issues it concerns such as global temperature change, sea-level rise, air pollution in urban areas. These challenges are difficult to grasp without looking through data. Within Sustainable HCI, a key focus has been on displaying data using eco-feedback displays (e.g. on water consumption, energy consumption) in order to promote individual behaviour change [5]. This has been criticised for assuming that people are rational agents who are able to act if provided with the right information [3, 16, 17]. Data physicalisation can help address this critique by leveraging not only our cognitive understanding of a phenomenon but also the potential for supporting embodied learning, engagement, and democratisation of data in order to include non-experts [4, 9, 10]. In so doing, data physicalisation can turn the presentation of data into an interactive process and foster a more relational stance toward the climate impact of our actions. In our own work, we have explored how the strengths of Data Physicalisation can make data on environment and behaviour more meaningful and actionable to people. We have worked with this as part of two distinct projects.

In the first project, we designed and studied how a low-tech data physicalisation of the climate impact from academic flying could facilitate engagement, discussions and negotiations amongst colleagues about the value of flying as part of work and how to move toward a low-carbon academia. A low-tech approach was applied in this project in order to

engage people with the data in a democratic [10] and non-descriptive manner while resisting the urge to design new technology [1], shifting the focus to everyday means of materialising CO2 emissions from flying.

The second project focused on the climate impact of food production throughout its life-cycle. To unpack this complexity, we designed a materialisation of CO2 into Carbon Bits and a data physicalisation, Carbon Scales, that was used to support collective sense-making of the impact of food production. We worked with both sustainability *through* and *in* design in an effort to both investigate how a data physicalisation can 1) engage people in collective sense-making around food sustainability in order to support food carbon literacy [8], and 2) be designed without introducing unnecessarily consumption. In Figure 1, images of these physicalisations can be seen.

2 CHALLENGES AND OPPORTUNITIES FOR FURTHER EXPLORATIONS

Based on the two projected outlined above, we have identified a set of challenges and opportunities for data physicalisation related to low-tech, low carbon physicalisation, scale and materiality.

Low-tech, low carbon. In both of our projects, we have deliberately worked with low-tech and low carbon approaches to data physicalisation. The increased material consumption in construction can be one of the drawbacks with doing data physicalisation as opposed to digital data representations [13]. Blevis [2] stresses the need to move away from innovation and disposal and toward renewal and reuse in interaction design. In our projects, we sought to reuse, salvage, and upcycle materials to construct the data physicalisation. While this approach led to a number of challenges such as finding specific materials and being comfortable with crude aesthetics, it also invited us to think more creatively with the materials we had at hand. Our endeavour with low-tech, low carbon data physicalisation originated from the fact that we as researchers are troubled by the innovation and disposal paradigm. For this workshop, we want to question the need for increasingly technical and complex forms of data physicalisations and invite other into discussions about how we can move toward a renewal and reuse paradigm in data physicalisation.

Collective action. In order to scale up our work in relation to sustainability, we have in our projects focused specifically on supporting *collective* sense-making of data through engaging larger groups of people in different contexts with the data physicalisations. We argue that scaling up can foster peer learning [20] and support action from the middle-out [14]. For instance, we have engaged employees on different levels (i.e., individual, department, institutional) in an organisation with questions about the sustainability of academic flying. This collective level can be described as a middle-out space, i.e. *"instances of intersection between perspectives, flash points for debate and disagreement, literal meeting points where people gather, and opportunities for values and political beliefs to clash"* [6, p. 30]. Intervening with a data physicalisation in such a context can support collective meaning-making processes, negotiations between different actors, and trigger action, i.e. act as a gateway or mediator on different scales. However, there are many unresolved questions with this framing, including how to navigate power relations and ethical questions.

Physicalisation of immaterial materials. In both our projects, we have worked with an 'immaterial material' [15] i.e. Carbon emissions. Carbon emissions can be seen as a 'waste' product of energy conversion and are both intangible and ephemeral. There are a multitude of connotations to carbon emissions and, thus, materialisation involves careful considerations about what connotations to emphasise which is a balance between playfulness and disturbance. We cannot say if this challenge also appears beyond the domain of sustainability; however, we found that, in the domain of sustainability, combining design principles data physicalisation and materialisation fosters tangibly and concretely make sensing of otherwise immaterial material of our everyday. Although, a question is: how does this translate into domains other than sustainability?

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