Towards an Ecology of Interconnected Data Devices

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CCS CONCEPTS

• **Human-centered computing → Visualization**.

KEYWORDS

Human Data Interaction, Data Physicalization

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1 INTRODUCTION

Human-Data Interaction (HDI) [6] is concerned with empowering people with new tools, mechanisms and concepts that allows them to better control, understand and direct the vast amount of data that is being collected about themselves and their environment. This HDI vision encodes human interaction with data in the form of three core principles [6]: *legibility*, *agency*, and *negotiability*. However, implementing these principles within a context of non-expert end-users is a fundamental challenge [2, 10].

We argue that a key challenge in enabling empowerment and agency of end-users in data-driven system is to build accessible, understandable, and situated visualization and configuration tools. Physicalizations, which are *"physical artifacts whose geometry or material properties encode data"* [5], have been proposed as way to embody and visualize complex data to users. Through its physical, embedded and situated form factor, users are directly exposed to representations of complex data information systems. We propose that Physicalizations as 'data hubs' can be a central point to improve user's *legibility* with data [6], to allow for reconfiguration of data collection and presentation *agency*, and to enable end-users to define access and sharing models *negotiability*.

As HDI is concerned with large amounts of personal data, to create more personalized and tailored experiences for individuals, it is important to reflect on the challenges from the user perspective. To give an example, how do these core principles manifest and/or can be effectively operationalized in the data devices users interact with daily, and how can they make complex data more accessible, comprehensive, and tangible to them? The introduction of the Internet of Things (IoT) reshaped the *"nature of data collection from an active feature of human-computer interaction to a passive one in which devices seamlessly communicate personal data to one another across computer networks"* [6]. Hence, it is important to think of constructive ways to describe the *complete ecology of devices and networks*, that goes beyond the user and the data collection.

In this paper, we reflect on two exemplar qualitative user studies on the physicalization of data, and discuss their relation to the three core principles to illustrate how physicalizations can enable HDI. Subsequently, we reflect on the three core principles (from a user experience perspective), and propose to apply them from a more ecological perspective, considering the ecology of data devices that people interact with, rather than isolated cases.

2 CASE STUDIES

While there are many example works evaluating user interaction and engagement with data [1, 4, 7–9], we focus on two exemplar case studies – Econundrum [7] and Physikit [4] – and discuss how the core principles of HDI are reflected in these works.

2.1 Econundrum

Econundrum [7] is a data sculpture providing a simplified mapping of users' dietary choices to carbon emissions to encourage food habits that might produce lower environmental impact. Users can provide data input to the system via a phone application, in which they submit which out of 10 food types they consumed over four different meals, and three portion sizes. This data is visualized real-time in their personal data disk via colored LED lights and icons showing the food types consumed, and height change (from the ceiling) showing the overall level of impact of each user. The installation was situated in an university workspace, and the users consisted of a small co-located community of co-workers, although visiting spectators from elsewhere in the building could view the installation as well.

2.2 Physikit

The system of Physikit [4] consists of physical cubes (PhysiCubes) controlled by a digital touch interface, for members of a household to visualize environmental data – e.g. as air quality, temperature and humidity – in their home environment. The users can interact with the touch interface to reconfigure the behavior of the PhysiCubes – such as change in light, vibration, and movement – to visualize different data streams from an online database. They can then move around and appropriate the PhysiCubes in their home environment. Additionally, they can explore the raw database online and compare their data to other households.

3 CRITIQUES FROM A HCI PERSPECTIVE

Analyzing the two case studies in light of the three core principles of HDI we discuss how each of these principles are reflected in the design of the systems:

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3.1 Legibility

'Legibility' *"is concerned with making data and analytic algorithms both transparent and comprehensible to users.* Econundrum [7] provides a connection between the abstract and complex concept of carbon emissions caused by different food products by cross-referencing this dataset with personal dietary choices, creating a simplified dataset (10 food types) that can be created, observed and discussed by a small community. Whereas the visualization of Econundrum provided an initial insight, it's limitation – as expressed by questions and concerns of participants [7] – was that the system did not provide transparency on the calculations behind the visualization, preventing a further learning and deeper understanding about the topic. In contrast, Physikit [4] provided transparency on the collected data by allowing users to explore the raw dataset online, and compare their own data to others for reference.

3.2 Agency

'Agency' refers to the ability for the user to manage their data, and to *"engage with data collection, storage and use, and to understand and modify data and the inferences drawn from it"*[6]. The visualization of Econundrum [7] had a predetermined mapping, and users had no access to the data they created via the phone application, creating little room for agency. On the other hand, the touch interface of Physikit [4] allowed users to create their own mappings between data streams and visualization on the PhysiCubes.

3.3 Negotiability

'Negotiability' concerns *the means to navigate data's social aspects, to support interaction between data subjects and their policies"*. Negotiability might be 'non-applicable' as these research works involve clear consent procedures for data collection, both personal data collected through the devices, as well as other personal data collection through interviews. Additionally, in the example of Econundrum, users agreed to being indirectly identifiable via a geometric symbol on their personal data disk. However, reflecting on these systems in a real-world scenario, it could be further explored how these systems can support the ability for the users to negotiate their data experiences, i.e. how they can change and decide what is shared where and when.

4 TOWARDS AN ECOLOGY OF INTERCONNECTED DATA DEVICES

As demonstrated in the case studies above, the three core principles can manifest in different ways and in different elements of these exemplar systems, such as in the physical visualization, interaction devices, or online database. To reflect more constructively on the challenges of HDI from the user perspective, beyond the user and data collection, we propose to treat it as an ecology of interconnected data devices. With the aim to extend the three core principles, we take an ecological approach [3] and consider the different physical and/or digital elements through which users interact with their data, and how they relate to each other. Instead of looking at single devices (i.e. visualization, phone, sensor), HDI concepts can be expressed more completely through an ecology of interconnected data devices, allowing us to reflect on how these conceptual ideas manifest in the different physical and digital elements of an ecology of data devices.

The advantage of this perspective is a more constructive and pragmatic outlook on how users interact with data, as we can provide clear input–output methods, create an inventory of how the data flows between different interconnected devices, and explain the different relations between devices and/or users (e.g. introducing a new device to the home). The concepts of legibility, agency, and negotiability can come to expression in different devices, at a different time and/or location, and with multiple (different) users. To give an example, whereas legibility expresses itself in the (physical) visualization, agency is likely to happen in the configuration devices. Moreover, beyond the example systems of Econundrum [7] and Physikit [4], we envision future ecologies of a central 'data hub' with a multiplicity of different interconnected data devices and physicalizations, that can be used to control all data in and out a physical space.

Drawing parallels between the conceptual core principles, and actual physical setup and infrastructure within one ecology of interconnected data devices, will help us in designing these systems in the future, and to tackle open questions such as: *"How would data relations change within the HDI ecology with the introduction of a new device and/or user?"*; *"What is the role of physicalizations as a mediator in the HDI ecology?"*; and *"How to design physical data representations that visualize data flows?"*

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