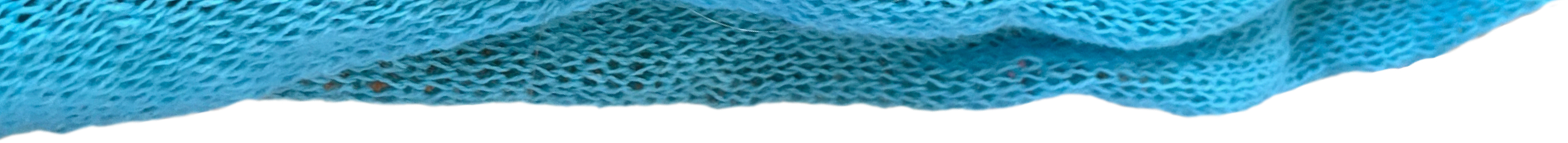

# A Year of Interaction Around Town: Gathering Traces with an Interactive Knitting Machine and Community Stitch Markers


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## ABSTRACT

Devices for digital fabrication are becoming increasingly smaller and more portable, enabling digital fabrication research to move into new environments. In this exploratory research-through-design project, we aimed to physicalize data on-the-go using a portable digital fabrication device, and gathered community annotations and traces of the journey the machine went on with "stitch markers". We describe the development of *The Life of a Small Town*, a portable knitting machine that was adapted to knit rows of stitches in response to sensor data. The machine travelled throughout a small town and "popped up" at local art events to sense and physicalize social gatherings held by an arts organization over the period of one year. Individuals participating in events could also decorate their own "stitch markers" to annotate and pin to the data. In this paper we discuss the insights from an analysis of the stitch markers and traces of the year-long journey.




DIS '24, July 1–5, 2024, IT University of Copenhagen, Denmark © 2024



ACM ISBN 979-8-4007-0583-0/24/07…
https://doi.org/10.1145/3643834.3660736



### Authors Keywords

data physicalization; traces; data sculpture; knitting; knitting machines; textile; fibre arts; fiber arts; artwork

### CSS Concepts

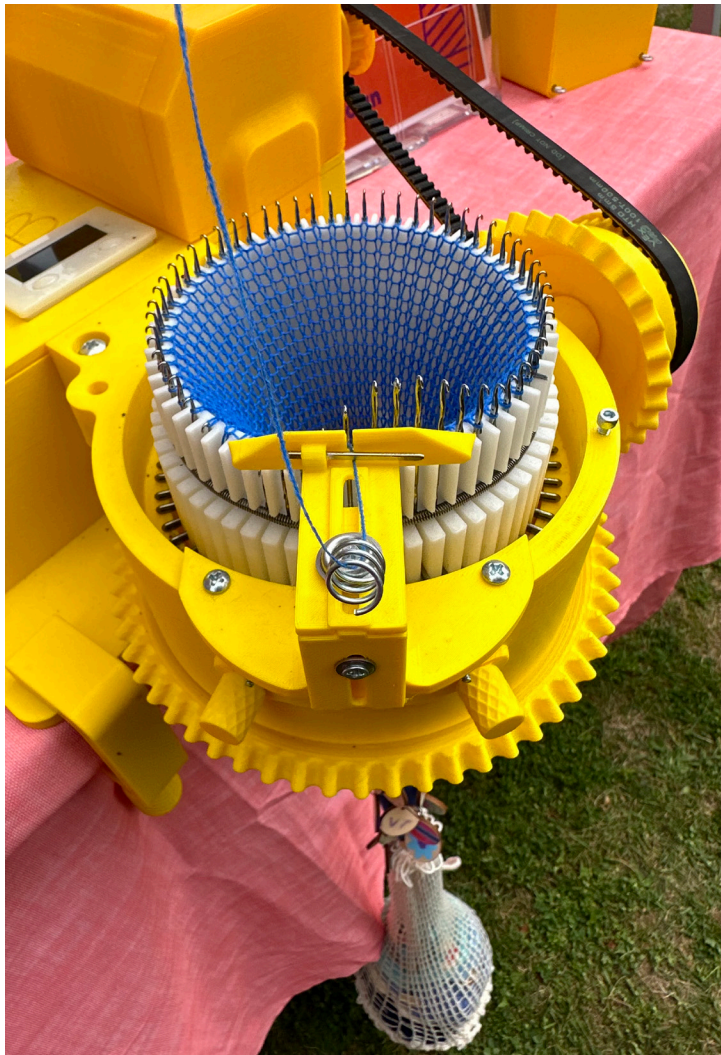
• Human-centered computing~Human computer interaction (HCI)


## INTRODUCTION

In this paper we use a research-through-design project to explore and document a real-time, portable, and annotatable data physicalization. This two-year project (one year of designing and planning, and another of implementation) captures the insights from the development of an interactive knitting machine that travelled throughout a small town during the pandemic recovery year to physicalize art events and the process of coming together again.

### Motivation

During the pandemic, many cultural organizations and institutions turned to innovative forms of programming to enable individuals to continue to interact with the arts even when they couldn't physically gather together [41]. During the re-opening and reduction in physical distancing guildelines, *The Life of a Small Town* was commissioned by Critical Mass (an arts organization in Port Hope) with the goal of physicalizing the community coming out of the pandemic, as well as to celebrate their 10th anniversary. As we learned through this project,



Critical Mass is different than other art organizations in that they hold events out in the community, rather than in one central main location, and as a result we wanted to measure and physicalize their events while on-the-go. This "travelling" arts organization became especially important during the pandemic due to their ability to, for example, hold events outside and enable their community to continue to interact with the arts in a safe way. In the design of our data physicalization device, we wanted *The Life of a Small Town* to be able to highlight and physicalize this unique organization and the events they hold throughout Port Hope.

### Contribution

We document the insights from a digital fabrication and data physicalization device that had several novel elements and was deployed long-term, in the wild, for a period of one year. Our contributions in this paper include:

**(1) Design journey:** We discuss the insights from building and maintaining this work over the period of one year. We discuss the adaptions we had to make to the design of the machine based on constraints that came up during the deployment.

**(2) Annotation analysis:** We analyze the stitch markers that were added to the public physicalization to better understand the ways that individuals would like to annotate public data physicalizations.

## RELATED WORK

### Recording Histories in Tangible Objects

Objects in our physical environments show the traces of their use such as the "desire paths" walkers create across landscapes [22], the shine of items that are often touched [29], visual markers of wear and repair [26, 35, 37, 46], and how we re-purpose items in our environment (like using a chair to hold yesterday's clothes) [16, 18, 82]. Within HCI, researchers have aimed to further extend the story-telling ability of tangible objects by using digital technologies to both record and play-back memories. These projects aim to design with the traces of use, to reveal and highlight how objects are used [66]. For example, the History Tablecloth was a tabletop that would physically remember and visualize where items were place upon it [25]. Some tangible user interfaces (TUIs) use their history of use for persuasive goals such as the Power-Aware Cord which lights up based on energy usage [27], or the Thrify Faucet that curls up when you've used too much water [78]. Other projects aim to record use for peer-to-peer learning or project inspiration, such as the app Roaming Objects which recorded the history and journey of shared items in a Tool Library [19].

One design direction is to leverage our meta-data to link TUIs to our vast personal digital archives and "virtual possessions" [55, 56] including videos [74], photographs [9, 10, 57, 81], location data [43, 83], or audio [52 – 54] for remembrance or reflection. For example, moving a physical slider on a radio to listen to music from one's past [52, 54], or adjusting the lens on a telescope to go through one's photo archive [9, 10]. For physical heirlooms, you could imagine walking through a city and experiencing how a loved one recorded it based on location metadata [43]. On a larger scale, the research project DataCatchers provided individuals with physical devices that displayed socioeconomic data based on their location [6, 24]. All of these research projects aim to consider how tangible objects could help connect us to our virtual histories or meta-data traces. In this current research we use tangible tags, or "stitch markers", on a community data physicalization to better understand the types of annotations individuals would like to make to crafted physicalizations.

### Textile Traces

Knitting as a fabrication method has what researchers call "temporal-material entanglements" where the process of fabrication and knit result are tied to temporal memories [42]. Within HCI, researchers have explored how we can further extend these qualities in crafted items. For example, the research project Spyn [67 –69] explored how digital data (such as location, time, and recorded messages) can be digitally "pinned" to physical locations in a hand-knit item. The system enabled individuals to create a digital "pin" linked to a specific location in their knitting to build up a digital record of the journey the hand-knit item went on during the process of creation [68, 69]. Other projects have aimed to use crafting tools to record the journey such as Needle User Interface [50] which can record and share how someone stitches, Data Things [51] which created 3D printed shapes of a crafter's hand movements while crocheting, and MetamoCrochet [58] which enables a creator to make "marks" on a textile with an augmented hook and colour changing yarns

Others have leveraged knit patterns to incorporate data and digital traces into knit items. For example, the Tempestry Project aimed to visualize climate change through hand-knit temperature data [4], and Knitting the Curve was a communal hand-craft project where individuals knit out their local COVID-19 data [48]. In one of our previous projects, *The Life of a Building*, we aimed to physicalize visitors to a local art gallery during the pandemic recovery year [38, 39]. DIY crafters have further "hacked" personal computerized machines to enable individuals to upload patterns to their machines for digital fabrication. This has enabled several research projects on incorporating data into custom knit patterns [28, 40, 61]. HCI researchers are further extending the usability of incorporating data sources into fabrication. For example, supporting more iterative processes with data sources and digital fabrication [80], expanding the types of data that can be used in pattern making [1], enabling the sharing of patterns across machines [31], and enabling individuals to embed programs (i.e. link back to them) in the physical knit results [85].

### Data Physicalizations

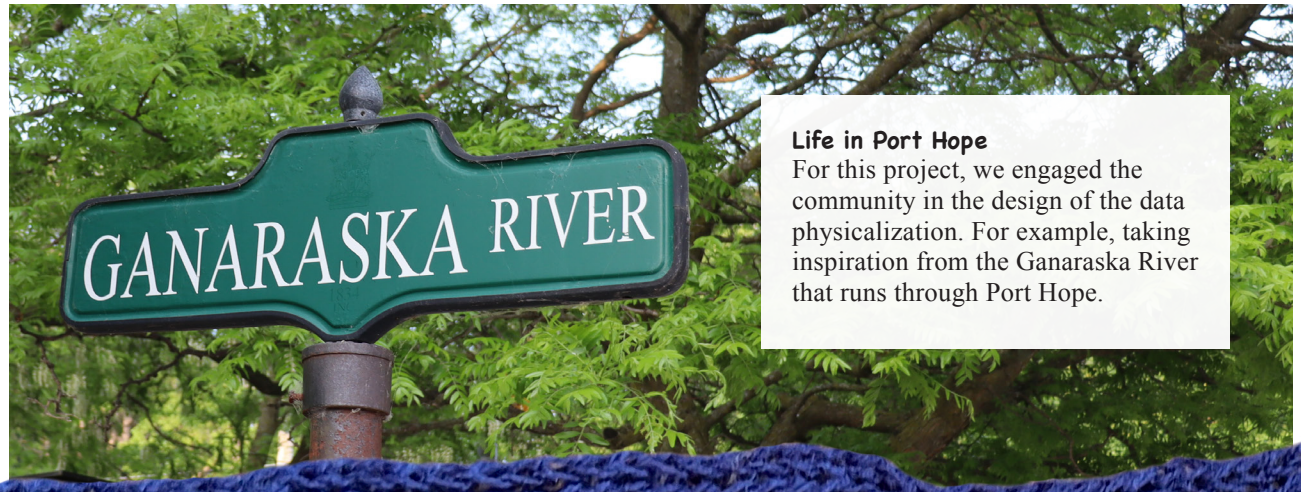
Overall, knitting is an exciting fabrication method for crafting data physicalizations, which are defined in HCI as "a physical artifact whose geometry or material properties encode data" [36]. This broad area of research expands the material characteristics that data can provide as well as how and where it is presented [32, 73]. Among data physicalizations, data sculptures are physicalizations that hold both aesthetic (sculptural) and functional qualities [84]. Researchers are leveraging new digital fabrication tools to develop aesthetic data physicalizations with a wide variety of materials such as ceramics [14, 15], wood [71], play-dough [7], liquids [47], bubbles [11] and even food and other gastronomic experiences [44, 45, 70].

As research into digital fabrication expands, these machines are also becoming smaller and more portable [8, 59]. This will increasingly enable researchers, designers, and artists to create data physicalizations on-the-go, but will also create new challenges such as what happens when digital fabrication devices are brought to new environments [5], or out in nature [62 – 65], and the new maintenance tasks this will create [30, 75]. In this paper we begin to explore these questions with a relatively simple fabrication device that travelled for a year throughout a small town.

## DESIGN BRIEF

*"Critical Mass: A Centre for Contemporary Art is a Port Hope-based not-for-profit arts organization dedicated to bringing contemporary art experiences to their community, in Port Hope, Ontario. All of our lives have been shaken by both the pandemic and the important cultural and social issues brought to the forefront this past year. We are now at a time and place of change. Where do we go from here? As we move into our second decade as a centre for contemporary art, we are looking for artists to look widely, think deeply, discuss and lead new programming that addresses current societal shifts to expand our thinking and deepen our relationship with every member of the community. Critical Mass exists to generate interactive contemporary art experiences for all. What have we learned? How have we adapted? What do we carry forward? What do we leave behind?"*

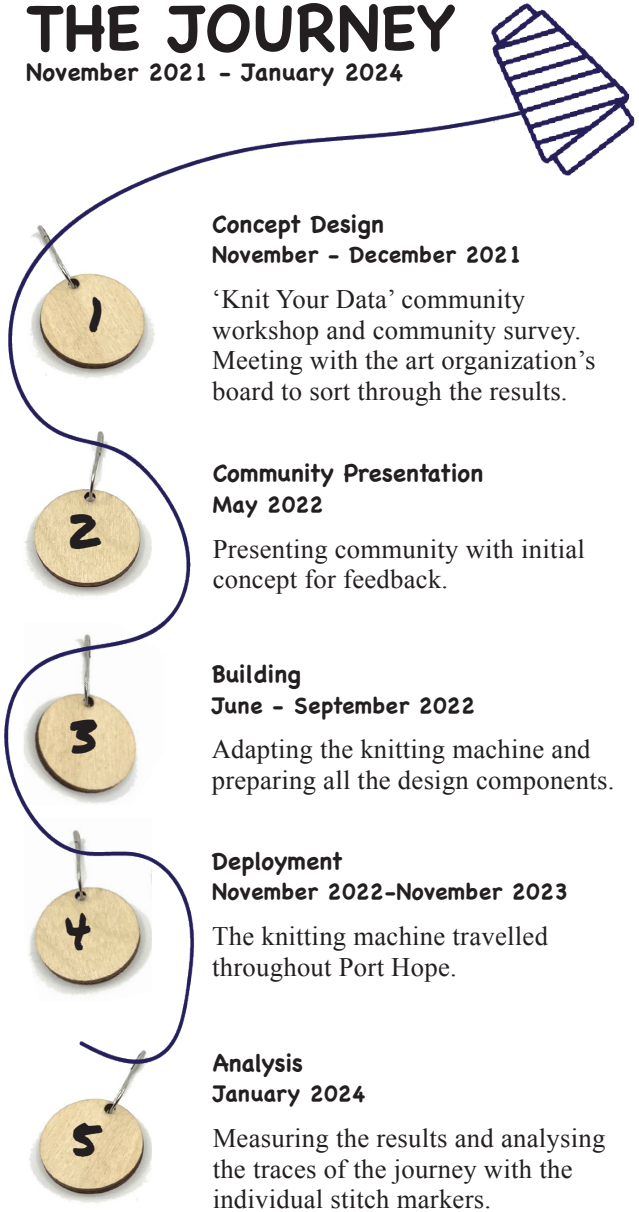
To address this brief we proposed knitting the Port Hope community with the textile associations that knit items have of warmth and coziness. Over a two-year period, one spent understanding the community and developing the design of how the physicalization would work in that context, and another adjusting it while in the one-year deployment, we explored how to physicalize this community with soft digital fabrication.




**Life in Port Hope**
For this project, we engaged the community in the design of the data physicalization. For example, taking inspiration from the Ganaraska River that runs through Port Hope.

## THE JOURNEY

**November 2021 - January 2024**




**Concept Design**
**November - December 2021**

'Knit Your Data' community workshop and community survey. Meeting with the art organization's board to sort through the results.

**Community Presentation**
**May 2022**

Presenting community with initial concept for feedback.

**Building**
**June - September 2022**

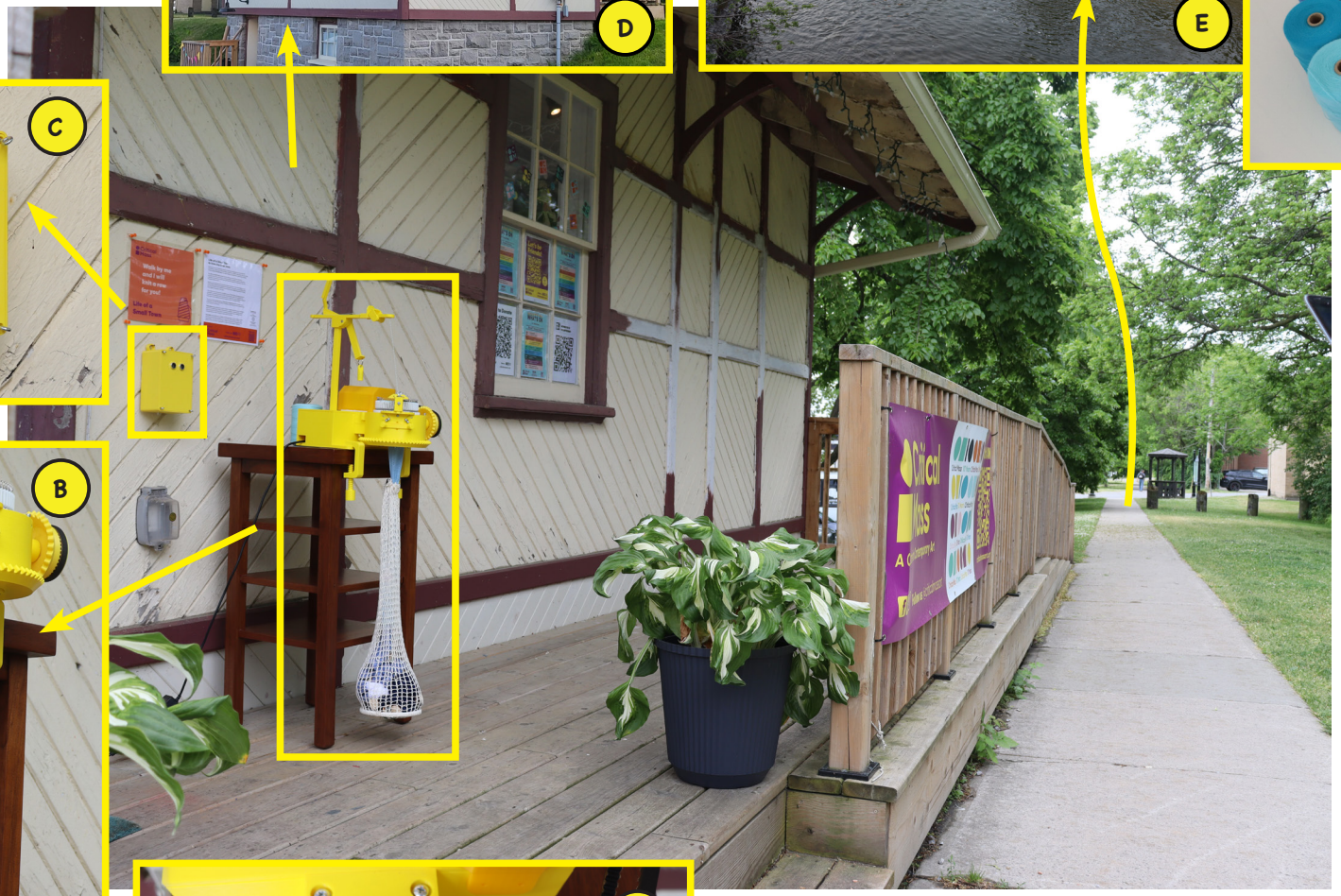
Adapting the knitting machine and preparing all the design components.

**Deployment**
**November 2022-November 2023**

The knitting machine travelled throughout Port Hope.

**Analysis**
**January 2024**

Measuring the results and analysing the traces of the journey with the individual stitch markers.




## THE LIFE OF A SMALL TOWN: PROJECT SUMMARY

We adapted a circular knitting machine (**A**) so that it could knit data on-the-go (**B**) physicalizing sensor data of individuals who walked by the machine (**C**) at events held by Critical Mass (**D**) across Port Hope. We changed the yarn colour each month to match seasonal changes in the Ganaraska River (**E**), and participants could decorate "stitch markers" (**F**) to create traces of the journey the machine went on.

## STEP 1: GETTING TO KNOW YOU

### `Knit Your Data' Workshop

To start off the project, and introduce the concept of knitting data, we created an online 'Knit Your Data' workshop. During the workshop we gave an overview of how to knit your own data with a cord knitter made out of a toilet paper roll and popsicle sticks, with examples such as knitting a week of TV consumption by knitting whenever you watch TV, and changing the colour of yarn each day. The goal of this workshop on hand-crafting data [2, 21, 49] was to convey the types of data that could be gathered and physicalized with a simple circular knitting machine.

### Community Survey

We then created a community survey to better understand how folks in Port Hope mark time in their community with questions about the aesthetic feeling of Port Hope (taste, smell, sounds, personality, etc.). We used these probe questions with the goal of getting unexpected and inspirational data [23]. Critical Mass distributed this survey through their newsletter, website, and social media. After a month of receiving responses, we placed all the responses on an online whiteboard, and with the Critical Mass board of directors (including executive committee, directors at large, communications committee, curatorial committee, and staff) conducted an affinity mapping activity to group the results.


### Lesson #1: Life Around the Ganaraska River

We learned that the Ganaraska River, which runs through the middle of Port Hope, is a continual presence throughout the year. Port Hope was originally built around this river, and historic events frequently relate to it. For example, the yearly DIY boat races in the Spring where folks "Float Your Fanny Down the Ganny" [77] aim to commemorate floods that occurred in the 1980s. Community members discussed the ways that changes in the river (such as fish migration and seasonal changes) were felt or sensed throughout the year. As a result, we wanted to use the changes in the Ganaraska River in the data physicalization to mark time over the year.

### Lesson #2: Critical Mass Travels

We learned that Critical Mass holds events throughout the year around Port Hope. They aim to bring art experiences into this small but close knit community (total population of 17,773, and urban population of 12,587). They also use seasonal changes to, for example, hold events outside during warmer months, or inside community organizations (such as the local theatre) during colder months. In the survey, folks talked about their favourite yearly Critical Mass events. As a result, we learned that a travelling data physicalization would be best suited to this art organization, as well as a way to annotate where the physicalization went.

## STEP 2: DESIGN DECISIONS

### Seasonal Changes in the Ganaraska River

Based on Lesson #1 (Port Hope's connection with the Ganaraska River), we used this connection to demarcate time in the knit record. We provided Critical Mass with 12 colours of yarn, each representing seasonal changes in the river. For example, during the winter we have white for ice and snow, spring with light blues, summer with bright blues, and fall with darker shades from the fall of tree leaves.

### Annotating the Data with Stitch Markers

Based on Lesson #2 (Critical Mass travels), we wanted to annotate and capture where the organization, and the knit physicalization, travelled to throughout the year. To do so, we added blank "stitch markers" (**A**) that individuals attending events could decorate to annotate the knit record. Knitters use stitch markers to mark a place in their knitting, for example, when they need to hold a stitch in place, or want to mark a spot to return to later [60]. As a result, we thought stitch markers could contextualize the data without taking away from the textile materiality of the physicalization.

### Measuring the Community

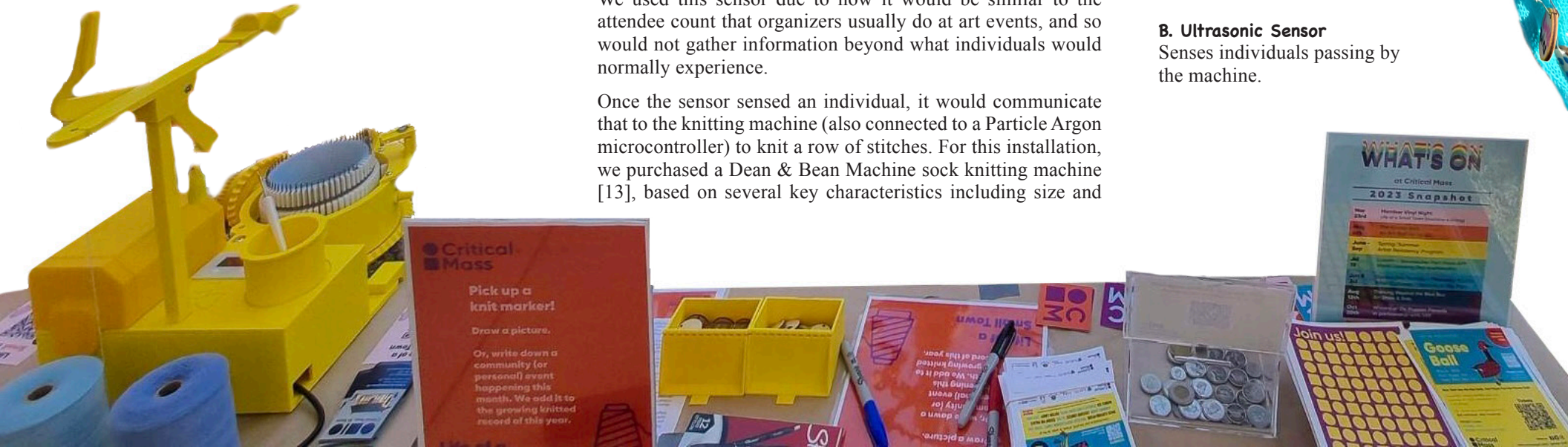
Based on Lesson #2, we adapted a portable circular knitting machine so that we could physicalize the community on-the-go. We created a system with multiple Particle Argon microcontrollers. These microcontrollers tether to the Critical Mass director's phone Wifi hotspot with unlimited data. We did this to provide remote updates to the system when needed via Particle's web portal (i.e. without needing to travel to Port Hope), while still allowing the installation to move to different locations.

To measure the community, we created a portable sensor box (**B**) that Critical Mass could bring to events and would measure folks who attended, choosing yellow filament to correspond with the Critical Mass colour palette. The box included an ultrasonic rangefinder sensor attached to one of the Particle Argon microcontrollers. The ultrasonic sensor would measure when something passed by it, and when placed at the entrance of an event would then capture the flow of people attending. We used this sensor due to how it would be similar to the attendee count that organizers usually do at art events, and so would not gather information beyond what individuals would normally experience.

Once the sensor sensed an individual, it would communicate that to the knitting machine (also connected to a Particle Argon microcontroller) to knit a row of stitches. For this installation, we purchased a Dean & Bean Machine sock knitting machine [13], based on several key characteristics including size and

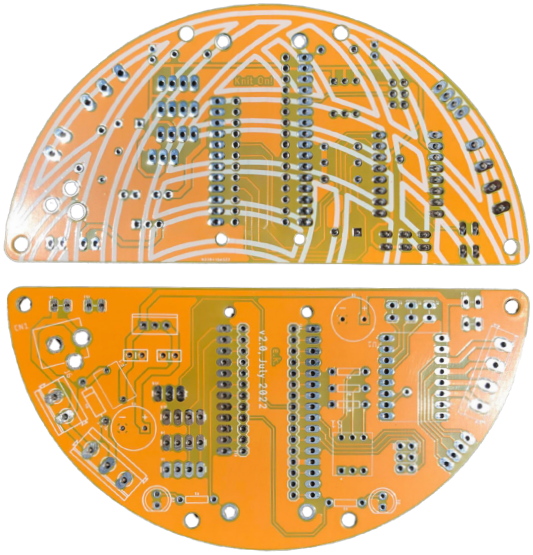

**A. Yarn Colour & Stitch Markers**
Physicalize when and who interacted with the machine.

**B. Ultrasonic Sensor**
Senses individuals passing by the machine.

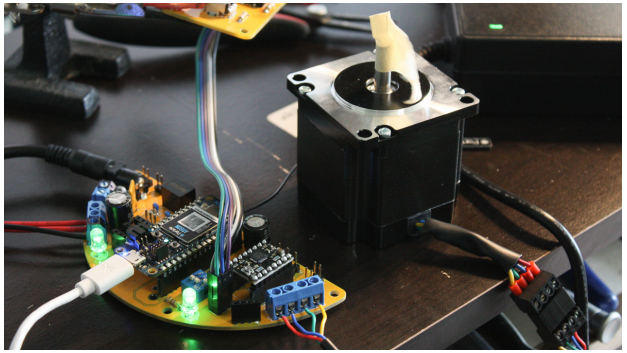


the ability to clamp it to tables for increased portability. Once this machine arrived, it was adapted by removing the hand-crank and replacing this with a servo motor (**A**) and custom printed circuit board (PCB), designed in the shape of a yarn-ball (**B**). The knitting machine is controlled with a Particle Argon microcontroller. The circuit board hosts connectors for an auxiliary interface keypad, stepper motor, I2C peripherals, and an external power switch.

The stepper motor is driven using a A4988 or DRV8825 stepper motor driver, a common driver to 3D printer boards. The board is powered through a DC input jack and a 24 volts transformer. That then goes to an efficient switching voltage regulator to then give 5 volts to the microcontroller. The 24 volts also goes to the stepper motor driver to power the off-the-shelf stepper motor. This stepper motor does what the hand-crank would have done previously. It spins the floor gear on the knitting machine, which in turn moves the cylinder holding the needles. Needles are raised when they reach the yarn feeder, and then lowered to create new stitches. This results in a row of stitches getting knit each time someone attends a Critical Mass event (**C** & **D**).

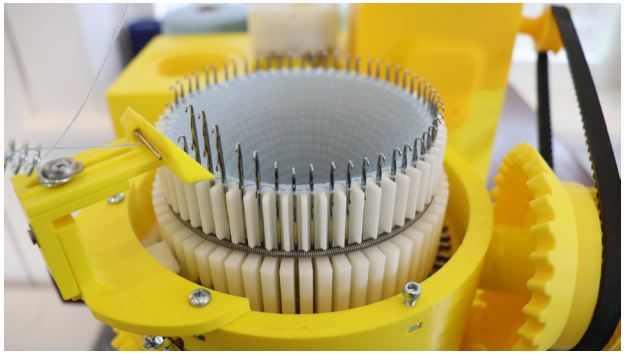


A. We replaced the hand crank with a motor.



B. The circuit board was designed like a yarn ball.

C. The knitting machine and sensor went to events.



D. Each person would cause a row to be stitched.

## STEP 3: DEPLOYMENT TWEAKS AND UPDATES

### Holding the Data On-the-go

#### V1. Let It Fall

Mid-way through the deployment enough yarn was knit that we had to figure out how to hold it.

#### V2. Contain the "Data"

We used a vase to contain the data. However, the yarn kept twisting, and jamming the machine.

#### V3. Rotate with the "Data"

We tested a container with a plastic bag and binder clip that would move with the needle cylinder.

#### V4. Knit a "Net"

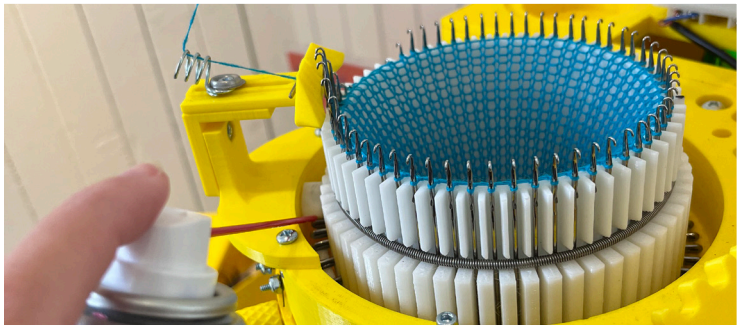
To replace the bag we hand knit a "net" for the data, continuing on the river theme, that would hold the data as it grew. The net rotated with the machine as it stitched rows.

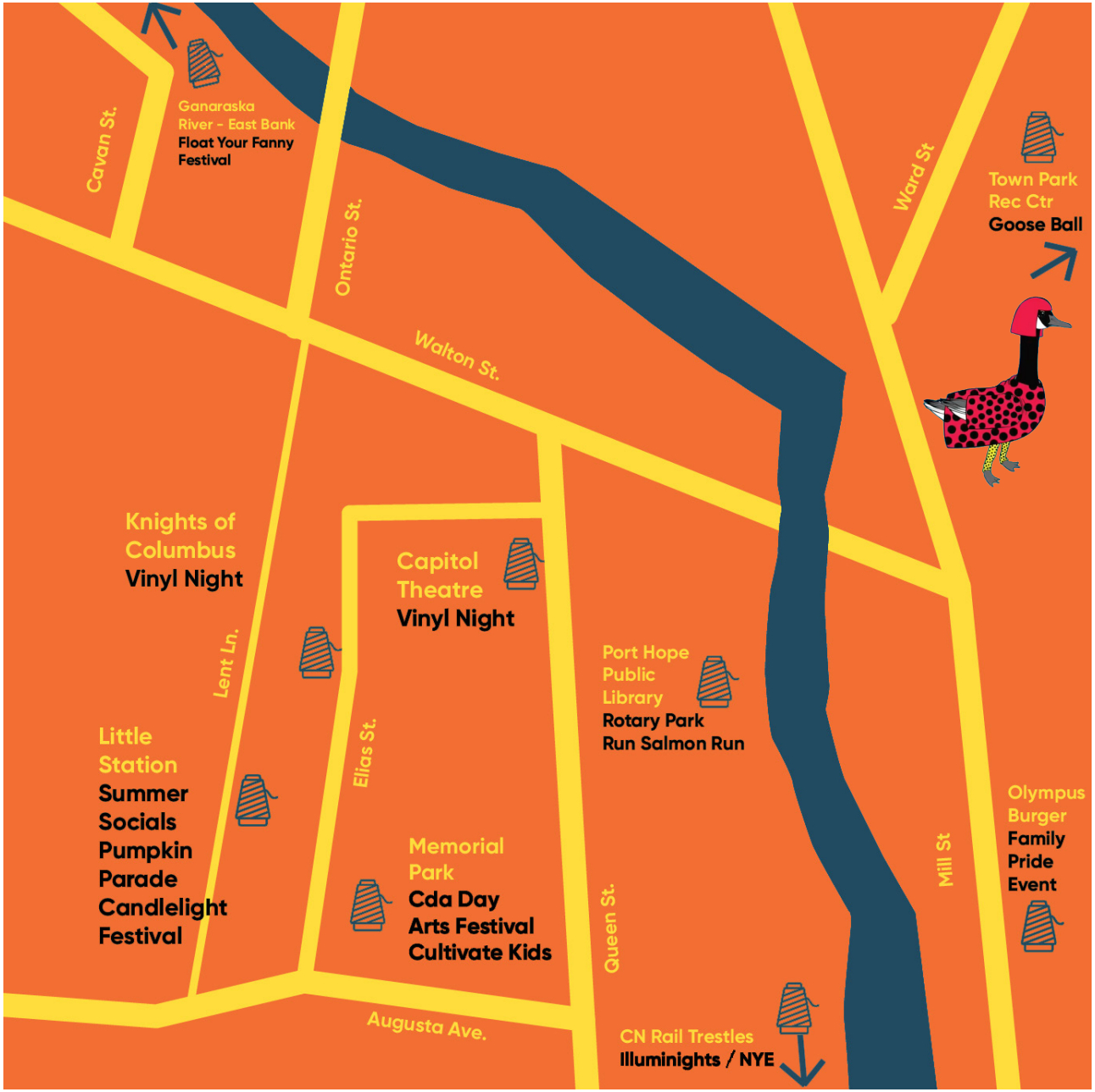
#### The Weight of the Data

This machine was made for knitting socks, but in making one very, very long sock eventually we needed to add modular weights to the back of the machine to counterbalance the weight of the knit data.

#### Maintenance

Most events were held outside, and as a result mid-way through the deployment we needed to incorporate maintence cycles to keep the gears from grinding and jamming, similar to the lube maintenance one does on a 3D printer.






## STEP 4: ANALYSIS

### Where Did It Go?

Throughout the year the knitting machine travelled to nine different locations throughout Port Hope, with some locations holding multiple events. These locations and events are marked on the map with a yarn cone icon. Some events the machine attended included:

### Pumpkin Parade

The day after Halloween the community lines up their pumpkins to share their designs and then donate the pumpkins to feed animals at a local farm.

### Float Your Fanny Festival

An event where the community makes DIY boats and races them down the river. Groups gather on bridges to watch.

### Vinyl Nights

Bring your vinyl records on a set theme and dance the night away.

### Goose Ball

In the spring, geese take over Port Hope. In the first week of May while NYC is having their MET Gala, Critical Mass holds their Goose Ball, where folks dress up as their favourite artist.

In total, the knitting machine attended 15 events throughout Port Hope.


**How Much Data Was Knit?**

Other than the initial green yarn, which was used to get the machine started, the stitched data from the year of community interactions was 10.59 meters long (1059 cm). The knit record was used to tangibilize the impact that Critical Mass events had in the community at the April 2024 Council Meeting for the Municipality of Port Hope. When taking the record out of the knit bag we also noticed the nice sound of the wood stitch markers chiming together.


November 2022
263 cm

December 2022
40 cm

January 2023
90 cm

February 2023
14 cm

March 2023
111 cm

April 2023
55 cm

May 2023
65 cm

June 2023
100 cm

July 2023
77 cm

August 2023
74 cm

September 2023
8 cm

October 2023
60 cm

November 2023
102 cm

**How Did the Community Use the Stitch Markers?**

For this project, we wanted to better understand how individuals would want to decorate the stitch markers. The goal of this analysis was to provide recommendations for what types of contributions artists and designers should make space for when crafting community data physicalizations, and how they can support these annotation practices. In total, 160 annotated stitch markers were contributed to the knit record. To analyze the stitch markers we used affinity mapping on an online whiteboard where all the stitch markers were uploaded and then iteratively sorted with a focus on content types. These were first sorted into 2 groups (drawings and text), and then subdivided further into the final categories of (1) icons, (2) name, (3) abstract, (4) message, and (5) colour.

**Icon x 58 (36.25%)**

These included stitch markers with illustrations of recognizable objects.

**Name x 47 (29.38%)**

Mostly first name (37), 4 first and last, 18 initials. *Showing only examples of initials for anonymity

**Abstract x 37 (23.13%)**

These included stitch markers with abstract colour combinations or repeating patterns.

**Message x 10 (6.25%)**

Stitch markers with a short phrase or saying, or marking an event such as “snow storm”.

**Colour x 8 (5.00% )**

These included stitch markers that were completely covered or filled in a single colour.

## DISCUSSION

### Encoding Data into Textile Patterns

For this sock knitting machine, we used it beyond its intended purpose. Knitters are also increasingly adapting domestic knitting machines for digital fabrication with kits and tutorials like img2track [12], Electro-Knit [79], and AYAB (All Yarns Are Beautiful) [2]. Researchers are also exploring creativity support tools, for example more "physically situated" tools for knitting, such as automatically creating knit patterns from photographs [1]. Programs such as Dynamic Toolchains [80] enable more flexible and iterative fabrication workflows (such as swapping one source of data for another for digital fabrication). Research projects such as KnitScript [31], are making it easier for researchers to control a wide variety of knitting machines, as well as potentially share instructions across different machines. All these innovations will make it increasingly easier for individuals to import various forms of data into knit textiles.

This is also an exciting opportunity for artists and aesthetic data physicalizations, in that there are already a wide variety of fabrication machines created throughout the history of making and craft that are not currently used for digital fabrication. For example, any hand-crank device (from hand-crank punch needles to bow making machines) could be adapted for motorized control and digital inputs. For example, imagine a device producing a bow during moments of celebration. How might these new form factors and materials change how we think about data, and the more diverse types of data that might be valuable [14, 17, 70]? In HCI the predominant focus of data is for behavioural change and self-improvement [34], but we are made of so many more values and motivations than just these. Through this travelling artwork we demonstrate how adapting these devices will bring digital fabrication to new materials and fabrication techniques, and how this can be used for recording local histories. At the same time, using these machines for data physicalizations will bring up unexpected issues that will only be uncovered while they are 'in-the-wild'. For example, when knitting a sock individuals don't come up against the issues we faced when knitting a tube several meters long, and weighing many pounds.

### Traces of a Year

Previous work has explored how individuals construct and contextualize data physicalizations, finding that participants' labelling practices were intertwined with making [72]. In this project, we further aimed to explore how participants would like to annotate a machine-crafted data physicalization that travelled and knit data for a year. By adding the ability for individuals to decorate their own stitch markers and pin them to the data, we learned more about how individuals would annotate a public data physicalization. Interestingly, compared to other crafted traces, such as the research project Spyn [67– 69] which enabled individuals to connect parts of their own knitting to a digital record or "pin", our participants added other types of information highlighting the important differences between public and private annotations. Rather than recording the precise journey of the crafted item, participants added their own illustrations, initials saying "I was here", abstract doodles, and messages. At the same time, our physical stitch markers had the spatial constraints common of data physicalizations [3, 32, 36, 76], such as the amount of space available to decorate, which limits the detail that could be provided in comparison to virtual annotations with unlimited "space" [33].

## CONCLUSION

In this paper we cover the design journey of creating *The Life of a Small Town*, and the results of its year-long journey around Port Hope. From our deployment, and the tweaks we had to make to the machine while "in-the-wild", we came up against our own creative misuse of this sock knitting machine, which in not being used to knit socks faced new constraints. We discuss where the machine went throughout the year, how much data it knit, and analyze the content of the stitch markers to better understand how individuals would want to annotate a public data physicalization, and one made of crafted materials. These findings will help future artists, crafters, and researchers to better understand how to support these data annotation practices. Overall, we are excited about the possibilities for crafted data physicalization beyond traditional digital fabrication devices.


## ACKNOWLEDEMENTS

A big thank you to Critical Mass for supporting and commissioning the creation of *The Life of a Small Town*, and to all the residents and visitors of Port Hope who participated in this project. Critical Mass was able to commission *The Life of a Small Town* with funding from Ontario Trillium Foundation's Resilient Communites Fund. This project was funded by Canada's Social Studies and Humanities Research Council (SSHRC) through the New Frontiers Research Funds (NFRF) grant: Exploration stream #NFRFE-2020-1271.

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