Guiding visualization practice with questions: 10qviz.org

Arzu Çöltekin and Alyssa Goodman

Abstract— Visualization expertise is complex to break down into simple set of rules in that it requires both cross-disciplinary scientific understanding as well as a sense of artistic mastery and craftsmanship. To be able to properly study why a visualization might or might not work well, and establish an evidence-based cause-effect framework, one needs to have sufficient literacy in mechanisms of human information processing such as sensation, perception and cognition as well as computational sciences such as statistics, data science, and computer graphics. On the other hand, dozens of software are readily available that produce static or interactive visualizations at the press of a few buttons, available to all citizens, including scientists and data journalists who work intensively with graphics even though they may not have any formal training in visualization. In this paper, we discuss if this seemingly chaotic 'democratization' process be accompanied with a distilled set of expert- and literature-driven *questions*, rather than instructions, to guide anyone who visualizes data / information as rules of thumb.

Index Terms—Visualization, literacy, guidelines

Introduction

Visualization, both as a product and as a process, is of critical importance in many professional domains, including nearly all sciences ranging from studying microscopic phenomena in biology (e.g., Cruz, Arrais, & Machado, 2019) through mezzo scale ones geography (e.g., Çöltekin, Griffin, & Robinson, 2021) to macro scale structures in astronomy (e,g,, Goodman, 2012). To the disappointment of visualization researchers, the design of this important facilitator (i.e., visualization design) is often guided by software defaults and instinct. Neither the average software nor the human instinct is great guides for designing visualizations: It is rare that software development processes are in collaboration with visualization researchers or design professionals, and software developers are rarely trained in cognitive and perceptual sciences to systematically assess the implications of their design choices on humans. Instinct can lead to outcomes that please a personal aesthetic, though does not necessarily lead to effective, correctly understood and interpreted visualizations. This is because there can be a mismatch between people's preference and performance with visualizations (e.g., Hegarty, Smallman, Stull, & Canham, 2009; Lokka, Çöltekin, Wiener, Fabrikant, & Röcke, 2018; Smallman & John, 2005). In design communities a well-known motto is "designer is not the user" (Çöltekin et al., 2020; Helminen, Hamalainen, & Makinen, 2010), which alludes to the fact that expert users, such as the designers themselves differ in their usage patterns and performance with visualizations, which is supported by a plethora of evidence from empirical studies (Çöltekin et al., 2016; Çöltekin, Fabrikant, & Lacayo, 2010; Roth et al., 2017). Due to lack of awareness that one should neither rely of software defaults or own instincts, many people accidentally produce ineffective visualizations in interdisciplinary contexts (including scientists and data journalists). On the other hand, a body of well-evidenced knowledge is emerging from empirical studies on how people experience visualizations, as well as when and why visualizations fail to facilitate what they aim to facilitate. Thus, there is a clear *knowledge transfer gap* between the visualization researchers and those who create them as a by-product of their work. For example, a recent study demonstrates that while visualization communicates moved away from rainbow colors scheme, others continue using it (Golebiowska, & Çöltekin, under review).

- *Arzu Çöltekin is with Institute of Interactive Technologies, University of Applied Sciences and Arts Northwestern Switzerland, Switzerland. E-mail: arzu.coltekin@fhnw.ch.*
- *Alyssa Goodman is with Center for Astrophysics, Harvard University, E-mail: agoodmam@cfa.harvard.edu*

Given the above, we believe an approachable, easy-to-digest, yet well informed guide without jargon is important to create and promote. However, the multi-layered, interdisciplinary visualization knowledge is not easy to distil into practicable rules of thumb. In this paper we briefly present a question-based approach to guide the practitioners of visualizations based on visualization research into rules of thumb optimized for scientists and data journalists who are not trained in visualization design. Specifically, we offer the reader a set of questions they need to ask themselves before making visualization decisions. We believe using questions rather than commands may trigger thinking case by case, making the guidelines work for fundamentally different cases.

1 The ten questions

Based on a series of brainstorming sessions by authors and a literature study, we came up with the following questions:

1. Who. Who is your audience? How expert will they be about the subject and/or display conventions?
2. Explore-Explain. Is your goal to explore, document, or explain your data or ideas, or a combination of these?
3. Feature recognition. Is feature and/or pattern recognition a goal?
4. Predictions & Uncertainty. Are you making a comparison between data and/or predictions? Is representing uncertainty a concern?
5. Dimensions. What is the intrinsic number of dimensions (not necessarily spatial) in your data, and how many do you want to show at once?
6. Categories & Clustering. Are there natural, or imposed, categories within the data? Are you interested in clustering?
7. Abstraction & Accuracy. Do you need to show all the data, or is summary or abstraction OK?. How literally accurate does your visualization need to be?
8. Context & Scale. Can you, and do you want to, put the data into a standard frame of reference? Is a single scale OK, or do you need more than one at once?
9. Metadata. Do you need to display or link to non-quantitative metadata?
10. Display modes. What display modes might be used in experiencing your display?

These ten questions are work-in-progress questions, and they may remain that way for a long time to come. However, they capture a fairly comprehensive set of visualization knowledge and can guide the decisions that follow. While there would be also some technical considerations—such as *data sources* (are your data all in one

file/source, or many?), *formats* (are/is your data files/file in a standard format, and/or can they/it be put into one?) or considering *custom code* (are you interested in a custom solution, which may mean writing new code, or are you seeking a more off-the-shelf and/or GUI-based solution? Is a combination OK?)—, and these ten questions are by no means a final solution to turning all bad visualizations into good ones, they provide a sense of which decisions matter as a starting point.

To detail each question in a live document and enable interaction and reach out to non-visualization communities, we created a blog (Figure 1) at the URL https://10qviz.org/.

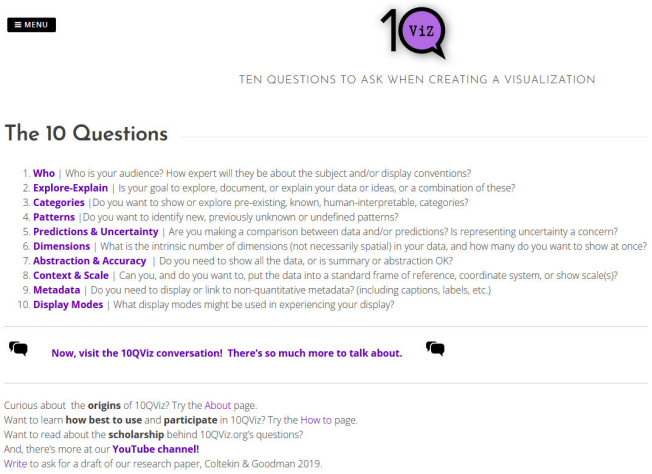

Fig. 1. 10Qviz.org blog front page.

The blog summarizes and illustrates examples for each question, and allows contributions by others via guest posts, integrated commentary as annotations of text and graphics, as well as the more traditional forum-like discussions. We also maintain additional social media channels such as a twitter account (https://twitter.com/10qviz) and youtube (https://tinyurl.com/10qviz) as a companion to 10QQViz and reach out beyond the usual visualization communities.

2 Conclusions and Outlook

Our approach is a work-in-progress effort to develop a question-based visualization guide for non-experts. We are working on a literature review examining each of the 10 questions from multidisciplinary perspectives, and plan conducting two user studies: in-depth expert interviews to reevaluate our 10 questions, and an end-user focused study where we test how well the questions are understood and/or if non-experts can answer these questions for their own use cases.

References

Çöltekin, A., Brychtová, A., Griffin, A. L., Robinson, A. C., Imhof, M., & Pettit, C. (2016). Perceptual complexity of soil-landscape maps: a user evaluation of color organization in legend designs using eye tracking. *International Journal of Digital Earth*, 1–22. https://doi.org/10.1080/17538947.2016.1234007

Çöltekin, A., Fabrikant, S. I., & Lacayo, M. (2010). Exploring the efficiency of users' visual analytics strategies based on sequence analysis of eye movement recordings. *International Journal of Geographical Information Science*, *24*(10), 1559–1575.

Çöltekin, A., Griffin, A. L., Slingsby, A., Robinson, A. C., Christophe, S., Rautenbach, V., … Klippel, A. (2020). Geospatial Information Visualization and Extended Reality Displays. In *Manual of Digital Earth* (pp. 229–277). Singapore: Springer Singapore. https://doi.org/10.1007/978-981-32-9915-3_7

Çöltekin, A., Griffin, A., & Robinson, A. (2021). Visualizations. In *Geography*. Oxford University Press. https://doi.org/10.1093/obo/9780199874002-0224

Cruz, A., Arrais, J. P., & Machado, P. (2019). Interactive and coordinated visualization approaches for biological data analysis. *Briefings in Bioinformatics*, *20*(4), 1513–1523. https://doi.org/10.1093/bib/bby019

Golebiowska, & Çöltekin (under review). What's wrong with the rainbow? An interdisciplinary review of empirical evidence for and against rainbow color scheme in visualizations. *International Journal of Photogrammetry and Remote Sensing.*

Goodman, Alyssa A.,. (2012). Principles of High-Dimensional Data Visualization in Astronomy. *Eprint ArXiv:1205.4747*. Retrieved from http://adsabs.harvard.edu/abs/2012arXiv1205.4747G

Hegarty, M., Smallman, H. S., Stull, A. T., & Canham, M. S. (2009). Naïve Cartography: How Intuitions about Display Configuration Can Hurt Performance. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *44*(3), 171–186.

Helminen, P., Ha¨ma¨la¨inen, M. M., & Ma¨kinen, S. (2010). Redefining User Perception: A Method for Fully Capturing the User Perspective of a Product Concept. In *Volume 5: 22nd International Conference on Design Theory and Methodology; Special Conference on Mechanical Vibration and Noise* (pp. 223–230). ASMEDC. https://doi.org/10.1115/DETC2010-28698

Lokka, I. E., Çöltekin, A., Wiener, J., Fabrikant, S. I., & Röcke, C. (2018). Virtual environments as memory training devices in navigational tasks for older adults. *Scientific Reports*, *8*(1), 10809. https://doi.org/10.1038/s41598-018-29029-x

Roth, R. E., Çöltekin, A., Delazari, L., Filho, H. F., Griffin, A., Hall, A., … van Elzakker, C. P. J. M. (2017). User studies in cartography: opportunities for empirical research on interactive maps and visualizations. *International Journal of Cartography*, 1–29. https://doi.org/10.1080/23729333.2017.1288534

Smallman, H. S., & John, M. S. (2005). Naive realism: Misplaced faith in realistic displays. *Ergonomics in Design: The Quarterly of Human Factors Applications*, *13*(3), 6–13.