Exploring Physical Visualization

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Abstract

Physical visualization has been demonstrated to be more efficient than on-screen representation for information visualization tasks [5]. In addition, it has been suggested that physical visualization might be particularly memorable or engaging [12], but this has yet to be explored empirically. This paper describes a potential evaluative study that would explore differences between flat, on-screen bar graphs and extruded bar graphs, a simple form of physical visualization. Specifically, memorability of information, user engagement, accuracy and efficiency of information retrieval using physical and on-screen graphs would be compared. Broader challenges and possibilities for the evaluation of physical visualization are discussed.

Author Keywords

Physical visualization; tangible visualization; data physicalization; information visualization; evaluation

ACM Classification Keywords

H.5.2. User Interfaces: Evaluation/Methodology

Introduction

An alternative to screen-based representations, physical visualizations "map data to physical form" rather than on-screen or printed pixels [5]. Such representations offer a set of possibilities different from flat representations of data.

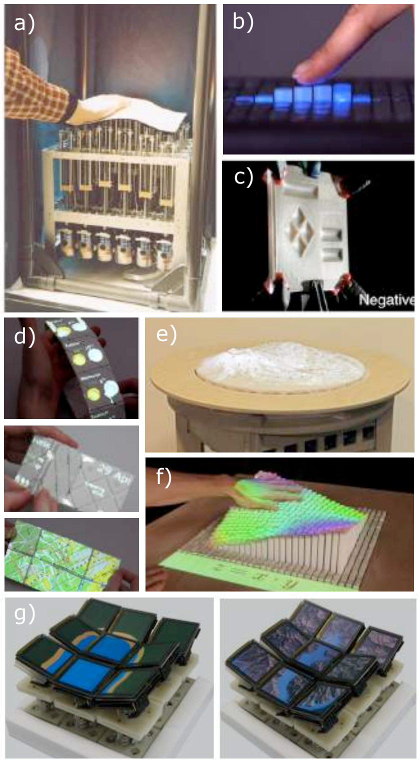

Figure 1. Shape-changing interfaces or actuated displays which could be used for information visualization:

a) FEELEX [4]
b) Lumen [8]
c) Changeable Physical Buttons [3]
d) Paddle [10]
e) Relief [6]
f) inFORM [2]
g) Tilt Displays [1]

Previous work suggests that physical visualization is more efficient than screen-based representation of data for information retrieval. Jansen et al. showed that use of 3D bar charts for information visualization tasks resulted in faster performance than did use of on-screen representations [5]. The observed differences in performance were attributed to the ability to touch (but not to manipulate) the physical representations; visual realism was also suggested as a factor in the faster information retrieval [5].

This work raises several questions: Might we see similar advantages to physicality for a form of visualization not considered problematic for on-screen viewing, or for very simple representations of data? Are differences in efficiency visible when inherently 2D visualizations (i.e. visualizations that do not use a third dimension in an on-screen format) are made physical?

In addition to their efficiency, physical visualizations could be superior to traditional representations along other dimensions. Vande Moere suggests that "what a pixel-less display might lose in resolution and information bandwidth, it could make up in a richer, more intriguing and memorable experience that nonetheless communicates complex information and insight" [12]. Though common characteristics of physical visualizations *not* tied to physicality might play a role (e.g. novelty and scale), level of engagement and memorability of physical visualization are yet unexplored. As the volume of data we encounter on a daily basis increases, representation techniques that have the potential to make data stand out, promote curiosity, make it easier to begin engaging with a representation, or make examination of data particularly interesting or enjoyable merit examination.

Relatedly, as suggested by Vande Moere, physical visualization might be promising in a 'casual infovis' [9] context [12]; here, such characteristics might be of even greater importance than within a traditional infovis setting.

In addition to work on physical visualization, work in the realm of shape-changing interfaces also motivates the proposed investigation. Though not created for the (sole) purpose of information visualization, shape-changing interfaces already in existence might be used for the display of data; several examples of such interfaces are shown in Figure 1. Though relatively coarse-grained, one can imagine how they might serve in the display of data, with segments changing position in order to most effectively display a particular physical representation. Such displays have already been used in communication of data that is inherently spatial. Are they useful in other contexts, namely, in displaying non-spatial data? In future, as shape-changing interfaces become more fine-grained and have greater capacity for display, and 'physically dynamic surfaces' [1] come into mainstream use, we might see the physical as an element of visualization done "on-screen". One can imagine a screen where individual pixels could be extruded, essentially a screen-based, vertically-oriented, higher-resolution version of inFORM [2].

With the advancement of shape-changing interfaces, as well as the advancement and increased accessibility of digital fabrication (a result of lower costs and lowered entrance barriers, in part due to software such as MakerVis [11]), the creation of physical representations is becoming more probable and more promising. If this is how data might be displayed in future, it is pertinent to examine how physical representations might differ from current representations. Stemming from the above, the purpose of the proposed investigation is to compare memorability and engagement, as well as accuracy and efficiency of information retrieval using extruded bar charts, a simple form of physical visualization, with that using on-screen versions of the same bar charts.

Study Design

Participants will be invited to perform a series of information visualization tasks (as in [2]), using extruded bar charts, and on-screen bar charts. Physical graphs will be constructed from foamcore, and presented as if they were onscreen (Figure 2). Tasks will be based on those in [2], typical of things one might do when examining a visualization, modified to fit a chart with a single row of bars rather than a matrix of bars.

Figure 2. Extruded bar charts.

In order to examine efficiency and accuracy, the time taken to complete each question will be recorded, and answers marked for correctness. After completing the study, participants will be sent a follow-up email soliciting details of what they remembered of the data presented. Response will be free-form, and requested within 24 hours of receipt of the initial email. In order to examine memorability, participants' email responses will be examined for datasets and data points recalled. These will be coded by technique (i.e. whether the participant viewed a particular dataset in physical or on-screen form). User engagement will be examined via Likert-scale responses to questions such as "I was immersed in these tasks", "The presented data was engaging", posed after answering the questions associated with each graph.

Limitations and Future Work

The proposed investigation has several limitations. The novelty of physical visualization might conflate measures of engagement and memorability. In addition, engagement is difficult to operationalize – posing Likert-scale questions might not be the best way of doing so.

Though related to both engagement and memorability, understanding is another parameter that might be used in evaluation of physical visualization. Physical visualization could facilitate greater understanding of a particular dataset, via double encoding of information already present in the visual modality, new representations that take advantage of an additional dimension or standard representations that allow for interaction in new ways. Even our language associates physicality with understanding; we use terms like "grasp" and "have a handle on [a topic]" to describe understanding. Research in education and developmental psychology indicates physical object manipulation promotes understanding [5]; this is related to the theory of embodied cognition, the idea that "cognitive processes are deeply rooted in the body's interactions with the world" [13]. However, relatively few investigations have directly compared physical and non-physical versions of the same task, and thus the importance of physicality is remains debatable [7]. Future work could explore how physical visualization might facilitate understanding.

Conclusion

Physical representations might promote curiosity, facilitate greater or more efficient understanding, or be more memorable or more engaging. Exploring user engagement with and understanding of such representations, as well as memorability of data presented in this manner is pertinent as the volume, velocity and variety of data in our lives is ever increasing.

In the past, representations of data were designed primarily for print. With the advent of computers, visualization came to be designed for viewing onscreen, and the possibility of interactivity developed. Now, the possibility of designing for physicality also exists. Here, an evaluative study is proposed which explores potential differences between flat, on-screen bar graphs and extruded bar graphs. Such investigations are relevant as the creation of physical representations become more prevalent and more promising.

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