CITY VIS 2019 WORKSHOP

CITY VIS
WORKSHOP

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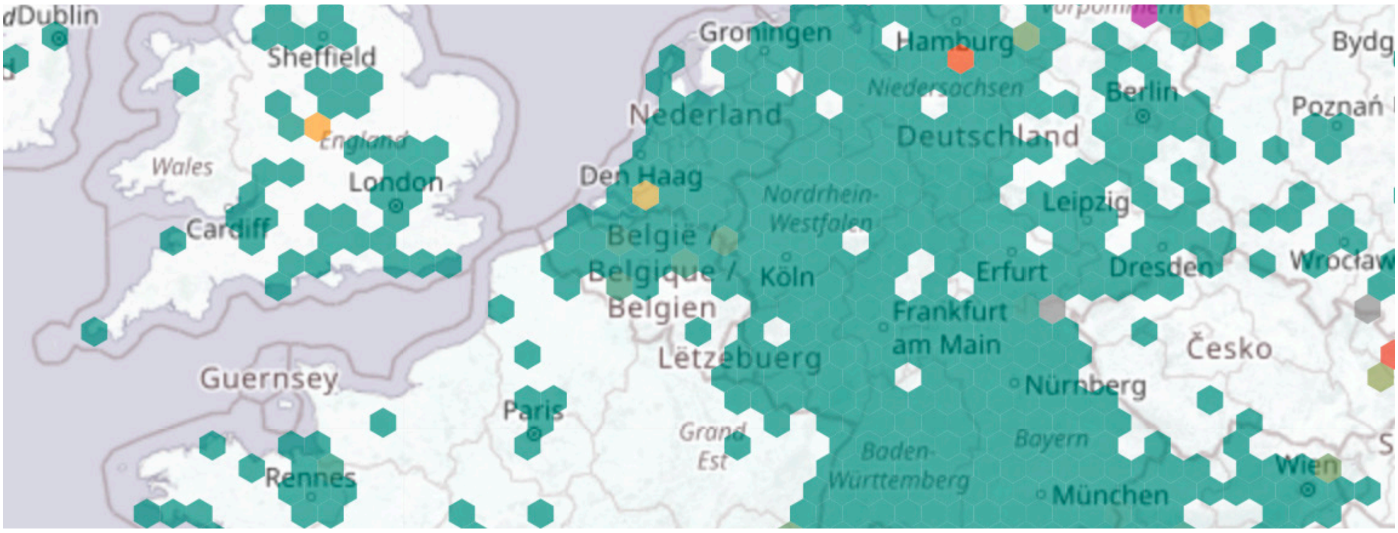

See Figure 3.

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WAYS OF SEEING URBAN DATA: CRITICAL VISUALIZATION AND THE LIMITS OF AIR QUALITY DATA

Keywords: Air quality data visualization, Visualization critique, Feminist visualization

1. RESEARCH PURPOSE

Urban air quality data visualizations are increasingly present in both scientific and public realms; for example, EU member states are obliged to report on air quality [9]; an increasing amount of grassroots-organized projects use low-tech sensors to collect air quality data and visualize them to monitor the readings [26]; and scientific research aims to understand, model and predict air quality [e.g. 14, 27].
Current challenges in air quality visualization concern design processes and usability [13], but also the overall framing, tasks and objectives of air quality data visualization. Addressing these challenges means considering the design of the interfaces available to citizens—created by citizens themselves, companies or governmental institutions and based on do-it-yourself (DIY) or official sensor data.

Air quality visualizations currently largely fail to take into account how sensor data may be contingent, incorrect, inconsistent, incomplete, political, complex, relative and situated. In other words, these limitations of the data—despite their importance—are not represented within visualizations. In fact, due to certain design choices, they may even be disguised.
This work seeks to rethink the visual language that is used to display air quality data, based on an account of the data assemblage and data settings they implicitly represent. This paper proposes starting points for re-questioning visualizations and design processes that, I argue, need to be considered when furthering our engagements with critical air quality data visualization.
Reconsidering how exactly air quality data are visualized and communicated leads to questions regarding how different visualization techniques may facilitate empowering interactions between data, citizens and the matter of air quality itself.

2. BACKGROUND

This project draws on work that engages with critical perspectives on the entanglements of data practices [e.g. 3, 5, 19, 21, 32] and work that seeks to challenge visualization practices through critical lenses [e.g. 4, 6, 7, 8, 22, 23, 31]. Situating the work amongst research areas in and around social sciences and digital humanities offers some fresh perspectives on how data—e.g. air quality data—are visualized and on the conventions that have emerged. I will specify the critical perspectives on data and data visualization that are particularly thought-provoking when applied to air quality sensor data.

D'Ignazio & Klein [4] argue that the actual bodies involved in data practices are currently obscured in data visualization. Indeed, they suggest bringing back these bodies. Two of their observations are particularly intriguing here: 'Bodies are rendered invisible' and 'Bodies go uncounted' [31]. These points raise questions regarding the perspective from which air quality data are visualized and extend to whose standpoints are (not) represented in the data set itself as well as how this representation is accounted for in the corresponding visualizations. Relatedly, Drucker pushes us to consider enunciative theory, which 'marks visualizations as situated, partial, historical, authored, observer-dependent, and rhetorical' [8].

Loukissas [21] argues that 'all data are local' and emphasizes the necessity to connect to the local conditions and contexts of data production— focusing on the data setting rather than the data set—in order to critically understand, use and make sense of data [21, 22, 23]. Air quality data, however, are usually monitored, utilized and visualized from a distance, taking into account only the quantitative data based on the sensors' readings and their geographical context, perhaps including other variables, like traffic, for analytical purposes. This approach is partly enabled by open data standards, which allow for data sets to travel far beyond the data setting, without much context or extensive meta-data, and being accessible and downloadable from anywhere.

Without considering this local and social situatedness of air quality data, we neglect opportunities that may help to make sense of the readings in a meaningful way.

3. APPROACH

While investigating the sociotechnical data assemblage [18, 19] and the local data setting [21] of air quality sensor data, one can start to understand the construction and limitations of air quality data. Applying this approach to a grassroots-driven DIY sensing project, using ethnographic methods, the following implications emerge: the sensors' workings/errors and how to make sense of the data are contingent and relative; diverse objectives and politics motivate sensing practices; sensors and the respective data deeply entangle into everyday lives and homes; the extent of social and local representation vary within the community, the data and the visualization.

The challenge however is to translate these insights into visual language—to move forward from visualization criticism, and rather philosophical ideas, towards a broader, more expressive visual language. This challenge requires reconsideration of air quality visualization techniques in order to facilitate representation of the limits and implications of data sets, bringing back bodies and local data settings.

If we are to make visible the specific issues of air quality data, a range of methodological approaches can be applied such as alternative design approaches and collaborative methods involving citizens. The conceptual and practical framework for this is currently being developed and based on social and humanistic research.

Some starting points and preliminary results follow below, focusing on what, I argue, is currently missing in air quality visualization and which implications might need to be considered.

4. ORIGINALITY

The increasing visibility of urban data visualization in many different contexts offers a testbed for a productive interplay between visualization criticism and design to rethink how exactly we visualize data—data that may be of public relevance.

Recent examples in the area of air quality visualization, coming from both academia and society, mostly focus on two approaches: a) web-based interfaces showing (average) readings with maps and graphs [e.g. 1, 10, 20, 24, 25, 28, 29, 33] or b) physical and situated ways to represent air quality data [e.g. 2, 30, 35], often located between science, art and visualization. This project considers web-based data visualization interfaces and how they can allow for a locally and socially situated experience of air quality data.

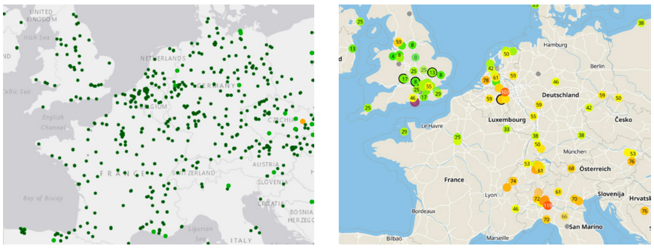

Figure 1: Maps of European Environment Agency (left) and PurpleAir (right) [10, 28].

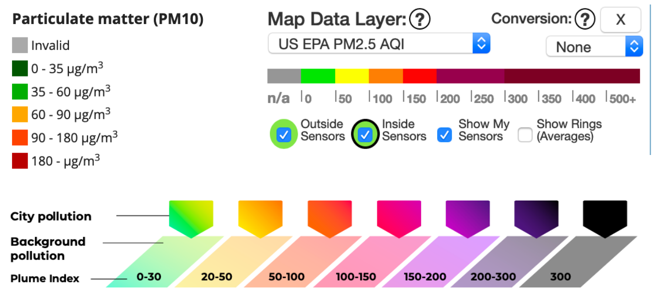

Figure 2: Scales of European Environment Agency (top left), PurpleAir (top right) and Plumelabs (bottom) [10, 28, 33].

5. PRELIMINARY RESULTS

Most air quality maps consist of base maps superimposed with color-coded visual symbols representing the sensor readings (Fig. 1). These usually represent average values of the readings covering a time span of, for example, five minutes before calling the website. The symbols are usually color-coded according to a scale from the minimum to maximum values of the possible sensor readings (Fig. 2). Some local features, like common infrastructure, land use types and names of bigger roads and districts, become more explorable by zooming in. Besides their geographical location, there is usually no additional information on the sensors or their local and social contexts.

Representing the data through homogeneous maps obscures the situatedness and contingency inherent to this data, and further suggests that the sensors generate accurate and consistent readings. However, sensor data often have gaps as there are errors or because there are no sensors available at certain locations. Many maps—through their design and analytical techniques, like interpolation—somewhat imply that there is a whole to see, an 'everything to know' ([12], cited in [23]), when there is not (Fig. 3). Although the data themselves are homogeneous (as they are digital, structured data) the social and local contexts in which these data come into existence are heterogeneous.

Moreover, readings of air quality are usually represented through a bird's eye view to be globally compared. As the data are considered to be of relative rather than absolute

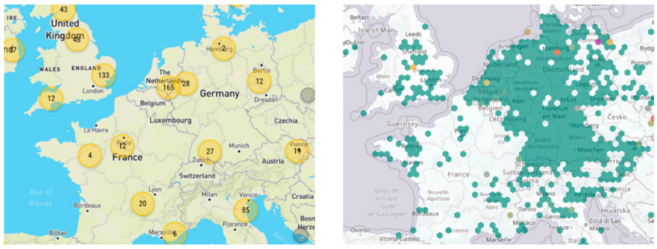

Figure 3: Visual symbols covering a bigger area than the sensors actually represent. Smartcitizen (left) and Luftdaten (right) [24, 29].

meaning, comparing them globally seems helpful. Overall, however, it is hard to interpret the data solely from this top-down view and without considering any local knowledge. The participants of sensor projects, the sensors and the deriving data represent a myriad of diverse social and local conditions, which makes it questionable as to whether the data are comparable on a global scale.

These aspects show how the limitations of air quality sensor data are currently neglected in visualizations. Visualizing air quality data through common maps and graphs omits much of the design space and, with that, the opportunities that may enable empowering interaction with the visualized data.

6. NEXT STEPS

The aim of my research project is to extend the visual language for air quality data visualization. That means exploring techniques that enable representing a range of contextual information, revisiting the choice of graphical primitives and exploring the design space. A key challenge is to enable communications on the data setting, while not leaving out the data set itself. Some of the specific design issues that will be explored are the following:

- What are useful ways, other than annotations to include contextual information?
- Which visualization types, other than maps, may be useful?
- How can we visualize (temporary) data gaps, sensor errors and uncertainties?
- How can we visually communicate whose perspectives are (not) shown and which air quality data we do (not) have?
- How can we visualize friction, heterogeneities, situatedness and partiality?
- How can high-level visual overviews be balanced or enhanced with detailed contextual information, while not hiding information at first?

To date, the design of air quality data visualizations does not typically consider issues such as these. However, previous work on uncertainty visualization [11, 15, 16], the design of nothing [17, 34] and approaches to visualization from digital humanities [8] points towards approaches that may allow a data visualization to include interpretative and qualitative dimensions.

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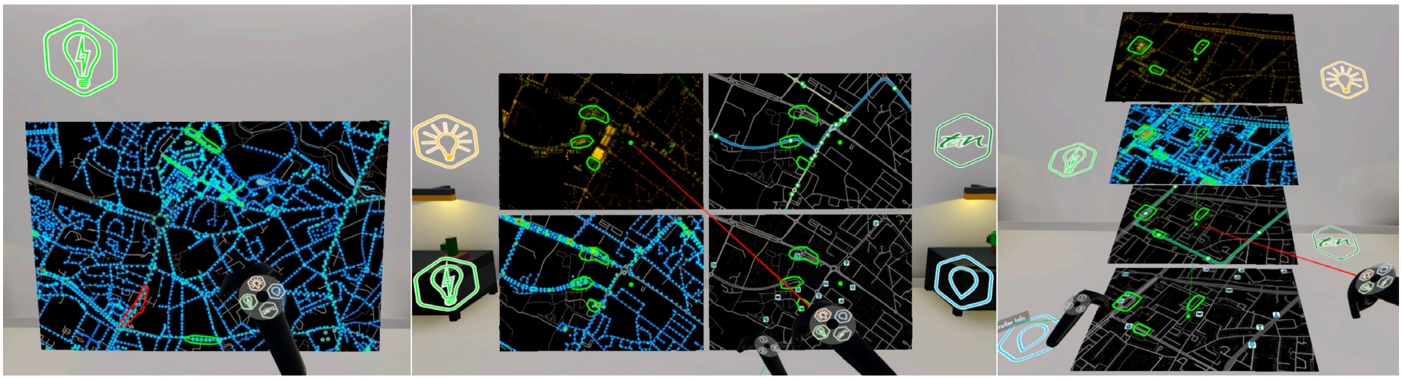

Figure 1: Three map juxtaposition systems experimentally compared: Blitting (switching), a grid, and a stack of layers.

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LENSSTACKVR: EXPLORING MULTILAYERED URBAN DATA IN VIRTUAL REALITY

Keywords: Urban Data Visualization, Virtual Reality, Multiple and Coordinated Views, Focus + Context, Immersive Analytics

1. RESEARCH PURPOSE

We first investigated different methods of visualizing multiple heterogeneous layers of geospatial data to aid decision-making in urban planning. For a simulated citizen participation task, we developed three prototypes that utilize the advantages virtual reality (VR) provides to different degrees (Fig. 1). Based on favorable findings from a formal experiment and expert feedback, we now extend the capabilities of one of those systems to suit explorative tasks.

2. BACKGROUND

Faced with the multitude of heterogeneous geospatial data available for cities, it is often necessary to take more layers of information into account than can easily be merged into one map during analysis or exploration. Literature exists on evaluating methods of presenting two layers [3], and proposals for vertically stacking layers of geospatial data [1]. We extend that research into multiple layers, focus on the urban environment in particular, and take advantage of VR systems.

3. APPROACH, DESIGN, METHODOLOGY

Working with researchers in urbanism and considering the work of Gleicher [2] on visual comparisons, we developed a task that asked participants to select areas in a city that are in need of improvement in terms of public lighting. This was chosen as an example that requires understanding and balancing the information presented in multiple spatial layers, in this case: light pollution, energy consumption of street lights, transportation networks, and points of interest. Because of the overlapping nature of these data, juxtaposition and simple switching (blitting) of these layers were chosen as practical approaches, and we implemented three prototypes to compare (c.f. Fig. 1).

Test participants (naïve, N=26) rated the stack system highly in terms of ease of use and visual design, and measurements (system interactions and oculometry) showed faster task completion times as well as a larger number of comparisons (changes of gaze from one data layer to another) than with the other two systems (a grid or blitting). The closeness of the layers and the vertical arrangement which presents a high coherence between layers apparent-

ly invited users to linger less and make larger and quicker saccades to compare the layers.
While we kept the functionalities of the three systems on equal footing for a fair comparison, with the confirmation of the stack's validity we could then extends its capabilities beyond what would be feasible with the other systems.
The common interactions were *panning* and *zooming* of the map via 3D controller gestures, and placing markers that were linked with lines across the layers.
With exploration in mind, we propose to add a *base layer*, with 3D buildings on the ground below the stack to create a *Focus + Context* view (Fig. 2).

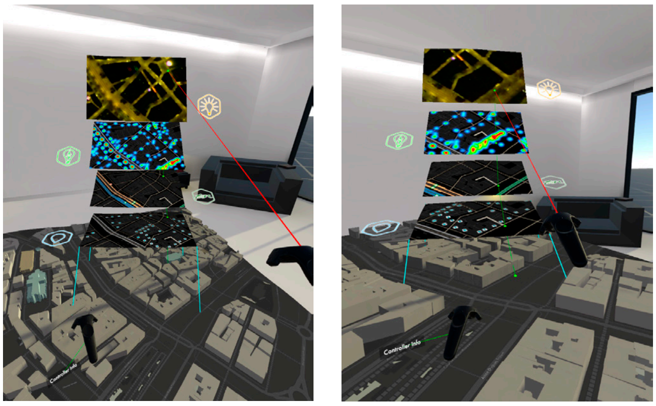

Figure 2: A standing and sitting view of the multilayer lens stack over a city.

The user is not restricted to a seated position anymore, and instead free to move around a room with a large area of the city on the floor. As before, the map can be panned and zoomed, but the stack, which now acts as a multilayered *lens* can be positioned as needed, and its orientation follows the viewer (billboarding). We also enabled users to rearrange the layout of the "lens stack" to fit their needs: enlarge or shrink the windows, change the vertical distances between them, change their order, and adjust their tilt. It is also possible to elevate the base layer to desk height, or scale it up so far as to be immersed in the urban geometry. The lens' scale can be increased to zoom into an area while keeping the base map on a small scale. Finally, we can stereographically project one selected data layer or the base map on a sphere or other non-planar surface surrounding the viewer, further aiding the focus + context paradigm by extending the extent of the map that can be seen.

4. ORIGINALITY

The originality stems from our research into visualizing more than two data layers of the same geospatial region at a time. While a low number of layers is still quite navigable with blitting or a regular grid, the stack is poised to most easily accomodate a larger number of layers that would quickly render a switching system too cumbersome to navigate, and a grid too small to read. We also utilize the intuitiveness of 3D control for map navigation and the immersiveness of VR.

5. PRACTICAL IMPLICATIONS

Using Mapbox as a platform for managing urban data and its API for integration with Unity 3D, our system can quickly be adapted to any location and data. Using eye tracking and other measurements stemming from a VR implementation, we can continue to refine visualization parameters and explain and adapt to user behavior.

6. IMPACT

We extended research into comparative visualization of multiple geospatial data layers. The task design for the experiment set up to evaluate the proposed system was also directly useful for research in urbanism. Directly incorporating feedback from participants and urbanists into the layer stack system, we hope to create a useful tool for immersively exploring multilayered urban environments.

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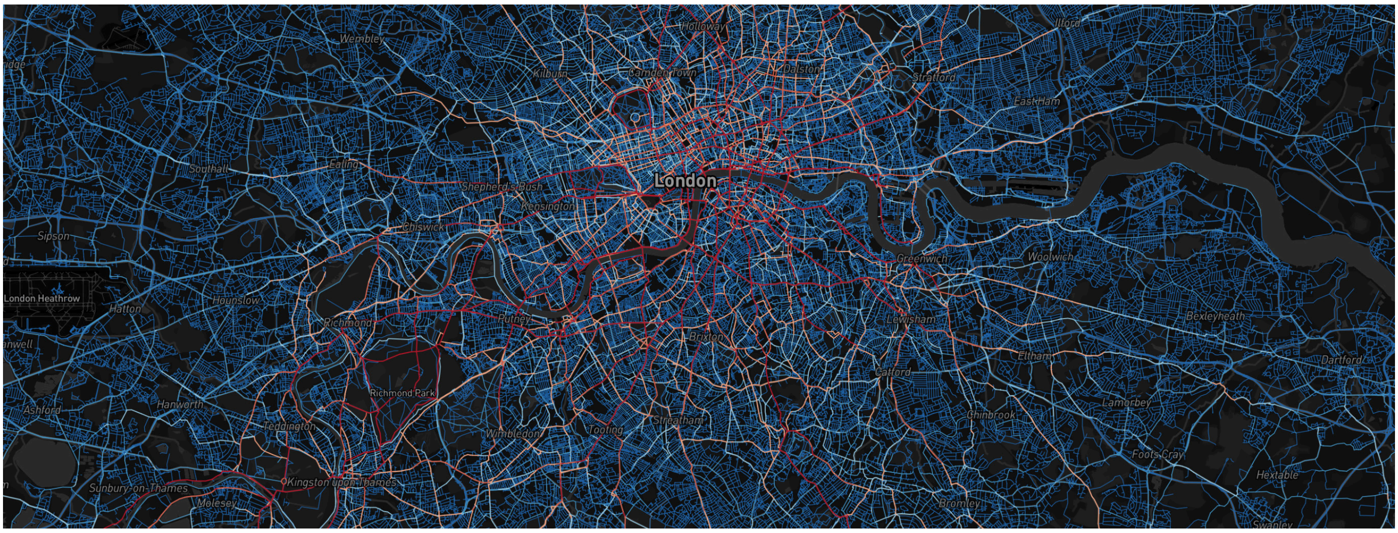

Figure 1: Interactive network flow map depicting patterns in over two million self-tracked bicycle trips across 747,534 street segments in London over a six-month period. Primary bike corridors are highlighted in shades of red. Less traversed streets are denoted in shades of blue.

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CARTOGRAPHY OF THE QUANTIFIED-SELF: MAKING SENSE OF LARGE-SCALE BICYCLING BEHAVIOR PATTERNS IN URBAN PLANNING CONTEXTS

Keywords: movement; bicycling behavior; quantified self (QS); cartographic interface; network flow map; urban planning

1. RESEARCH PURPOSE AND BACKGROUND

The rise in the affordability and use of geo-enabled smartphones and other wearables (e.g., pedometers, smartwatches, wristbands, etc.) has resulted in unprecedented amounts of personal movement data [13]. The large amounts of quantified-self (QS) data being generated in urban environments afford opportunities that extend beyond delivering 'self-knowledge through numbers' to the individual who engages in personal tracking activities. When aggregated and anonymized, this data can be used to, for example, inform city safety [16], routing choices [1], and exposure to air pollution [12]. The civic impact of such data, however, is constrained by the technical skills and resources available to city planners, transportation agencies, and local advocacy groups.

The purpose of this research is to address the question of how to design a cartographic interface to serve as a mediated platform for making large amounts of personal movement data more accessible, usable, and actionable to those tasked with assessing large-scale bicycling behavior patterns in urban centers. The interface discussed in this abstract is specifically focused on utilizing personal movement data contributed voluntarily by a large number of users of Strava, an activity tracking platform and social fitness network. Note that technology development described in this work was carried out while I was employed by Strava Metro, leading interface development. Metro is a small division of Strava that partners with and licenses aggregated and anonymized activity data to a variety of organizations that are taking data-driven approaches to city planning.

2. APPROACH

A two-and-a-half year cartographic design approach was taken to arrive at an effective visualization tool for an urban planning audience. The principles of cartographic representation, as well as interaction science frameworks relevant to data visualization and cartography (e.g., the Information Seeking Mantra [10] and taxonomy of cartographic interaction primitives [9]) provided a conceptual and theoretical foundation for the work. Interface development followed a client-centered design model adapted from Robinson et al. [7] to defining and refining interaction flows based on various stages of system development. Scenario-based design techniques [8], specifically a hypothetical use case scenario and complementing claims analysis, were then employed to evaluate design rationale, provide task-based user documentation, and identify focused opportunities for future user testing.

The resulting interface consists primarily of an interactive flow map that depicts counts of bike trips, commute-designated trips, and bicyclists aggregated to a linear street network (see figure 1). In addition, the interface provides an option to view a non-aggregated, rasterized heatmap of the GPS points that represent the activity traces used in the creation of the other views. An innovative technical framework consisting of map matching [14], spatial data aggregation, vector tiling, and network flow mapping was implemented to render and enable interaction with large geospatial datasets in the browser. The design approach and technical framework resulted in an interface that supports city planning professionals and stakeholders, who possess limited or no expertise in geographic information systems, in easily distinguishing commute from recreation bicycle corridors; identifying candidate areas for fixing or creating new bicycle facilities; and, quantifying ridership before and after infrastructure change.

3. IMPACT AND OPPORTUNITIES

The cartographic interface has been delivered to transportation agencies, local advocacy groups, and researchers across the globe and is being used to make more informed decisions on city planning. For example, Transport for London leverages the dashboard and the underlying data that support it to model network demand and assess the potential for growth in bicycle transport throughout the Capital. In Queensland, the Department of Transport and Main Roads uses the interface to quantify the impact of cycling infrastructure investment. Texas Public Radio published a piece on how the Texas Department of Transportation and local planning organizations were using the interface to better understand how cyclists were moving across the State's network to prioritize where to construct new facilities and bicycle infrastructure [3]. The piece highlighted the significance of the interface for allowing stakeholders to quickly identify patterns in behavior and distill actionable insight.

This work reflects a unique opportunity; in that a novel and impactful cartographic interface was conceptualized and created in an industry setting, while also being grounded in academic rigor. There exist opportunities to extend the framework to support multiple data sources and incorporate dynamic, agent-based modelling visualizations that relay a more complete and representative depiction of how individuals and entities move and interact across a network. Crowdsourced fitness data only represent a subset of the active population and should serve to complement and extend more traditional approaches to active transportation surveillance and analysis [2, 4]. User-generated fitness data, for example, can be correlated with survey and counter data to more effectively model the flow of cyclists across a network [15]. Additionally, supplemental data on crash incidents, roadway characteristics, and environmental factors can be integrated with crowdsourced activity data to help prioritize safety initiatives and inform why some routes are more popular than others [5, 6, 12]. Ubiquitous computing and the onset of Internet of Things (IoT) technologies further create potential for integrating personal movement data into smart city initiatives and urban interaction design. This can result in a more humanized, bottom-up approach to city planning [11].

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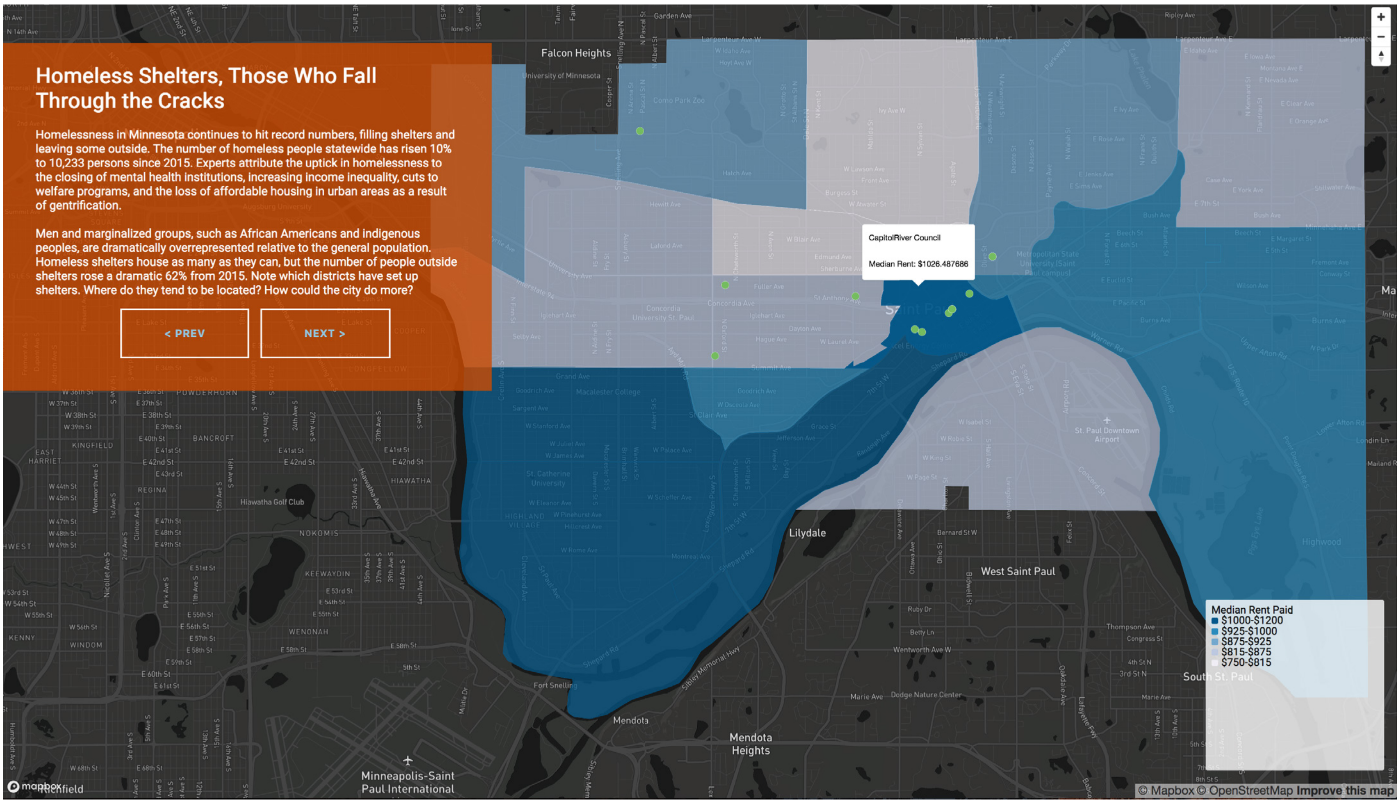

Figure 1: One of three views of the visualization is an interactive map that displays distracts and key structures of homelessness in Saint Paul, Minnesota alongside a narrative providing contextual information.

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VISUALIZING HOMELESSNESS IN SAINT PAUL, MINNESOTA

Keywords: movement; bicycling behavior; quantified self (QS); cartographic interface; network flow map; urban planning

1. INTRODUCTION

In this paper we present a visualization of home- lss- ness and housing data for Saint Paul, MN using mixed methods. This work is the culmination of a term project for the graduate level CSci-5609 Visualization course at the University of Minnesota. To explore data visualization in a real-world context with meaning- ful datasets and visibility, the instructor and students partnered in Spring 2019 with the City of Saint Paul's Office of Technology & Communications and the Bell Museum of Natural History. The structure included onboarding meetings, checkpoints with feedback from stakeholders, and a final public show- case at the Bell Museum held at the end of the semester. A demo can be found at [4].

2. RESEARCH PURPOSE

We sought to create a data-driven visualiza- tion to present a narrative for the general urban resident that fuses personal experience with data to examine urban processes, scenar- ios, and issues concerning homeless- ness. Blending expository and exploratory elements with interactivity, our goal was for residents to learn about the state of their city and connect with the often hidden experiences of those who have fallen through the cracks.

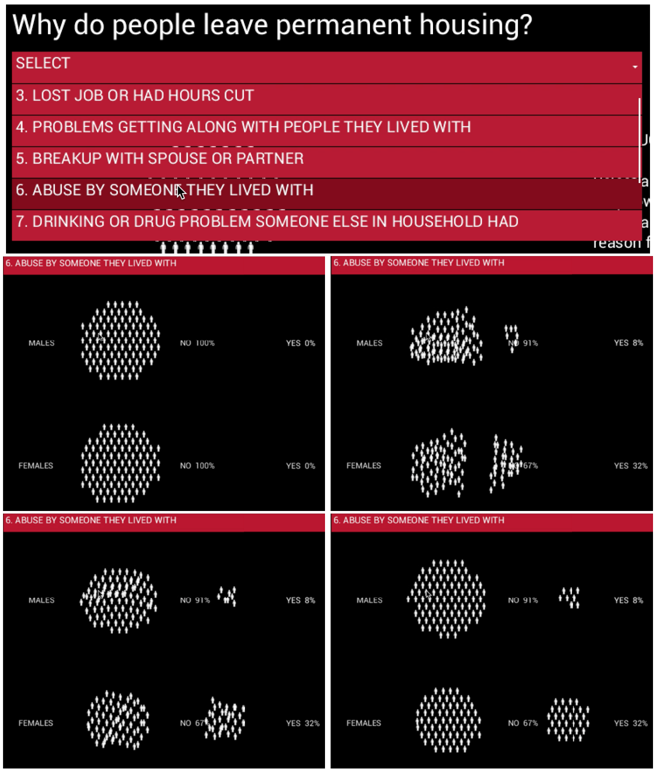

Figure 2: The user selects one response (top), and figures move from "no" to "yes" area to show the proportion of affirmative responses. Smooth motion produced by velocity easing. This example shows 8% of males and 32% of females selected "abuse by someone you lived with" as a reason for their current experience with homelessness.

In addition, we aimed to help residents become more engaged and informed when making their voices heard in local politics. We also hoped to learn how best to leverage collaboration with city officials and museum curators and administrators to enable the interdisciplinary co-creation of the visualization as well as provide guidance in facilitating public-facing interactive data representations.

3. BACKGROUND

Research on homelessness often lies embedded in data tables and lengthy reports, away from the eye of general resident. When found, this research can be difficult to connect with due to lack of interactivity and overbearing academic language. In St. Paul specifically, research on homelessness is compiled into a handful of reports [1, 9]-reports displayed separately from human-centered data, such as interviews and stories. Although data visualization has previously been used to depict homelessness data [3, 5], this work does not combine human-centered data, quantitative data, and interactivity into a holistic presentation.

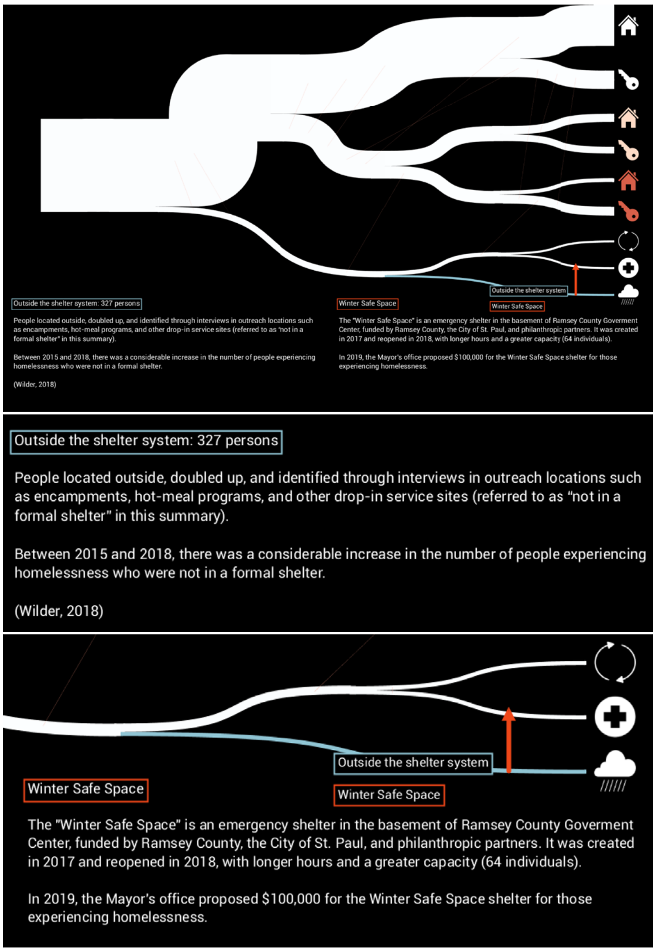

Figure 3: Ramsey County annotated population tree, with an example of user interaction (top). Mousing over the branches and arrows summons their labels, and clicking on each brings descriptive text into focus. Clicking a branch summons definitions about the population in the bottom-left, whereas clicking arrows fills the bottom-right with text about the intervention or trend. These texts are expanded in (middle) and (bottom), respectively.

4. DESIGN

In order to paint a more complete picture of this multifaceted issue, we organized the visualization as an integrated set of three data views, presented sequentially to users. We created three novel interactive views to examine homelessness and housing affordability as a paradigm to cultivate more informed city residents through a human-centered lens. We use interactivity in all the views to maintain the users attention and investment in tandem with narrative elements from human-centered data to create an empathetic connection, as displayed in the Figure 1 map. The three views are as follows,

- The user starts with a view of one result of the homelessness survey conducted by Wilder research [9]. In particular, we animate the responses to the question: "Why did you leave your last permanent residence?".

Figure 2 shows human-shaped icons moving in response to user interaction, as if directly answering the user's questions. Testimonials gathered from news articles and the Shelter Interview Project [7] accompany the proportions to illustrate the experiences lived by the people who answered in the affirmative. The predominantly dark color scheme evokes the night, when public places close and housing problems manifest. The user directs the flow of information while the animation and human-centered data immediately engage them.

- The user next moves to a view of an interactive storytelling map to illustrate housing affordability and homelessness data spatially across neighborhoods using data from the American Community Survey [6], and public housing data from the St. Paul Public Housing Agency [8] (Figure 1). This was created using the Mapbox.js framework. The user steps through a narrative providing contextual information on rising rents, stagnant wages, and what it means to be classified as cost-burdened. This narrative is mirrored by a map displaying the locations of homeless shelters and public housing, and classifying neighborhoods based on income, rent, percent cost-burdened households, and percent in poverty. The user is prompted to find patterns on their own at the end of each narrative section, and is allowed to change what is displayed on the map at various points.

- Finally, the user faces an annotated population diagram (Figure 3). Divergences in the tree shape split the population of Ramsey County into increasingly specific groups, while the width of each branch gives the proportion of the population. Impor- tant definitions and research results from organizations like the Minnesota Housing Partnership [2] are available through user interaction. By clicking on the "cost-burdened" branch, for example, the user learns that households spending more than 30% of income on housing must make trade-offs between housing, health care, and education. The tree is annotated by arrows representing trends or policies that affect the connected populations. Details, such as the budget for the Saint Paul 4(d) Rent Incentive program, dynamically appear when the user clicks on the arrows. Figure 3 illustrates this flow for the Winter Safe Space shelter servicing people outside the shelter system.

5. ORIGINALITY

Our visualization goes beyond what is available in existing reports on homelessness in the city of Saint Paul. Moreover, this work also shows what is possible in a new model of instruction where a graduate-level computer science course was co-sponsored by both the city of Saint Paul and the Bell Museum of Natural History. This project spanned an entire semester, and serves as a testament to the possibilities of a mutually beneficial relationship between city governance or museum curators and the academic environment. There were multiple collaboration sessions throughout the semester, during which city stakeholders provided feedback that shaped the development of the project, including the encouragement of story- telling in the map and the inclusion of city budget elements in the intervention elements of the population diagram. With the feedback received by the city's data portal team and Bell Museum adminis- trators, our work embodies a collaboration of graduate academics, stakeholders in the city's data presence, and experts in public-facing visual presentation.

6. PRACTICAL IMPLICATIONS

At the end of the semester, this work was presented at the Bell Museums "Saturday with a Scientist" pro- gram, where the public engaged with these visualizations. The language in our three views allowed engagement across a variety of age groups and educational backgrounds. The interactive map in particular allowed Saint Paul residents to view a narrative alongside neighborhood-specific information to see how many of their neigh- bors are cost-burdened on average and if homeless shelters or public housing structures are nearby, showing the success of the blend of expository and exploratory elements.

7. IMPACT

Visualizing homelessness and housing affordability in an interactive fashion via storytelling and integration of human- centered data enabled us to facilitate learning and exploration for the average urban resident. We also showcased the interdisciplinary collaboration between academic, municipal government, and muse- ological institutions. We believe future work concerning how to visualize policy proposals around housing affordability and how to engage children through visualization of homelessness could add to residents' interests in the topic. Additionally, further study could ex- plore housing for marginalized populations, including black people, indigenous people, and LGBTQ+ youth.

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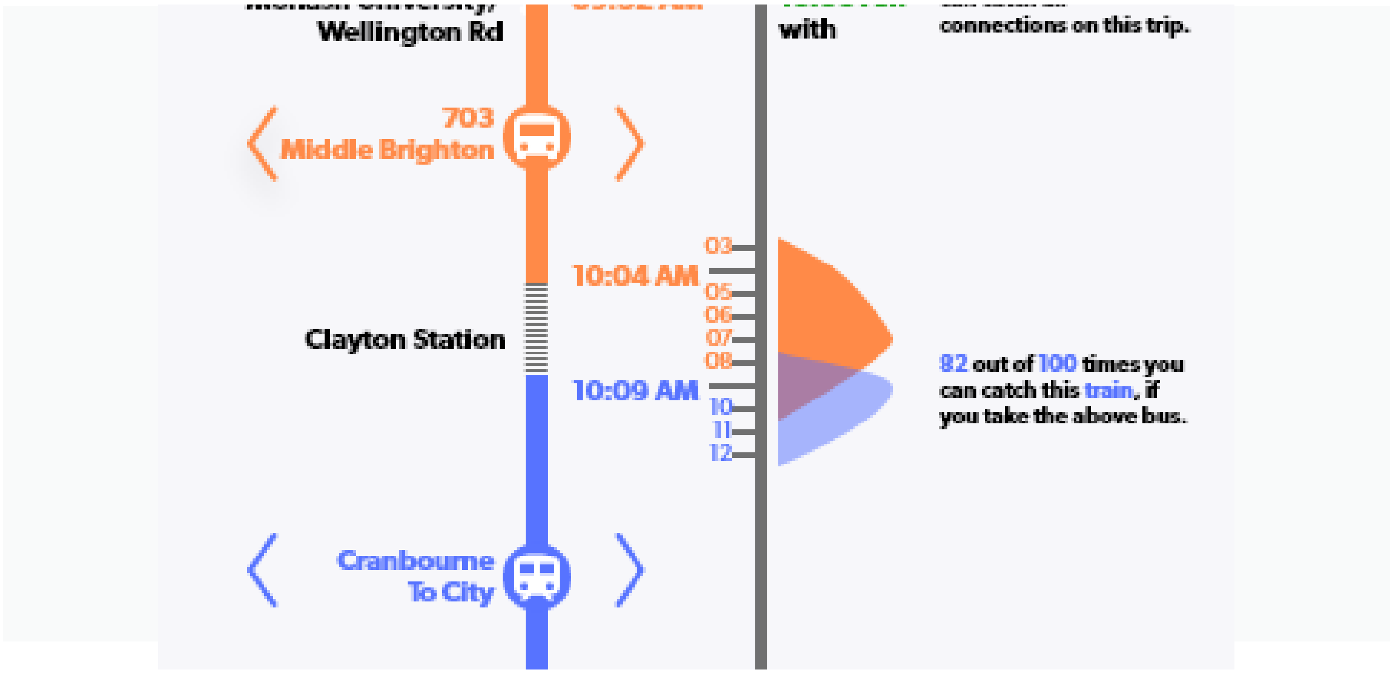

See figure 1.

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COMMUNICATING UNCERTAINTY IN PUBLIC TRANSPORT: MELBOURNE AND MUMBAI

Keywords: Uncertainty visualisation; Public transport; User centered design;

1. INTRODUCTION

Public transport is critical to the sustainability of any city. But often the arrival and departure schedules of public transport comes with uncertainty. We are exploring the possibility of communicating the associated uncertainty with any means of public transport to the commuters. This we believe may help commuters make an informed decision while using the public transport. For this purpose, we are designing a mobile app interface and plan to conduct user study in two thriving cities of the world: Melbourne and Mumbai. The choice of city is guided by the author's familiarity with the two cities. In Melbourne, the public transport of victoria (PTV) has the real time data of bus, train and tram available with them, where as in Mumbai the public transport does not have real time information available. After conducting the study at Melbourne, we plan to conduct a qualitative study at Mumbai. From the two studies, one qualitative at Melbourne and other qualitative study at Mumbai, we aim to gain insights as how to design solutions for communicating uncertainty information to non-experts.

The public transport in Melbourne consists of Train, Bus and Tram to move around 5 million [1] people living in Melbourne, where as Mumbai's public transport consists of Suburban Railway, Metro, Monorail and Ferry to support 23 million [2] people of Mumbai. The public transport system in both the cities vary in terms of infrastructure, expansion plans, use of technology, demography and the commuter's perception towards it.

2. DESIGN CHALLENGE AND PROTOTYPE

We are facing two key challenges

- **Communicating Uncertainty to non-experts:** The associated uncertainty is modelled as probability density function and it will be essential to see how non-experts (commuters) perceive the shown visualisations. We are exploring what extra information we need to provide with the shown visualisations to help commuters understand the visualisation.

- **Visualising on a mobile screen:** Small screen size of the mobile devices impose design restrictions to the visualisation.

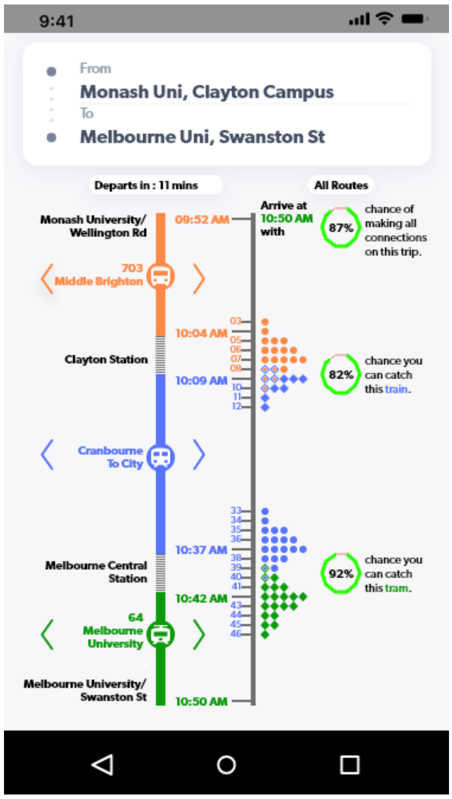

Figure 2: Using Quantile Dot plot and Probability in Percentage

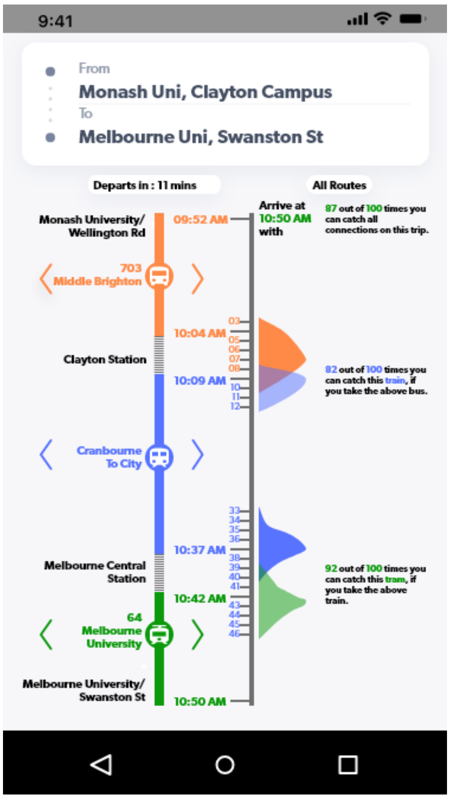

Figure 1: Using Density plot and Natural Frequency

In our prototype we have included two visualisation designs: density plots and quantile dot plots [3] and three ways of communicating probability: percentage, natural frequency and standardised word expression. We mined the arrival and departure times of bus, train and tram from the API of Public Transport of Victoria (PTV) for 30 days and generated the probability density functions and the likelihood probability.
People reported that often they make transfers among various public transports in order to reach their destination. Hence, the uncertainty information becomes significant. Our design communicates the overall uncertainty information and also the uncertainty associated with the individual options.

We conducted a pilot study of our high fidelity prototype to gather feedback on the design. But the pilot was restrictive in the sense that the participants reported to have familiarity with statistics and visualisation. We conducted a follow up study with 49 participants by simulating the real time public transport catching scenario, who are every day commuters of public transport. With each participant the user study session lasted on an average 1 hour. We also plan to conduct a longitudinal study over a period of 30 days using a android application.

2. DISCUSSION

For Melbourne, the time table information is available in GTFS format and the PTV (Public Transport of Victoria) has a dedicated mobile app. The prototype at this stage is designed for public transport in Melbourne. We are about to start large scale user testing at Melbourne. We will be starting the requirement gathering for Mumbai to understand the data available for various modes of public transport and how people currently use any mobile app for public transport.

3. CONCLUSION

It will be interesting to see how non-experts use this uncertainty information for making transit decisions. We hope to gain insights on the design process to be adopted while developing solutions for communicating uncertainty to non-experts. It will also be interesting to see the impact of demography on the design of the mobile app while we develop it for two very distinct cities: Melbourne (Australia) and Mumbai (India).

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PARTICIPATORY DEEP MAPS: TOWARDS DISCURSIVE USER ENGAGEMENT WITH DATA VISUALIZATIONS

Keywords: Multiview; Multiperspective; Multilayer; Urban data visualization; Immersive analytics

1. BACKGROUND

This paper introduces the concept of deep participatory maps, an approach to democratizing the way local knowledge is collected, shared, and discussed using interactive data visualizations. While geovisualizations provide a useful frame of reference for mapping spatial data and local knowledge, generally, they remain artifacts of a unidirectional creation and communication process: from the data source to the audience. This process is curated by the cartographer, visualization designers, or any other author. Typically, this results in a singular perspective onto the underlying data and the represented issues.

In this paper, we propose *participatory deep maps* as a promising approach to multilayered geovisualization to allow for polyvocal and participatory mapping. It provides mechanisms for annotation, discussion, data collection, storytelling and other activities of participation. Deep maps have traditionally been described as conceptual maps that “include the discursive and ideological dimensions of place, the dreams, hopes, and fears of residents” [17]. Here, we are interested in the participatory potential of such deep maps. Our observations are based on a literature review on tools for map annotations, revealing common patterns for participation and annotation. Also, we’re motivated by four cases from current collaborations in the fields of peacemaking, population demographics, and street ethnography that seek for participatory mapmaking. We finish with a set of challenges for studying and designing participatory deep maps. Our discussion has implications beyond geovisualization and potentially applies to data visualization more generally.

2. MOTIVATING CASES

In recent research projects, we have encountered the need for novel forms of geovisualizations that allow for participatory and polyvocal mapping. In the following, we briefly describe these cases as motivations for our work with participatory deep maps.

Mapping local opinions: In a previous project [10], we compared various ethnographic methods on a street-level to produce local knowledge. Go-along interviews as well as intercept surveys unearthed diverging spatial narratives: there was no consensus about the character of a street among its residents, but rather a complex and entangled meshwork of opinions, anecdotes and feelings. *One problem throughout the study was the visual representation of these georeferenced, yet largely unstructured and highly opinionated data. Through deep participatory maps, we imagine interfaces that allow citizens to directly annotate streets and regions to express a wide range of opinions and thoughts, either following an ad-hoc survey or as part of an openended and ongoing mapping process.*

Mapping peace and conflict: In a recent workshop on the use of digital tools and data visualization to support inclusive peace processes in conflict regions [7], we identified the need for mapping location, time, and extent of violence: armed conflict, explosions, remote attacks as well as related indicators such as blocked streets and electricity outages. In most cases, a complete view of such a situation is impossible due to incomplete data, dynamic changes, subjective opinions, and contrary interests. We believe, this requires integrating existing datasets from news sources, public sources and other databases. *Currently, integrating diverse data sources is a painstaking and highly technical process but we want to imagine lightweight interfaces for selective and manual integration and visualization. Specific visualization problems include uncertainty and possibly contradictory information in these sources.*

Mapping personal stories: In the same workshop, it was called for visibility of personal stories in conflicts. One participant stated that "the first part of transitional justice is being heard." Existing maps lack a feedback channel for people to situate themselves in a visualization and contribute their own experiences, stories and other types of local knowledge. *Thus, it is of high importance that participants can express their opinion, contribute data, enrich the maps with personal data and potentially create and share their own visualizations easily.*

Mapping social frontiers: Ongoing research on social frontiers— "places of sharp difference in social/ethnic characteristics between neighbouring communities" [4]— is based on available census data. There is high demand to examine, how social frontiers in the data relate to residents' knowledge about neighbourhood boundaries as well as data and insights generated by other researchers. *Backchanneling this knowledge to researchers can provide meaningful explanations on the emergence of social frontiers and help develop strategies to aggregate these data.* As an example, census data has limited granularity since it is aggregated within existing administrative boundaries. Cohesive social territories do not necessarily follow these boundaries. Finding ways to incorporate residents' subjective perception of neighbourhood boundaries (e.g., by letting them draw on a map) can provide a link between observations in data and explanatory context.

3. RELATED WORK

We now review tools and interfaces, currently able to partially support participation on maps in our motivating cases. These include methods for collaboration and communication in the context of information visualization and mapping. Our participatory maps are asynchronous and distant cases, in the words of the CSCW-matrix [9]. Respective visualization interfaces have been equipped with techniques to comment, graphically annotate, and discuss different states of the visualizations [8, 16]. While in these cases, annotations and discussions primarily aimed at the generation of hypotheses and collaborative sensemaking [19], people also provided contextual knowledge about the data at hand, such as insight on the data, detected patterns and different interpretation levels [15]. Participatory maps aim to take these annotations on step further by providing more customized mechanisms for annotation and expression.

Established map services like Google Maps or Open Street map (OSM) offer a small range of tools like markers with comments and individual icons to depict locations, paths, and zones, and share them with others. On OSM, users can suggest edits or disagree with the position or classification of geographic features, consequently triggering a process to correct supposedly wrong information. Other mapmaking and visualization platforms implement features to display geo-references annotations and callout lines.[1] [2] StorymapJS can create annotated links between locations that allow for the narration of place-based stories through time.[3]

Other tools allow for more public participation: With Hoodmap[4], users can classify quadrants of a city according to pre-defined categories. A Swiss newspaper[5] invited it's readers to guess the Swiss border on a map with only two major cities as orientation. The actual border and the collective drawings of all readers were then shown, revealing different levels of effort and knowledge.

Storytelling with maps is common in infographics and news outlets including techniques such as small multiples, highlighting, callout lines, specific symbols, or local insets as shown in atlases and potentially data comics [3]. In interactive visualizations, incorporating the audience as part of the story is an established way of fostering engagement [2]. However, participation here refers to pre-scripted exploration, rather than open-ended participation, question-asking and sharing of opinion.

PPGIS [12] has a standing history in the representation of decentralized spatial knowledge. It's emergence represents a milestone in challenging the one-sidedness of digital maps. Therefore, it demonstrates the impact that participatory features can have on spatial representation. Another, more political demonstration of this is the

[1] https://blog.datawrapper.de/locatormap-calloutlines/
[2] https://flourish.studio/examples/
[3] https://storymap.knightlab.com
[4] https://hoodmaps.com/edinburgh
[5] https://www.nzz.ch/storytelling/geografie-kenntnisse-wie-gut-koennen-sie-die-schweiz-aus-dem-gedaechtnis-zeichnen-ld.1306768

anti-eviction mapping project (AEMP) [14], a countermapping platform in the tradition of critical cartography. It depicts a powerful collection of maps, visualizations and most importantly oral history of places to document the process of gentrification in the San Francisco Bay area and the resistance against it. Juxtaposing these approaches reveals a major difference on how they deal with a multiplicity of narratives: PPGIS platforms seek to minimize “the structural knowledge distortion” [18] by consolidating the rich knowledge base of a community into mapable geographic entities. AEMP on the other hand scatters them across different maps without connecting them among each other.

What is missing is a single platform that allows for a co-existence of a multiplicity of spatial narratives in one map and interfaces to collect and share them.

4. CHALLENGES

Motivated by the existing cases and a first review of existing work, we identify six challenges for the design and implementation of participatory deep maps:

Personal stories: Map visualizations provide a base to tell stories, i.e. narratives that tell personal views or explain what is visualized and the data's context. *We could not find any interfaces that go beyond annotation, markers, and websites of map pictures but to provide more customized interactive and engaging versions for storytelling such as videos [1] or data comics [11].*

Integrating additional data: One simple and often practised way of data integration is linking to external resources. However, Drucker criticizes the incapacity of conventional interfaces to “alter data structures of a visualization through direct input” [6]. Building interfaces that allow an audience to augment the underlying data with own perspectives and provide for an immediate visualization of them is a yet unsolved task. This challenge involves the design of user interface elements as well as embedding these elements in an user experience that invites for contributions. Another question that is to be answered is the appropriate anchor and scope of augmentations: Does an audience discuss geographical points, data points, visual marks, or other existing authored contributions? How can an integration happen technically? How can it be achieved visually and without cluttering the map?

Fostering & visualizing discourse: Typically, there is no consensus about what, where, when, and why something happened: contributions from different authors can question, augment, comment, or disagree with the data or other authors' perspectives. Existing interface design patterns have limited ability to represent this multiplicity. Therefore, one central challenge is to draft design patterns for participation in discourse. These patterns should work towards “exposing multiple facets and enabling a variety of interpretations” [5] of the data and the discourse around it. Moreover, we need to find effective forms to visualize these data alongside the original map to highlight places and areas with agreement and disagreement, which types of contributions exist, how the contributions are related, which topics are discussed, which places are related in a single narrative or through all the narratives.

Moderation: Human or automated moderation can solve problems related to the potentially unstructured and open nature of data from participatory processes such as ambiguity, disagreement, incomplete data, or wrong data. Central moderation by a single authority can be a reliable way but can also introduce bias towards that authority's stance. Implementing bottom-up mechanism for content visibility, i.e. voting systems, averages, trust-networks) could address this issue, but would also promote a mainstream narrative over a silenced voice. To the best of our knowledge, no such structures have yet been explored and designed for data visualization.

Fostering engagement: In order to participate, the audience needs incentives. Personal visibility, advocating for once's opinion, fun, or monetary rewards can inform engagement strategies. However, engagement goes further by calling for ways to author, serialize and share local knowledge across different media and social groups.

Analyzing participation: The audience's information and interactions are a rich source of data about a given topic. Eventually, these data can—if collected according to existing data protection laws—give insights into disputed areas, ways in which information is discussed, collaboration strategies, the level of visualization literacy and trust with data visualizations, as well as a rich source of unstructured data about local and other forms of knowledge relevant to the visualization or the topic [13]. *We need to develop tools and methods that allow us to understand* *participation with map visualizations to understand how we can improve both the visualizations, visualization interfaces, and their explanation.*

5. CONCLUSION

We believe that addressing these challenges is non-trivial and instead requires better user and visualization interfaces as well as as codes of collaboration. The presented cases are an entry point and can serve as a fertile medium to rise up to these challenges and explore the inclusive potential of visualization.

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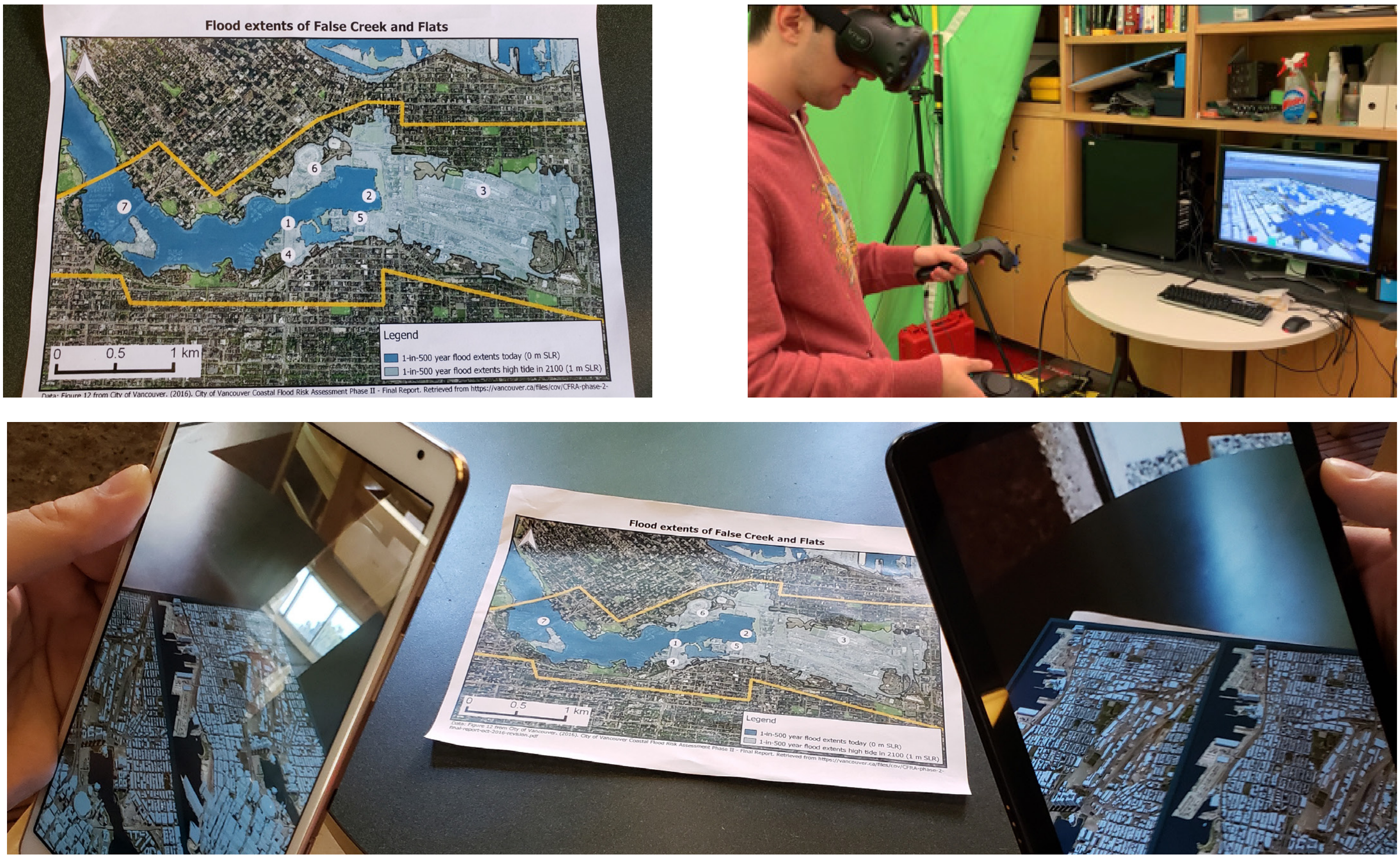

Figure 1: (Top lef) Example of conventional 2D map visualization medium typically used in FRM. (Top right) Example of a flood visualization prototype we built using immersive VR. (Bottom) Example of a collaborative mobile AR application we built, allowing interactive control and display of water levels during storms, comparing current and projected future water levels for scenarios of the same probability.

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EMERGING VISUALIZATION INTERFACES AND THEIR IMPLICATIONS FOR FLOOD RISK PERCEPTION AND MANAGEMENT

Keywords: Flood; Risk Communication; 3D visualization; game engines; mixed reality; virtual environments.

1. INTRODUCTION

Increasing global sea levels, growing risks of fluvial flooding and intense development across the world make understanding and managing risks an integral part of urban development. Most metropolitan areas across Canada are at-risk from coastal, fluvial or flash floods and the magnitude and frequency of events is projected to increase [1]. Amidst growing costs of providing disaster assistance, the responsibility for managing flooding is increasingly being shifted towards at-risk populations [2]. A recent survey illustrates that half of people living in designated floodplains in Canada express no concern at all related to flooding risk and majority also expect flooding to decrease in coming decades [3]. This worrying risk perception among exposed populations is combined with equally concerning deficits in knowledge availability about flooding risks, where most communities in country have outdated maps that are not suitable for public communication [4]. This context of a need to understand evolving inundation risk and significantly improve public understanding of risks provides opportunities to explore emerging visualizations.

2. PURPOSE OF RESEARCH

In response to a growing interest in implementing interactive 3D visualizations of flood hazards and risk, our work assesses the interplay of conventional versus emerging 3D data characterizations of flood processes in urban risk analysis and communication. We are investigating the potential of emerging 3D interface technologies to support perception, interpretation of flood risk scenarios. We are interested how mixtures of visualization design, and interface affordances support (or impede) creation of knowledge and situational awareness of flood risk scenarios using visual analytical tools. We consider how emerging visualization and interface platforms such as 3D game engines, virtual (VR) and mixed reality (MR) embody visual analytical capabilities different from conventional spatial information platforms. We explore their strengths and limitations, how they may deliver new ways to perceive, interpret, communicate and manage flood risks in urban context.

3. APPROACH

Our work has three components. First - a critical assessment of conventional spatial data and interface use, critical review of potentially disruptive technologies such as 3D game engines, virtual and mixed reality interface platforms applied to flood risk communication and analysis. Second – implementation of 3D engine, VR and mixed reality flood risk visualization prototypes designed based upon observation and engagement with active urban planners, using multiple types of spatial data (LiDAR; inundation models; GIS) across several spatial resolutions and temporal scales. Third – empirical evaluation of the impact of integration and use of these visualization platforms into the Flood Risk Management (FRM) process – focusing on their role in supporting, enhancing, or impeding risk communication and perception, co-construction of situational awareness, and risk management processes.
Through this work, we aim to investigate whether rigorous FRM practice (analysis/communication) is supported, impeded or enhanced by emerging 3D visualization methods. We aim to identify opportunities to add value to FRM practices, through guidance for design and commentary on usefulness and feasibility of integrating emerging interface technologies into routine FRM practice and factors that may impede their uptake.

4. PRELIMINARY FINDINGS

In our work so far, we have investigated the scope and extent of existing examples of visualization methods and interfaces applied to flood risk management (FRM) and governance (FRG). We have critically reviewed trends in visualization of flood hazards; trends and themes in increasing use of 3D geovisualization methods and 3D platforms for FRM and their implications for flood risk perception, communication and practice. We have also designed and built some preliminary flood visualization prototypes using immersive virtual reality (VR) and mobile tangible augmented reality (AR interfaces (see figure 1).

4.1 Visualizations

Traditionally, flooding risks have been communicated through flood maps, illustrating likely extent of flooding of a certain probability, critical infrastructure and residences at risk [4]. Recently, there has been a groundswell in the use of 3D platforms (such as game engines) as new platforms with which to visualize coastal and urban flood risks. This trend is sparked by decreasing complexity and cost (free software) of producing compelling data-driven 3D visualizations of hazards and the existing gaps in visual flood risk communication, where most maps currently available are not suitable for public communication [4].
The 3-dimensional representation of a potential flooding area could be useful for co-creation of risk understanding through the reduced abstraction of the depicted phenomena, which enables diverse set of stakeholders to provide meaningful input [5], [6]. Recent progress in the application of game-engines for visualization of flooding scenarios combined with LiDAR capture of urban landscape provide a promising topologically 3-dimensional alternative for analysis and communication of flood risks [7].
While game-engines possess some compelling visualization capabilities that often feature in media coverage, many have technical capabilities for data integration and processing that might provide significant analytical benefits for hazard awareness and risk management. they have not been explored particularly deeply. While game engines

may capture viewers' attention, it is also imperative that we are not seduced simply by attractive 3D graphics. We must interrogate their representational rigour, and the implications of employing 3D dynamic, interactive interfaces as mediums for critical flood risk management and planning. Since the growth of such attempts in research settings is relatively recent, there is no robust evidence of superiority of 2D or 3D representation of urban hazards for understanding of risks or improved situational awareness. Compelling risk visualizations must be supported with evidence-based visualization design and data science.

4.2 Emerging Interfaces

Researchers speculate that the benefits of complex 3D representations made possible by powerful forms of 3D data (LiDAR; SfM) and models cannot be realized via topologically 2D software, or via conventional flat-screen interface technologies [8]. Some researchers are beginning to use augmented and virtual reality interfaces for risk communication (tsunamis, mass evacuation), and to connect researchers, planners and public to the complexities of flooding risks in cities [9], [10]. Many mixed reality interfaces enable natural user interaction with 3D visualizations as well as provide semi-immersive user experiences that may connect users powerfully to digital representations of hazard scenarios. Such affordances combined with significant reduction in prices of VR and AR displays and interaction platforms make integration of these tools into daily planning practice viable, while also providing a number of promising research venues. New research methodologies are enabled by emerging interface platforms (e.g. HTC Vive Pro Eye; Microsoft Hololens 2). Their native integration of eye-tracking and ability to export that data could provide fruitful substrate to collect empirical data on the usability and usefulness of visualization tools.

5. FUTURE WORK

Our on-going work explores the role that collaborative virtual and mixed reality flood risk visualization systems can play in rigorous Flood Risk Management (FRM) and Governance (FRG). We are working to assemble evidence that informs us whether different combinations of data, 3D visualizations, and emerging interfaces support modify our ability to perceive, comprehend or respond to flood risks; or whether the affordances of these new platforms deliver different information experiences; or support alternate ways to co-create knowledge capital, that may transform our ability to characterize, perceive, and communicate flood risks.

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See Figure 1.

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DATA WALKING

Keywords: Walking, Data Gathering, Data Visualisation, Citizen Science, Open Source tools, Education.

1. RESEARCH PURPOSE

Data Walking is an ongoing research project exploring the potential of walking to gather environmental data and then through multiple walks and visualisations build a rich picture of that area. The project examines technology and tools for creative data gathering and experimenting with data visualisation, gain insight, and share knowledge. Working with participants on walks and through creating visualisations, the project aims to engage participants on issues relevant to our communities, and empower those communities with new skills and tools to create new knowledge and new tools.

2. BACKGROUND

Data Walking[1] began in London, 2015, exploring the potential of low cost technology to build a picture of urban spaces. An online repository[2] was created to store a year of walk data and the tools devised to gather it, so anyone could go on their own Data Walks.

Impromptu walks in cities I visited were followed by workshops in multiple cities. Each workshop has been a unique take on Data Walking due to the participants involved, the area explored, as well as constraints like available time and resources.

In 2018 a report (see figure 1) was printed detailing the aims of the project, practical advice on tools and methods to start Data Walks or workshops, and featuring the visualisations of designers, educators and students who took part in the project. The repository was expanded to support the book.

3. DESIGN/METHODOLOGY/APPROACH

GPS enabled microcontrollers and smartphones allow the accurate gathering of data by latitude, longitude and time are the crux of the method/platform. With this platform, a variety of sensors can be plugged in, or enable GPS data recording with another tool that normally has no facility to do so. Processing and other free software have been utilised in both data gathering and data visualisation, encouraging participants to engage with coding. However, knowing the exact location and time of a datapoint are not essential to conduct a Data Walk, and successful workshops have not used this technology. Equally, many processes have not been code-driven. The project approach has evolved from looking at quantities to investigating qualities.

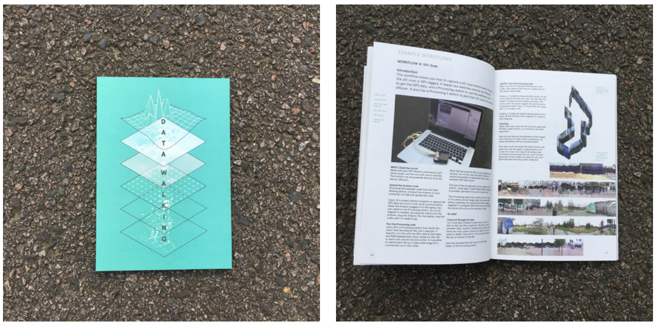

Figure 1: the Data Walking Report cover, and spread

Figure 2: Arduino with sensors held while walkingin North Greenwich

Typical Data Gathering Methods
Arduino + sensors such as light, temperature, sound, air quality
(see figure 2)
Smartphone photography
Note taking
Audio recording

Other Methods Explored
Object collection
Floor rubbings
Geiger counter radiation sensors
GPS enabled slitscans
3D capture with depth camera

Typical Data Visualisation Methods
Hand-sketched charts
3D printed charts and maps (see figure 3)
2D Charts and maps made with Processing (see figure 4)
Data-driven maps with Mapbox

Other Data Visualisation Methods Explored
Interactive 3D with Unity
Textile-based
Real-time light-based with Arduino + LEDs + sensors

Figure 3: 3D printed data cylinders

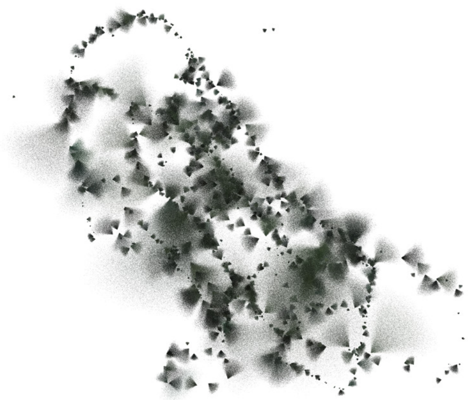

Figure 4: Map of green matter extracted from photos taken across the North Greenwich peninsula.

4. ORIGINALITY/VALUE

Data Walking contributes to existing and ongoing work by many other practitioners and organisations[3] using walking combined with citizen science and environment sensors[4], quantified self[5], urban exploration[6], big data[7], flaneurism, co-creation and participation[8,9], community initiatives[10], data-driven design[11], design research and data ethics[12].
Data Walking fuses some of these aspects together to cre-

ate a flexible and coherent workflow from data gathering, processing, and visualising for anyone with an interest in exploring urban areas through direct experience and expressing that with data visualisation.
Through overlapping skillsets, agile collaboration, Data Walking hopes to bring different disciplines closer together with creative data gathering methods and ambitious visualisations.

5. PRACTICAL IMPLICATIONS

By using Open Source technology and in turn sharing all the data, code-created tools, schematics for electronics, and workflows, this project and its transparent approach is about empowering those who want to explore urban environments through data gathering and visualisation regardless of expertise.
Data Walking makes use of a variety of tools and mediums and encourages practitioners to bring their own unique skillset and toolkit to the project. In this way a wide range of people from different backgrounds can participate with the project and potentially collaborate with one another, bound through a common interest/theme, common skill-set, or a desire to learn new skills.
While different technologies have been proven (or disproven) to be suitable for data gathering while walking, and workshops have raised some interesting discussion points and perspectives on urban spaces, a future phase of the project would benefit from focusing on a specific issue and digging deeper into it.

Figure 5: Participants in a workshop at Tatung University, Taiwan, showing a map created in Processing using Unfolding Maps Library

6. IMPACT

The project has had impact in different ways at different levels. The book has been distributed to designers, educators, journalists, and scientists in over 100 cities in 24 countries, and the GitHub repository of data and code is available to anyone. Feedback from those who have received the book has been positive, many stating it has inspired them to start their own walks or try new methods and workflows.
There have been conference and industry presentations, as well as workshops. Workshop participants range from students to professionals (see figure 5). Methods and lines of inquiry into urban spaces have also been utilised in academic teaching on information design projects.

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