Critical Review: Exploring Interactions with Physically Dynamic Bar Charts

Introduction

Studies investigating how data can be effectively presented to, explored and interpreted by users forms the core part of Information Visualisation ('InfoVis') to support users in the decision-making process. This review summarises and critically analyses Taher et al. [2015] whose paper explores the use of physically dynamic bar chart as a device for exploring user interactions with visualisations of data, to determine future work in this domain of Information Visualisation.

Summary of Contributions

Taher et al. seeks to extend existing work on use of physical visualisations (*physicalizations*) [Jansen et al., 2015] to investigate how users interact with *physically dynamic* bar charts as a way of exploring and manipulating shape-changing datasets in the physical world. Much of the existing work reliant on use of physicalizations involve problematic *static* models that do not respond to user interactions [Jansen et al., 2013] and are therefore "*disconnected*" from the source of the data when they are created. With the advent of shape-changing technology and tangible interfaces [Rasmussen et al., 2012], there is a window of opportunity for the manufacture of physically dynamic displays to help decision makers reason about and manipulate data sets in a non-virtual and non-static way. It is this motivation that leads Taher et al. to explore the ways users interact with data displayed in this mode to understand whether *physical* interactions with data (such as touching specific bars) or *gestures* (such as swiping a touch-screen) or a combination of the two is more intuitive to users interacting with data visualisations in order to solve common problems. Whilst the authors concede that the use of physical dynamic visualisations is not new [Leithinger and Ishii, 2010, Follmer et al., 2013], they claim there is little in the way of analysis into effective *interactions* with data of dynamic physical modality.

The authors pose several main research questions:

The point system described by the article to support the author's research is *EMERGE* - a 10×10 physical bar chart which uses a set of dynamic self-actuating rods with an RGB display projected onto it (Figure 1). This system allows users to interact with the dataset it represents using a set of 4 task-sets derived from subcategories of the taxonomy of interactive dynamics for visual analysis described by Heer and Shneiderman [2012] - *annotation*, *filtering*, *organisation* and *navigation* (Table 1).

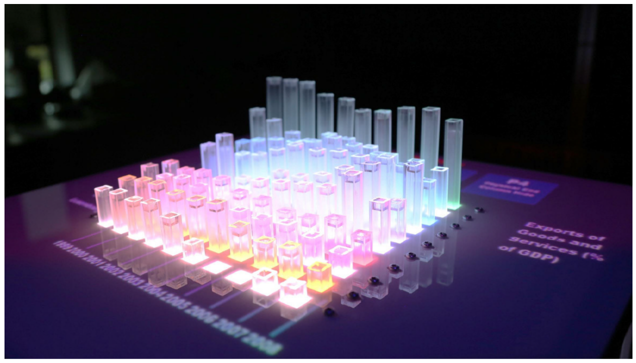

Figure 1: EMERGE: Exploring Interactions with Physically Dynamic Bar Charts using actuating physical rods and RGB LEDs to display international export data.

Heer and Shneiderman lay out 3 high-level categories in their model - *Data and View Specification*, *View Manipulation*, and *Process and Provenance*. (Figure 2). In this sense, whilst the selection of InfoVis model is careful and grounded in background theory, the choice of subcategories by Taher et al. for interacting with EMERGE is somewhat arbitrary and limited in scope, which invites further research into different forms of interactions with physicalisations from the taxonomy.

Table 1: Task-sets and interaction techniques explored during the user study with EMERGE: annotation, filtering, organisation and navigation with the category of Heer and Shneiderman [2012] in bold.

Task	**Overview**	**Interaction Techniques**
Annotation ***(Process & provenance)***	Selecting and marking individual data points.	Point, pull, press.
Filtering ***(Data view & specification)***	Hiding and refining data for enhanced perception and comparison.	Swipe away, manual press, assisted press, press shortcut, and press to compare.
Organization ***(View manipulation)***	Data arrangement by moving rows and columns.	Drag and drop with immediate transition and hide-all with transition, press with instant transition and hide-all with transition.
Navigation ***(View manipulation)***	Controlling the view of large data sets.	Scroll, directional arrows, directional press, and paging.

Data and View Specification	**Visualize** data by choosing visual encodings.
	Filter out data to focus on relevant items.
	Sort items to expose patterns.
	Derive values or models from source data.
View Manipulation	**Select** items to highlight, filter, or manipulate them.
	Navigate to examine high-level patterns and low-level detail.
	Coordinate views for linked, multidimensional exploration.
	Organize multiple windows and workspaces.
Process and Provenance	**Record** analysis histories for revisitation, review, and sharing.
	Annotate patterns to document findings.
	Share views and annotations to enable collaboration.
	Guide users through analysis tasks or stories.

Figure 2: Taxonomy of interactive dynamics described by Heer and Shneiderman [2012].

In reviewing previous research into static and dynamic visualisations

The main contributions of Taher et al. [2015] is threefold. First, the authors present a set of 14 potential interactions (both physical and gesture based) for manipulating and exploring data presented in dynamic physical bar charts. Second, the findings of their user study evaluates which of the 14 interactions are effective and intuitive in completing a set of data analysis tasks, and which interactions match users' initial preconceptions for how to achieve these tasks. Finally, a set of important design considerations are presented to advise future research on the challenges of presenting data in physically dynamic form.

Overall, we learn that...

Justifications for Conclusions

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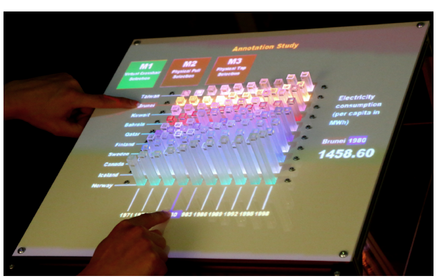

Figure 3: Annotation (Point technique).

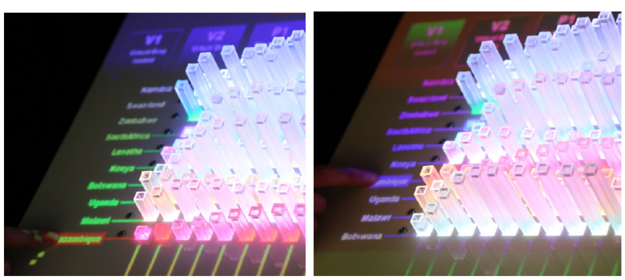

Figure 4: Organisation (Drag and Drop technique).

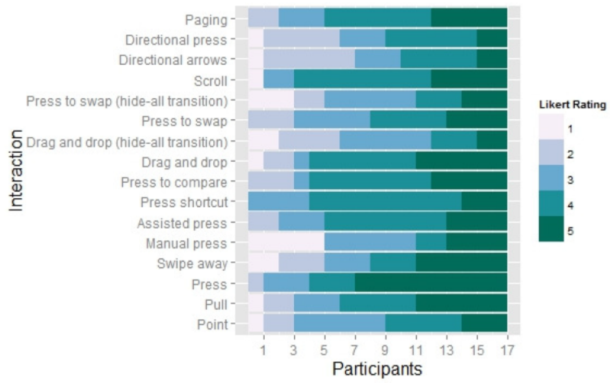

Figure 5: Likert scale ratings for helpfulness of interaction techniques. Range = 1: Strongly Disagree, 5: Strongly Agree.

Limitations and Suggested Further Work

Taher et al. [2015] present a respectable overview of potential techniques to interact with data presented in a physically dynamic form, but a set of limitations with their work leads to some questions being open to future research.

Authors:

- Data manipulation with external objects
- Multi-finger input
- Pressing over time
- Complex task explorations from taxonomy - undo/redo, different filtering (e.g. thresholding)
- Combining interactions
- Controlled studies with performance metrics (e.g. task completion times, accuracy)

Novel:

- Larger datasets - the 10x10 grid limits representations
- Technical challenges (actuation speed and noise, rod spacing, size of setup) may have mediated the results - no investigation e.g. parallel mediated regression testing into this.
- Study showed almost all participants hesitant to interact with system due to speed of actuation or noise of actuators

- Larger sample size - 17 not enough.
- Excluded vertical axis data - difficult to anticipate how this might change user interactions and behaviours.
- Not just bar charts!
- Complex datasets which change in real time - e.g. social networks [Federico et al., 2011].
- Different taxonomy - zoom, select, derive, sort, history.
- Lack of parametric data - study could investigate performance and accuracy of tasks being completed.
- Apply it to a specific context to compare across modalities in an educational setting for those who learn best by adopting kinaesthetic techniques [Pourhosein Gilakjani, 2011] or even used in a VR-kin setting [Tennent et al., 2017].

Conclusion

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Word count: 0 words (not inc. Citations, Figures or References)

References

Paolo Federico, Wolfgang Aigner, Silvia Miksch, Florian Windhager, and Lukas Zenk. A visual analytics approach to dynamic social networks. 09 2011. doi: 10.1145/2024288.2024344.

Sean Follmer, Daniel Leithinger, Alex Olwal, Akimitsu Hogge, and Hiroshi Ishii. inform: Dynamic physical affordances and constraints through shape and object actuation. In *Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology*, UIST '13, pages 417–426, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-2268-3. doi: 10.1145/2501988.2502032. URL `http://doi.acm.org/10.1145/2501988.2502032`.

Jeffrey Heer and Ben Shneiderman. Interactive dynamics for visual analysis. *Commun. ACM*, 55(4):45–54, April 2012. ISSN 0001-0782. doi: 10.1145/2133806.2133821. URL `http://doi.acm.org/10.1145/2133806.2133821`.

Yvonne Jansen, Pierre Dragicevic, and Jean-Daniel Fekete. Evaluating the efficiency of physical visualizations. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '13, pages 2593–2602, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-1899-0. doi: 10.1145/2470654.2481359. URL `http://doi.acm.org/10.1145/2470654.2481359`.

Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, and Kasper Hornbæk. Opportunities and challenges for data physicalization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 3227–3236, New York, NY, USA, 2015. ACM. ISBN 978-1-4503-3145-6. doi: 10.1145/2702123.2702180. URL `http://doi.acm.org/10.1145/2702123.2702180`.

Daniel Leithinger and Hiroshi Ishii. Relief: A scalable actuated shape display. In *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '10, pages 221–222, New York, NY, USA, 2010. ACM. ISBN 978-1-60558-841-4. doi: 10.1145/1709886.1709928. URL `http://doi.acm.org/10.1145/1709886.1709928`.

Abbas Pourhosein Gilakjani. Visual, auditory, kinaesthetic learning styles and their impacts on english language teaching. *Journal of Studies in Education*, 2:104, 12 2011. doi: 10.5296/jse.v2i1.1007.

Majken K. Rasmussen, Esben W. Pedersen, Marianne G. Petersen, and Kasper Hornbæk. Shape-changing interfaces: A review of the design space and open research questions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 735–744, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1015-4. doi: 10.1145/2207676.2207781. URL `http://doi.acm.org/10.1145/2207676.2207781`.

Faisal Taher, John Hardy, Abhijit Karnik, Christian Weichel, Yvonne Jansen, Kasper Hornbæk, and Jason Alexander. Exploring interactions with physically dynamic bar charts. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 3237–3246, New York, NY, USA, 2015. ACM. ISBN 978-1-4503-3145-6. doi: 10.1145/2702123.2702604. URL `http://doi.acm.org/10.1145/2702123.2702604`.

Paul Tennent, Joe Marshall, Brendan Walker, Patrick Brundell, and Steve Benford. The challenges of visual-kinaesthetic experience. In *Proceedings of the 2017 Conference on Designing Interactive Systems*, DIS '17, pages 1265–1276, New York, NY, USA, 2017. ACM. ISBN 978-1-4503-4922-2. doi: 10.1145/3064663.3064763. URL `http://doi.acm.org/10.1145/3064663.3064763`.