

Physical Metadata Visualisation: The Knitted Personal Library

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Figure 1: A Shawl Visualising a Personal Digital Library of 38 eBooks

ABSTRACT

Personal collections, be they books, music, or artefacts have significance to the owner, and provide conversation and engagement with visitors. For example visitors of physical libraries may browse the spines, select a book, and begin a conversation. When the collection is digital it cannot be engaged with in the same manner and it becomes more difficult to share and explore with others. Physical data visualisation is becoming more popular, supported by new technologies, such as 3D printing, and the resurgence of crafting. This paper reports our investigation of digital library and eBook metadata visualisation using knitting. We report on our design considerations, a digital prototype to explore knitted library shawls, and a knitted prototype for a personal digital library.

CCS CONCEPTS

• Information systems → Digital libraries and archives; • Human-centered computing → Information visualization.

KEYWORDS

digital library, metadata, physical data visualization, physicalisation

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1 INTRODUCTION

Visitors of physical libraries often browse the library by walking the stack, taking in the book spines as they pass the shelves [11, 14]. Libraries and bookshops are known as *third places* in which people “regularly visit and commune with friends, neighbours, co-workers, and even strangers” [24, 34]. By contrast, digital libraries lose this sense of open exploration, immersion, touch and serendipity [5]. Pomerantz and Marchionini even describe digital libraries as ‘impoverished’ in comparison to physical ones [34]. As Petroski argues the value we place on books is expressed in the ways we store (and thus display) them [30], recent attempts at visualising eBook collections may speak to a changing mindset about the appreciation for digital books. Most of these approaches, however, typically remain in the digital realm, and any cross-over into physical spaces are rarely sensory or tactile [16, 21]. Our research is driven by the challenge of allowing owners of a digital library to invite visitors to explore the library in a visual and tactile way. We explore this challenge through three Scoping Questions:

- (1) What are existing approaches to visualise object metadata, digitally or physically?
- (2) What are the design considerations for visualising digital content of a library in a physical object?
- (3) How to physically visualise a personal digital library?

This paper reports the investigation of data visualisation of a personal library using a knitted shawl.

2 RELATED WORK

Here we explore Scoping Question 1 and present work on physical data representation and visualising digital libraries.

Physical data representation. Physical representations of textual data historically appeared in formal setting such as quotes on stitched samplers [6] and as an occasional piece of art, such as the stitched straight jacket of Agnes Richter created in the 1890s [38].

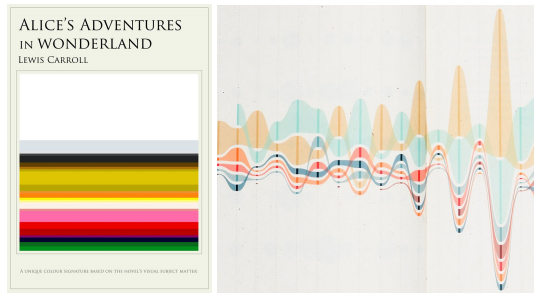


Figure 2: Stacked colours (l) [4], themes (r) [33] in a book

Richter’s jacket finds an expression through craft that reassures and expresses her of existence. Samplers similarly are often the only records that remain of the lives of historic women. This aspect of self-expression through craft has found a modern revival in maker communities [1]. Modern art also uses textual elements, such as parts of news feeds in the News Knitter Project [19]. Recently, crafting (digital or otherwise) has been recognised a distinct domain for HCI research [15]. Some physical objects embody and record social structures, oral stories and history, such as the Peruvian Khipu (knotted strings) [22], the Hmong Story cloth [10] and carvings in Māori meeting houses [17]. Similarly, women of the Yakama Nation recorded their personal histories by creating *ititamats*, balls of string into which significant events were encoded using series of knots, shells and beads [39, 31-33]. These objects may function both as recording devices as well as mnemonic devices to aid story telling [41].

Beginnings of using physical objects to explain the digital were made in the 1980s by Becker and McGill who aimed to explain 3D scatter plots through a 3D physical model [2]. The availability of sensor technology in consumer products allowed for experimentation with visualising sensor outputs. Seung Lee [20] tracked the first year of his baby’s sleep using a phone app, and visualised the data as a two-coloured knitted blanket. Similarly the Data-Knits project visualises binary code of computer viruses as knitted black and white shawls [9]. Artist Sam Meec [23] visualised people’s hours of work vs rest on a 5x3m knitted banner as a form of social commentary using a knitting machine. Sue Montgomery [26] recorded the proportion of female vs male speakers in council meetings in her two-coloured shawl knitting. Similarly, a German commuter created a striped shawl recording her daily train delay [25]. Perovich [29] visualises environmental health data in her *Dressed in Data* project [28] that creates clothing that visualise the pollutants found in people’s homes. Each piece is computationally designed, with laser cut lace elements cut into the fabric, while the *Touching Air* project created a series of three necklaces of perspex segments to represent large particulate pollution levels in Sheffield [35]. Wannamaker et al. [43] previously explored a textile medium for visualising digital data, and commented particularly on its easy integration into people’s lives. This aspect is taken up in our choice of a knitted shawl, which is portable while giving sufficient visualisation space.

Visualising books and libraries. A number of artists have visualised the contents of single books. For example, Jaz Parkinson

metadata	data type	public library	personal DL
Book ratings	numerical	✓	(✓)
Amazon sales rank	numerical	✓	(✓)
Genre	category	✓	✓
Dewey classification	category	✓	✓
ISBN	numerical	✓	✓
Author	text	✓	✓
Publish year	numerical	✓	✓
Themes	text / category	✓	✓
Keywords	text	✓	✓
Number of chapters	numerical	✓	✓
Number of words	numerical	✓	✓
Words per sentence	numerical	✓	(✓)
Price	numerical	✓	(✓)
Book cover	colour	✓	✓
Number of pages	numerical	✓	✓
Time reading	numerical	×	✓
Acquisition order	ordinal	×	✓
Acquisition year	numerical	✓	✓

Table 1: Metadata groups: external, work, book-specific, and reader characteristics (top to bottom)

	public library	personal DL
collection size	large	small - medium
visit	independent	with owner
purpose	information, entertainment	conversation starter
space	medium - large	small - medium
portability	no	yes / no
link to eBooks	desired	no

Table 2: Design constraints due to collection characteristics (top) and visualisation constraints (bottom)

visualised selected books by creating colour signatures [4] based on the number of times each colour is mentioned or evoked in the books. The colour word occurrences are grouped together to create coloured bands without repetition (see Figure 2). Hanna Piotrowska [33] used Italo Calvino’s conceptual book “If on a winter’s night a traveller” to visualise themes (see Figure 2, right).

A number of visualisation tools were developed to aid the exploration of collections [3, 7, 8, 12, 18, 44] as well as exploration of in-document relationships and geographies [13, 31, 32, 36] and support for playful exploration of digital collections [42, 45]. Most of these tools remain bound to digital representations, and are therefore largely out of scope here. For example, the *Visual Navigation Project* aims to bring exploration and tactile encounters that are familiar from physical libraries into the digital aspects of a library by developing 10 touch screen applications for the Oslo University Library [27]. Jones et al. [16] aimed to address the fragmented experience of physical and digital offers in a library through embedding interactive screen the physical bookshelves. Reitz studied the development of collections (i.e., change of metadata over time) to better understand a collection [37].

3 DESIGN CONSIDERATIONS

In investigating Scoping Question 2, here we outline the design considerations for our knitted data physicalization. There are constraints on the design from both the data to be visualised and the

physicality of the space in which the visualisation is to be presented. We considered two options for visualising eBook collections: (1) eBooks associated with a public library, and (2) a personal eBook collection.

Data design space. We identified 18 possible metadata in 4 groups which may be visualised and we considered the differences between public and personal collections. We hypothesised that certain attributes may be less desirable to share about personal collections, such as cost, rating, and sales rank information. In Table 1, ✓ refers to data that would be available and suitable, (✓) indicates unsuitability of the data, and ✕ indicates that the data would not be available.

Physical design space. We identified that a typical personal collection has different metadata to a public library collection (see Table 2). A personal collection visualisation is likely to be explored in the presence of the owner who may explain some of the visualisation concepts. Our goal for such a visualisation of a personal library is, among other goals, to invite conversation. For the purposes of this initial investigation of the data physicalization of eBook collections we chose to explore the visualisation of personal digital libraries in such a way that they can be shared in the wild with others. Because such a visualisation would need to be small to medium in size and portable with the collection owner, a piece of clothing, accessory, jewellery or object may be suitable. As the data to be visualised for a personal eBook collection may refer to 20 to 200 books (each with their own metadata), visualisation a small piece jewellery seemed unsuitable. Inspired by the concept that books contribute to adorning and furnishing a home, we selected a knitted shawl to be its portable equivalent to represent eBooks. This choice allows us to explore a number of different options for visualising the data.

Data and Visualisation. Here we discuss how the 14 suitable characteristics for a personal digital library (see Section 3) could be visualised in a knitted shawl.

Design options: We first explore the design options of a rectangular shawl that may be used to distinguish between the books in the library. We decided to use simple coloured stripes with possible addition of patterns (which were later abandoned as too time consuming). Figures 3 to 6 show two options each for rectangular and triangular shawl designs. The first shawl (Figure 3) mimics the shape of books on a shelf – uses ordering by acquisition, the second is more of a conventional triangular shawl shape – using a histogram-type ordering by length (Figure 4). The first rectangular shawl (Figure 5) uses stripes along the length of the shawl, which may for a large collection either result in a very wide shawl (flexible shawl width) or in very narrow stripes (fixed shawl width). The second rectangular shawl (Figure 6) uses block stripes across the length of the shawl, which would make it harder to see the pattern when worn. We decided to use a rectangular shawl shape for simplicity of the act of knitting on a machine, and selected the block stripe pattern for better visibility and wearability.

Data selection: Based on our exploration above, we concluded that a rectangular shawl only has 3 to 4 characteristics that may be used for encoding data: length of colour stripe, texture, colour, order of stripes. We therefore needed to reduce the list of characteristics and select the most pertinent or meaningful. We merged those categories that expressed similar aspects of a book, such as

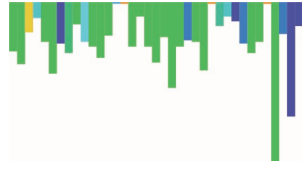


Figure 3: Book shelf design



Figure 4: Histogram design

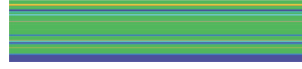


Figure 5: Long stripes



Figure 6: Block stripes

length (number of words, *pages*, chapters), acquisition (*order*, year), genre (*genre*, Dewey), and removed specifics that would be particularly challenging to incorporate (author name, ISBN, publish year, keywords). Then we omitted data that would be hard to obtain (time reading and cover colour), where possible preferring similar data (e.g., genre over themes, length of book over time reading). While the visual attributes of books (e.g., cover colour) could have produced interesting visualisations in colour and texture, these would have prevented us from using those aspects for any other characteristics. This resulted in the following list: *genre*, *length*, *acquisition order*.

Genre Colour schemes: To identify suitable genre classification we were guided by those available for personal eBook purchases (e.g., Google Play, Audible). From these we identified 52 categories, which were reduced to 21 categories (by merging closely related topics). We explored a number of different options for displaying these genres on a colour wheel. For example, one version aimed to associate themes with appropriate colours based on existing associations relating to creativity etc. This led to a categorisation where similar colours did not indicate similar themes (e.g., shades of green for sports, travel and business). While our final grouping achieved some better flow between similar themes by grouping these explicitly (e.g., blue – business & technology, red – fiction, yellow – self improvement, green – creative), we acknowledge that it uses a Western perception of genre grouping that may not be appropriate for other cultures. These basic colour schemes were used for both the digital prototype and the knitted visualisations, with colour variations being allowed to occur naturally based on available materials. The colour scheme may be further adjusted to consider subcategories to achieve a greater range of colour variation, based on personal preference.

4 DIGITAL PROTOTYPES

Before exploring a knitted prototype we created a digital prototype. The eBook data that was used for visualisation was obtained by exporting metadata from an audible audio book collection of one of our authors. As outlined in Section 3, we used three characteristics: genre, book length (measured in minutes), and acquisition order. A web interface has been created for uploading the data (<https://bit.ly/2Z0sRfE>), which takes csv files containing the fields ASIN (simple identifier), title (not used in visualisation), genre, duration (format hh:mm:ss), and purchase date (format mm/dd/yyyy).

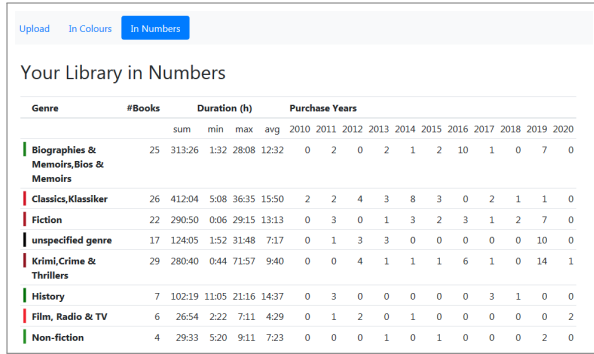


Figure 7: Digital Visualisation: Showing library statistics

When a csv data file is uploaded a number of options become available: visualising stacked groups of books (grouped by genre), a time line, and a simple statistic of the library. Figure 7 shows the statistics for the personal library. Next to each genre classification the assigned colour is shown (following the schema created in Section 3). Figure 8 shows the stacked books grouped by classification. This visualisation was inspired by Jaz Parkinson's book colour groupings [4] discussed in Section 2. We also explored a descending timeline of books. In this case each book was separated from the next by a light grey line to support distinguishing between subsequent books of the same genre. The book details and separators can be hidden; the visualisation could be toggled between ascending and descending. However, when considering the design of the timeline shawl as a physical object, it is no longer automatically clear in which direction the timeline flows.

5 KNITTED PROTOTYPES

Implications for our knitted prototype: Of the two visualisations, the timeline provides more information. Due to the reference time, it also conveys more personal information. It does, however, need some kind of separator between the books, as well as a directional *temporal marker* (attached to one end of the shawl to indicate the temporal direction). In addition, a timeline shawl allows to be continuously extended, while a stacked shawl conveys a snapshot.

Our goal for the knitted prototype was a rectangular shawl that provides a data visualisation of a personal eBook or audio book digital library (see Question 3). Based on our exploration of the digital prototype (see Figure 8), we settled on showing the growth of the owners library from first purchase to most recent purchase, with colour-coded genres and length of books expressed as length of stripes. For the knitted prototype we used the personal eBook collection of one author. This collection was different to the one used for the digital prototype as it contained fewer books: 38 books by 19 authors, published between 2004 and 2018 with 10 pages to 1520 pages, belonging to 6 genres (Google Books) up to 9 genres (Good Reads). In addition to traditional encoding methods (colour, size etc) knitting also provides some unique characteristics which can be utilised. One of these is the use of texture and patterns. As most of the team were new to using a knitting machine, and to



Figure 8: Digital Visualisation: Grouped and stacked



Figure 9: Knitted Prototypes

keep the process simpler and the visual complexity manageable, we decided not to use any coloured patterns at this point. Another factor is needle size and yarn thickness, which can be used to create a difference in the haptics of the fabric, whereby tighter needles (or thicker yarn) will create a stiffer fabric, while larger needles (or thinner yarn) create looser fabric. We investigated finish sizes of online knitting patterns as well as typical sizes of scarves, shawls, stoles, and wraps to determine the sizes we should work within. We found that commonly scarf widths range from 2.75" to 40" (7cm to 102cm), with lengths ranging from 51" to 87" (30cm to 220cm), while shawls had widths ranging from 15" to 67" (38cm to 170cm) and lengths ranging from 48" to 80" (122cm to 203cm).

Test Knits. To investigate the potential of DL visualisation in knitted fabrics, we conducted a series of test knits using both hand-knit and machine-knit methods to produce mini shawl prototypes visualising a fraction of the collection.

Factors that were explored included page count, fixed vs dynamic lengths, stitch type, and collection size. Our first prototype (see Figure 9, top) explored a long and narrow scarf following the principles used in the digital timeline prototype: each book shown in genre colour arranged in purchase order, with book size determining the rows of stitches. To ensure clear book distinction, individual books were separated by a garter ridge (created by using a line of purl stitches to end a block of stocking stitches). The scarf was created using predominantly stocking stitch, which caused the fabric to roll and warping and was deemed unsuccessful for this reason. Our second prototype (see Figure 9, middle) incorporated a garter stitch edging to combat rolling and resulted in a much more successful product for sitting well on the shoulders of the wearer or when laid flat for conversation. Prototypes 1 and 2 were developed in scarf proportions which resulted in potentially unwieldy products that are difficult to gain an overview of due to their length. Thus a shawl length and width was tested in Prototype 3 (see Figure 9, bottom) with wider dimensions allowing overview of a collection that did not roll in on itself and could be read more easily from beginning to end.

Knitting a personal library. We proceeded to knit the full-sized prototype that is shown in the paper’s teaser figure on the first page, using a knitting machine. Our knitting setup in the IoT lab is shown in Figure 10. This shawl incorporates all 38 books and provides information about purchase order, book genre, and book size. Genres are indicated by colour differentiation (see Figure 11) and the border between each book is indicated by a garter stitch, see Figure 12. A triangular temporal marker was added, see Figure 13. The marker currently has been attached to the most recent book and points toward the future. Currently the marker is somewhat small (8cm by 4cm) and therefore difficult spot when the shawl is worn but can be seen easily when the shawl is stretched out. The knitted shawl is shown in Figure 1. The final measurements of this knitted personal digital library visualisation is 180cm by 55cm (71” by 22”). Each row represents about 25 pages (scaling factor 1:25), leading to a shawl of 594 rows representing 15,809 pages in the library.

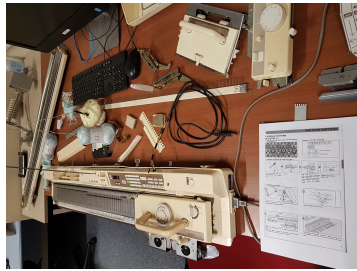


Figure 10: Knitting machine setup

6 DISCUSSION

We here discuss further aspects of our physical data visualisation which became apparent once object had been created.

Visualisation of different library sizes: Our work so far has focused on two personal libraries: one large audio library with 157 books in Section 4 and one smaller eBook library with 38 books



Figure 11: Genre changes



Figure 12: Book dividers



Figure 13: Temporal marker

in Section 5. Visualising the larger library by means of a knitting machine would have triggered another layer of challenges: Should the shawl be made longer to incorporate all book or should the library be scaled to 180cm length, leaving some books to be barely visible.

Visibility and communication point: The shawl was found to work very well as a conversation starter, and many local and visiting researchers have asked about the meaning of (genre) stripes and book dividers and many conversations about eBook reading and listening behaviour have occurred that would otherwise not have happened. It may be useful to include on a washing label the information about the colour scheme used for genres and the scale factor. It is so far unclear how two libraries with different numbers of books should be compared as the scaling factor would have to be different. In order make the temporal marker more visible, a simple tassel could be attached for highlighting. Furthermore, to support extension of the visualisation, the marker should be attached to the beginning of the shawl.

Tangible eBook library: This data physicalization provides a uniquely tactile as well as visual attraction about the contents of a reader’s personal digital library. The shawl is soft and pleasant to wear. Most people who engaged in conversations with the wearer expressed surprise as to the tactile nature and softness. During discussions about the visualised library, many people touched the shawl and ran their fingers along the ridges. This inclusion of section markers as a different stitch provides a tactile and visual identifier which increases the haptic nature of the shawl.

Machine vs hand knitting: These two modes of creating a knitted data physicalisation are not as distinct as they may appear, as both require considerable time investment into manual processes. Pieces created with either method can be extended using the other method. In either case, the encoding scheme (i.e. colour palette) would be decided before starting the crafting activity.

Visualising digital elements through crafting: We chose our knitting machine for its ability to work not only manually, and with punch cards, but to have a serial input that can be accessed via a standard FTDI to USB cable. Initial tests based on Becky Stern’s [40] hacking of a knitting machine were successful in printing via computer input. The long-term goal is to connect the knitting machine as a ‘thing’ to the Internet of Things (IoT) and to make it available for remote or collaborative knitting.

7 SUMMARY AND CONCLUSION

In this paper we present what we believe is one of the first attempts to physically visualise a personal book collection in a wearable object. The chosen article of clothing was a shawl due to the practicalities of size and the potential to provide a visual overview of personal digital library collections that this clothing item provided. We explored the need to pare back a data set that was complex and often repetitive in order to re-imagine it in this physicalization. Linearity of the collection was included in the visualisation to show how the collection has developed over time. Additionally, most data visualisations that we were able to identify in the related work had a discrete beginning and end yet the nature of knitted products is that these could be added to by the owner as their collection grows.

Finally, we wish to contribute to the discourse about how to re-imagine complex data through a physical medium by summarising decisions we took regarding our design process and medium, and their implications.

(1) Process decisions

- *Digital and physical ideation* processes provided opportunities for exploration.
- *Crafting* provided personalisation, but limits production scalability; pattern sharing enables reproducibility.
- *Production method* creates practical limitations (e.g., number of stitch types, size, sustainability).
- *Investment* of time and effort into the data visualisation was respected and appreciated by users.

(2) Medium decisions

- *Portability* necessitated simplification of data, and identification of main characteristics to visualise.
- *Extensibility* required special consideration (e.g., shawl can grow in length but not width).
- *Ethical considerations* posed restrictions on the visualisation medium (e.g. sustainability and recyclability).
- *Tangibility* of the visualisation medium created interest and communication opportunity.
- *Wearability* of the visualisation object was key to inspiring communication, but may obstruct clear viewing of the data, and limit comparability between datasets.

We found our knitted digital library created a third place, acting as a conversation starter with friends and colleagues. Our knitted physicalisation provides an opportunity for a reader to have their own collection with them as an article of clothing, a fashion-ware, a talking point, and a celebration of something unique and personal to the wearer.

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