Making-With-Data: Supporting DIY Data Physicalizations

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Abstract
We explore how DIY making techniques can support the democratization of data. We present two DIY data physicalizations: a CNC plotter for rapidly prototyping visualizations on paper, and a physical, dynamic bar chart of migrant deaths constructed with origami. We discuss several issues when embodying data through maker techniques: DIY guides, materiality, and the relationship between resources and knowledge. Finally, we propose several questions to discuss in the workshop.

Introduction
In this paper, we present two DIY data physicalizations created with a maker approach. Our intention is to explore methods of leveraging DIY techniques in a manner that will empower people working with data.

The increasing democratization of technology has empowered more people to gain a great variety of knowledge – people can find DIY guides, learn of the latest developments, and become active supporters or critics of the products they consume [13].

While this democratization has made data more *accessible*, accessibility does not guarantee data *comprehension*. Without comprehension, not everyone benefits equally in our data-rich society. One way to make data more understandable is to create physical visualizations, or data *phys-*

icalizations [6]. Physicalizations have be shown to be more memorable [10], more efficient [5], and more easily understood by general audiences [6], than digital visualizations.

However, authoring physicalizations remains a challenge for an everyday people. CAD tools aimed to help general audiences create physicalizations often focus on fabricating existing, templated designs [11]. One approach to authorship is to allow people to construct their own visualizations using tangible tiles [4] – however, tiles represent only discrete values [16], and cannot be carried around easily without disturbing the visualization. Authoring polished, high-fidelity physicalizations is also problematic, as accessing fabrication tools (e.g. 3D printer, laser cutter) outside of a makerspace/FabLab can be difficult for general audiences. Many other DIY methods of making are intended to be doable at home (e.g. home improvement, cosplay), or easily portable (knitting, crochet), leading to increased flexibility and freedom.

But why should makers care about data? For one, made objects and data can both be deeply personal. Makers often have a personal connection to the objects they create; the thoughts and experiences of the creator's process are embedded into the object itself. Similarly, the data we generate in our everyday lives – whether it be self-tracked, photographed, etc. – is full of stories about our lives, yet exists largely in the digital realm, intangible and numerical. Makers, though, have the skills to physically realize a concept into the real world. Life in Clay [14] is a prime example of how the maker expresses her personal data through pottery. By interweaving data into made objects, makers can communicate their stories through their creations.

In this paper, we explore how DIY making techniques can support the democratization of data, through two physicalizations made with data. We discuss two author-explorations of DIY data physicalization created with a maker-mindset: 1) a DIY CNC data plotter for drawing simple visualizations on sticky notes, and 2) a physical data visualization of migrant deaths in Europe over multiple decades made with origami springs. These projects are a result of the lead author's experiences in (a) information visualization; (b) computer programming; (c) digital fabrication (e.g., 3D printing); (d) and familiarity with online guides (Instructables).

CNC Plotter

We constructed a CNC plotter that draws bar charts onto sticky notes (Figure 1). Our plotter creates template axes with tick marks, and draws bar charts of adjustable sizes and heights based on user-inputted data point.

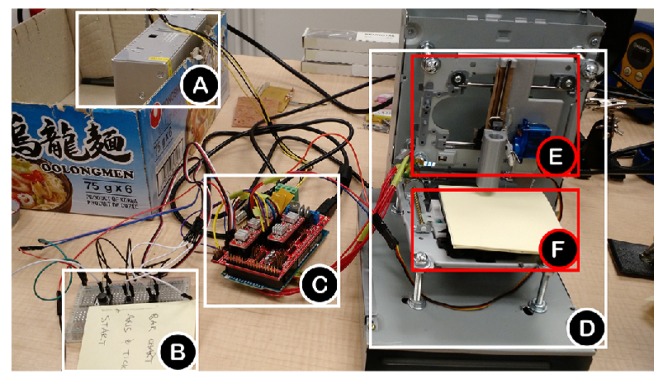

Figure 1: Our CNC plotter, containing: A) a power source to drive stepper motors; B) an interface to switch between drawing AXIS+TICKS, or BAR CHART modes; C) an Arduino with RAMPS board; D) the main body of the plotter, containing the E) mounted x-axis chassis with pen holder, and the F) mounted y-axis chassis with attached post-it notes. See Figures 2 and 3 for closeups.

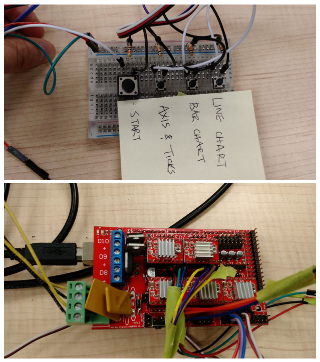

Figure 2: Closeup images of the interface (Figure 1B), and RAMPS board (Figure 1C).

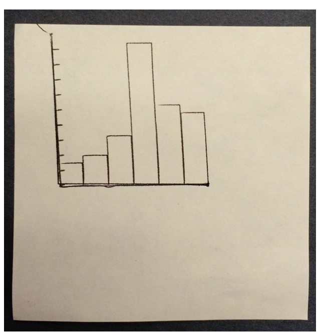

Figure 3: Sample output of the CNC Plotter.

We designed the plotter to support rapid prototyping of sketched visualizations on paper. While sketching visualizations is useful for quickly and expressively generating visual representations of data [15], the visualizations are difficult to rapidly prototype, as the artist must manually draw each visualization from scratch. Our goal was to quicken the process, by automating the drawing of repetitive elements (e.g. axes, bars) in a visualization.

Our plotter differs from alternative miniature DIY plotters available to the public, which can be novice-unfriendly and/or costly. The Piccolo[1] requires purchasing and laser-cutting materials from scratch, whereas the Egg-Bot[2] can cost $240+ CAD upwards for the base kit alone. Furthermore, these plotters do not run software intended for creating visualizations, making it more difficult to generate data visualizations from the plotters.

We based our plotter off an Instructables guide[3] by user *BIGDOG1971*, and modified the instructions according to the materials we already had on hand. We wrote our own software for the plotter specifically to work with the user's data.

The plotter is constructed from two old CD/DVD drives. The frames containing the stepper motors were used to drive the x- and y-axes of the device, while we constructed the base with the outer casing of the drives. We hooked up the stepper motors to an Arduino 2560 Mega shielded with a RAMPS 1.4 board. The board was connected to a power supply to provide sufficient power to the motors.

Components created: We 3D printed a small 5x5 platform for the y-axis bed, and a pen holder to be mounted on the x-axis.

Components purchased: We purchased several washers, and a small box of 3" machine screws (total cost: $7 CAD).

Components salvaged: We salvaged and disassembled the two CD/DVD drives from non-functioning equipment.

Miura-Folded Bar Chart

We constructed a dynamic physical visualization (Figure 4) of migrant and refugee deaths on the borders of Europe over multiple decades, using paper and cardboard. The actuated bars are created with Miura paper-folded springs, adjusting in height and saturation according to deaths over the years.

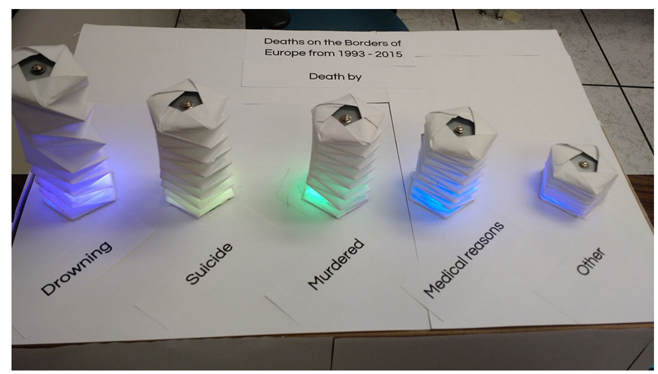

Figure 4: Visualization of refugee deaths. Paper springs moves up and down according to the causes of death in one year. Within each spring is an embedded LED, which varies in saturation according to comparative deaths to all years.

[1] http://www.piccolo.cc/
[2] https://egg-bot.com/
[3] http://www.instructables.com/id/ARDUINO-by-Myself-Mini-CNC-Plotter

Figure 5: The electronic components of the physicalization (Figure 4), and the interface to cycle through years. Note the same RAMPS board and power supply as the CNC plotter.

Figure 6: Our physicalization in the dark.

Our project spawned from data about the increased fluctuation of migrants in Europe starting in 2015 [2]. Tragedies such as migrant boats sinking in the Mediterranean have gained daily worldwide coverage in mainstream media. Sadly, the growing number of deaths has become almost commonplace in news, and the public has become desensitized to such information. Our goal was to re-engage public awareness in this topic by providing information on details about the refugee crisis through visualization.

The original dataset was gathered from an NGO-maintained list[4] of all known migrant and refugee deaths from 1993 to 2015. As the dataset contains thousands of rows, we aimed to convey the data to the general populace in a more understandable method through physicalization.

The visual representation is a 3D physical bar chart, where the bars move up and down according to the percentage of people who died through various causes of death (suicide, drowning, etc.) within one year. Each bar is embedded with an Adafruit Neopixel LED with differing color saturation, representing death by category in one year compared to total deaths in category. A user can step through each year in the dataset by pressing buttons to cycle forward and backward.

The bars are Miura-folded[5] origami springs, each driven by a rack, pinion, and servo motor to modify the height. We took the folding pattern from an Instructables guide[6] by user *sphere360*. We reused the same Arduino, RAMPS board, and power supply as the previous project.

Components created: The spring bars and cardboard frame were constructed with paper recyclables. For each bar, we 3D printed: a small disc to push the springs up and down, a rack and pinion, and a rack mount to hold everything in place.

Components purchased: None, for this project.

Components salvaged: The servo motors were salvaged from a bin of spare servos in our lab's workshop.

Discussion

Our two projects highlight several emerging issues when embodying data through making.

DIY Guides

Substitutions and Variants of DIY Guides. Perhaps one place to draw inspiration for DIY guide customization is cooking. While open-ended, it preserves structure and often offers substitutions for particular constraints (e.g., for dietary restriction or available resources) or opportunities (e.g., different kinds of yeast or preferments). DIY guides can suggest alternative components or steps (e.g., how to create a custom piezo sensor) which makers can use in place of a purchased component. Currently, we are not aware of any such documentation in the physicalization or making community.

DIY Guides for Visualization Authoring. Visualizing authoring is not a cut and dry process that cannot be easily followed with a DIY guide. Authoring a visualization is dependent on many factors: the underlying data, the user's ideations for the visual representation, and much more. DIY guides cannot teach you how to visually map data to graphical representations. Data itself is highly unique and variable; even the same dataset can spawn infinite visual representations. While tutorials for visualizations in digital tools (e.g. Excel, Tableau) exist, these tutorials teach users how

[4] http://unitedagainstrefugeedeaths.eu/about-the-campaign/about-the-united-list-of-deaths/
[5] https://en.wikipedia.org/wiki/Miura_fold
[6] http://www.instructables.com/id/Pentagonal-High-Tower-Spring/

to use the tool, and how to generate visualizations from existing templates, not working with the data itself. We are not aware of any analogous documentation existing in the physicalization community.

Materiality

Materiality and Data. Materiality plays a large role in both data physicalizations and making practices. The feel and aesthetic of a physicalization can affect how a viewer interprets it from first glance; inviting viewers to explore the physicalization through touch; influencing our emotional state [3]; or encoding data through its material properties [6].

Materiality and Making. Materiality holds even arguably greater influence on maker culture itself. Hacking practices are celebrated as a return to engaging with "more physical" materials. Materials invite exploration [13] and experimentation in hackerspaces [7]. Materiality is cherished especially in subcultures such as *Steampunk*, where practitioners scavenge raw materials for further crafts, and in turn the materials can influence the design process of future projects [13].

Materiality and Fidelity. Our projects were constructed mainly from salvaged or reused components (plotter), and scrap material such as cardboard and paper (refugee visualization). Compared to "non-maker" tangible visualizations such as InForm [1] and EMERGE [12], which are high-fidelity research prototypes, our physicalizations convey a low-fidelity, handmade aesthetic. We postulate that this may be more approachable and less intimidating for DIY novices, over refined projects which convey expertise and skill.

Relationship Between Resources and Knowledge.
The lead author explicitly chose a relationship with resources that reflects a particular ethos. We had a high degree of access to resources though our local makerspaces – including physical resources (3D printer, soldering station, power drill) and knowledge resources (local expert in soldering and electronics), along with relevant knowledge in coding and expertise in data physicalizations. The materials we used resulted from adopting a "less-waste", "low-cost", and "discovery-based" prototyping mentality, by using what components we had on hand at the time, figuring out how we could take them apart, and repurposing them for something useful. We used parts that are easily accessible, cheap, and environmentally friendly, and bought or created as minimally new components as possible.

Workshop Questions

Based on our paper, we propose the following questions for discussion in the workshop:

- How do maker techniques work in less resource-rich environments – such as "making-within-constraints" [9, 8]? For example, if refugees wished to tell their own stories through data-made objects, how could they make with limited resources?
- Could we leverage maker techniques such that visualization novices could better learn about data and visualization through making?
- Could we use DIY making techniques to support various data practices, such as self-tracking of data?

Author Background

Tiffany Wun is an MSc student at the University of Calgary, supervised by Sheelagh Carpendale and Lora Oehlberg.

Her research involves physical tools to support visualization authoring. She is interested in combining DIY techniques with low-cost and reused resources to create physical visualization authoring tools.

Lora Oehlberg is an Assistant Professor of Computer Science at the University of Calgary. Her research focuses on interactive tools and technologies that support creativity, innovation, and multi-disciplinary collaboration in domains such as interaction design, maker communities, and health-care.

Sheelagh Carpendale is a Professor of Computer Science at the University of Calgary. She leads the InnoVis Research Group and co-directs the Interactions Lab. Her research focuses on combining information visualization and human-computer interaction to better support everyday practices of people.

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