

APPENDIX

C. Example 1

A. Open Coding Procedure

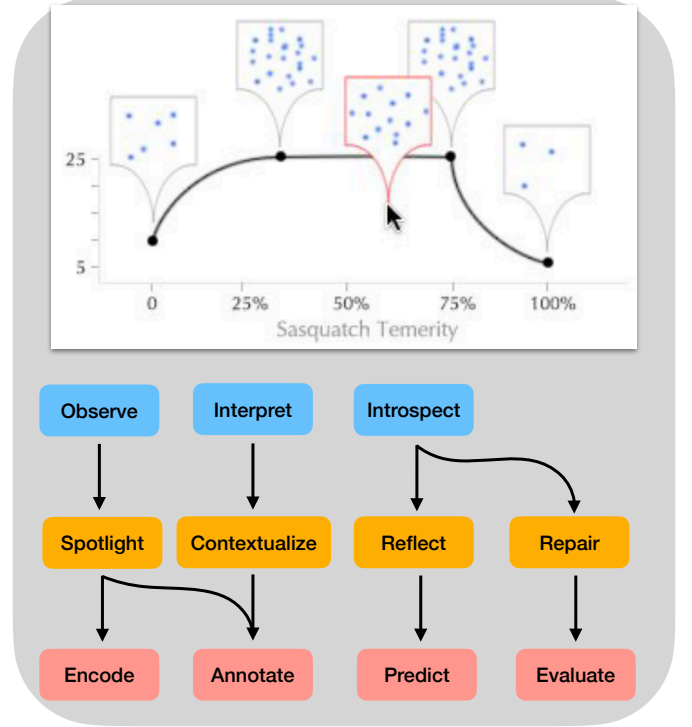
One author analyzed the filtered corpus of 52 papers, extracting *why* a visual augmentation or feature described in the paper was used (*objectives*), *what* purpose it served (*strategies*), and *how* it was realized (*tactics*). Codes for the extracted data were generated and iteratively refined, organized, and categorized through multiple rounds of discussion between two of the authors, with all authors reviewing the final design space. Our ideas and categories evolved significantly throughout this process (e.g., observing shared strategies across different tactics); we revisited prior examples to re-categorize when appropriate, doing our best to maintain consistent evaluation.

Other design space dimensions were considered, such as data semantics (e.g., type or distribution of data), usage context (e.g., news article, mobile, supporting text or tables, etc.), and chart characteristics (e.g., static vs. interactive, use of titles or captions, data representation, etc.). Overall, we found that many of these dimensions did not help to meaningfully partition the space of augmentations, as most were used to implement different variations of the same strategy (e.g., faceting vs. interactive steppers can both *sequence* a chart), but did not otherwise affect higher-level design objectives.

B. Augmentation Categorization of Paper Corpus

To assess the completeness of our design space in representing the existing literature, we revisited our paper corpus to categorize each paper along our design space dimensions. The outcome of this process is shown in Table A1, though we do not delineate how these dimensions relate to each other (e.g., which tactics support which strategies). We provide seven additional visualizations from this table in the following sections, showcasing how our design space can be used to describe and analyze their visual augmentations.

Dimensions in Table A1 are only activated based on the manner they are used or discussed in a given paper, including results from user studies, system features and design, or features of a design space / taxonomy. Further, we only activate dimensions that are used to communicate information beyond denotative graphical decoding (as defined in section II of the main paper). For example, Mackinlay’s APT system [40] presents a standard set of encoding choices (c.f., Fig. 15), though they are not discussed in the context of our higher-level design strategies (e.g., using *encodings* to *spotlight* particular information). If this were the case, then any discussion of chart types or *denotative* encoding choices (nearly all papers in our corpus) would qualify as observation and / or interpretation aids since they inherently affect chart comprehension [53], [54]. However, Mackinlay does discuss faceting (a *layout* tactic) in the context of *sequencing* (i.e., arranging content in a particular order), which can serve as an *observation* aid for identifying salient trends less obvious with standard encodings. We used this line of reasoning to identify strategies and objectives in a consistent manner for all tactics described in a given paper.



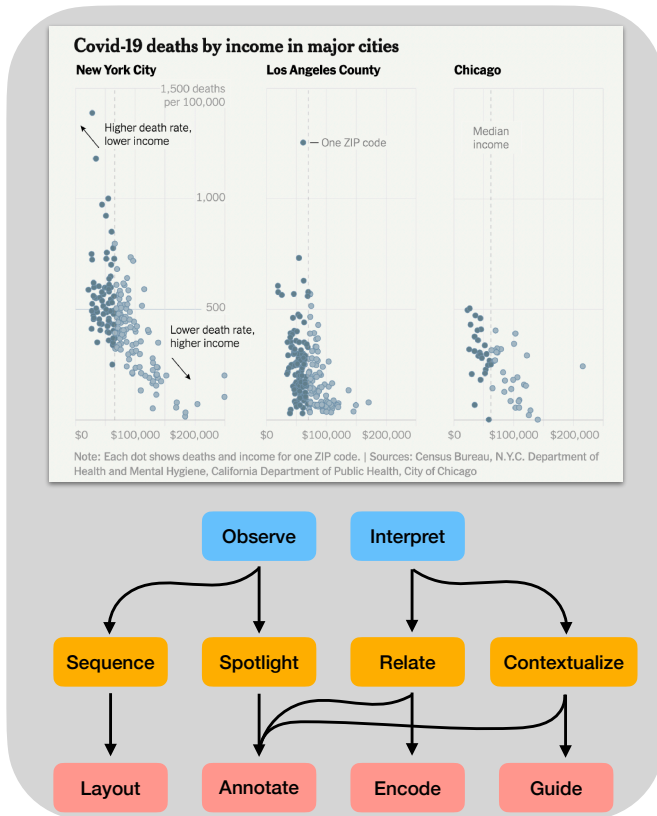
This visualization was used by Victor [2] to demonstrate complementary interactions between concrete examples (annotated pop-ups) and abstract representations (the underlying curve). Specifically, *annotated* cut-outs *spotlight* particular points along the curve’s path, with example illustrations for *context*. Further, readers can click anywhere on the plane to see an example at that point. This feature may encourage readers to *introspect* and assess their understanding in which they *predict* examples (prompting *reflection*), then clicking to *evaluate* their prediction and *repair* incorrect understanding. Readers’ interactions are *encoded* with a red hue for *spotlighting*.

Reference	Title	First Author	Year	Objectives			Strategies					Tactics													
				Observe	Interpret	Introspect	Sequence	Spotlight	Relate	Associate	Contextualize	Reflect	Repair	Animate	Layout	Transform	Annotate	Encode	Symbolize	Guide	Explain	Predict	Query	Evaluate	Simulate
[1]	Explorable Explanations	Victor	2011																						
[2]	Magic Ink	Victor	2006																						
[3]	Communicating with Inter...	Hohman	2020																						
[4]	A New Medium for Com...	Crichton	2021																						
[5]	Augmented Physics: Creat...	Gunturu	2024																						
[6]	Benefitting InfoVis with Vi...	Hullman	2011																						
[7]	Playable Data: Characteriz...	Diakopoulos	2011																						
[8]	Declutter and Focus: Empir...	Ajani	2021																						
[9]	Animations 25 Years Later:...	Chevalier	2016																						
[10]	CAST: Authoring Data-...	Ge	2021																						
[11]	A Deeper Understanding of...	Hullman	2013																						
[12]	A Review of Learning De...	Ploetzner	2020																						
[13]	Authoring Narrative Visual...	Satyanarayan	2014																						
[14]	Narrative Visualization:...	Segel	2010																						
[15]	Augmenting Visualizations...	Srinivasan	2018																						
[16]	A Taxonomy of Tools that...	Heer	2012																						
[17]	Useful Junk? The Effects...	Bateman	2010																						
[18]	Graphs as Aids to Knowl...	Shah	1999																						
[19]	Visual Arrangements of...	Xiong	2021																						
[20]	A Qualitative Analysis of...	Rahman	2024																						
[21]	Design Patterns for Data...	Bach	2018																						
[22]	Graphics for Learning:...	Clark	2010																						
[23]	Leveraging Text-Chart...	Sultanum	2021																						
[24]	Cognitive Theory of Multi...	Mayer	2005																						
[25]	Storytelling in Information...	Boy	2015																						
[26]	Communicating with Mo...	Shi	2021																						
[27]	Visual Explanations	Tufte	1997																						
[28]	Deixis and the Future of...	Hill	1991																						
[29]	Animation: Can it Facilitate?	Tversky	2002																						
[30]	What We Augment When...	Guo	2024																						
[31]	Do You Want to Promote...	Ancker	2024																						
[32]	V-FRAMER: Visualization...	Ge	2024																						
[33]	Watching the Election...	Cai	2024																						
[34]	Capture & Analysis of Ac...	Conlen	2019																						
[35]	Idyll: A Markup Language...	Conlen	2018																						
[36]	Scientific Communication...	Victor	2011																						
[37]	Do You See What I See? A...	Quadri	2024																						
[38]	A Multi-Level Typology of...	Brehmer	2013																						
[39]	A Survey of Perception-...	Quadri	2021																						
[40]	Automating the Design of...	Mackinlay	1986																						
[41]	The Arrangement of Marks...	Fygenson	2023																						
[42]	Animated Transitions in...	Heer	2007																						
[43]	Graphscape: A Model for...	Kim	2017																						
[44]	Gemini: A Grammar and...	Kim	2020																						
[45]	Visual Narrative Flow: Ex...	McKenna	2017																						
[46]	Explaining with Examples:...	Yang	2023																						
[47]	PersaLog: Personalization...	Adar	2017																						
[48]	Uncertainty Visualization	Padilla	2020																						
[49]	Visual Semiotics & Uncer...	MacEachren	2012																						
[50]	Understanding Comics	McCloud	1993																						
[51]	Explaining the Gap: Visual...	Kim	2017																						
[52]	Effects of Text Illustrat...	Levie	1982																						

TABLE A1

OVERVIEW OF PAPERS THAT WERE USED TO CODE OUR DESIGN SPACE, CATEGORIZED BY USE OR DISCUSSION OF OBJECTIVES, STRATEGIES, AND TACTICS. PAPERS ARE SORTED ACCORDING TO THE NUMBER OF OBJECTIVES PRESENT.

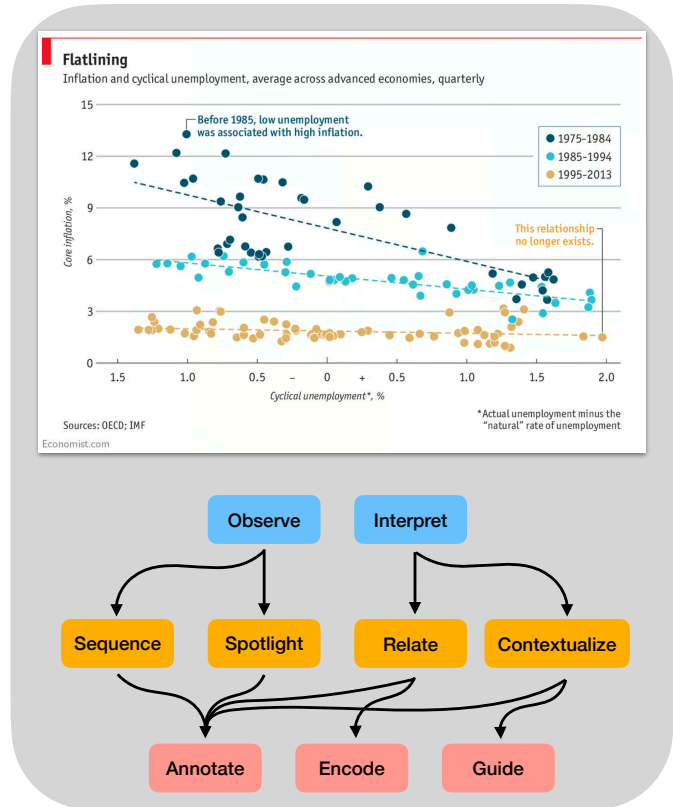
D. Example 2



This visualization from The New York Times [55] shows COVID-19 deaths stratified by three major cities (New York, Los Angeles, and Chicago) and income. Quadri et al. [37] used this chart in a pilot study to explore alignment between readers' takeaways and designers' intent.

Layout (faceting) sequences the different cities to observe differences in COVID-19 deaths. A dotted line annotation serves as a spotlight for the median income; points are color encoded to relate their position with the median divider. Text annotations and guides (title and footnote) provide important context. Finally, arrow annotations help spotlight outliers in particular regions (top left and bottom right) for the reader to observe.

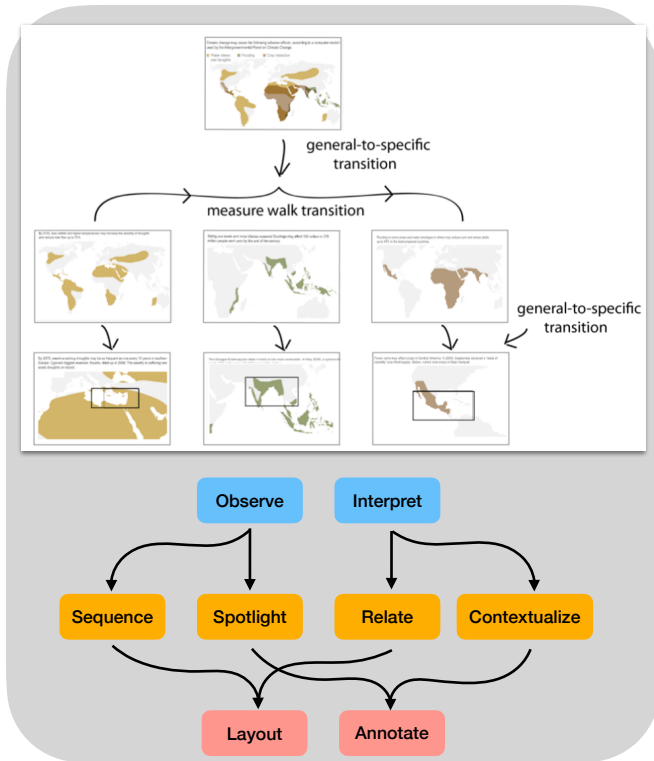
E. Example 3



This visualization displays the weakening correlation between unemployment and inflation across decades. Originally from The Economist [56], this graph was used by Adar and Lee-Robbins [57] to illustrate learning objectives.

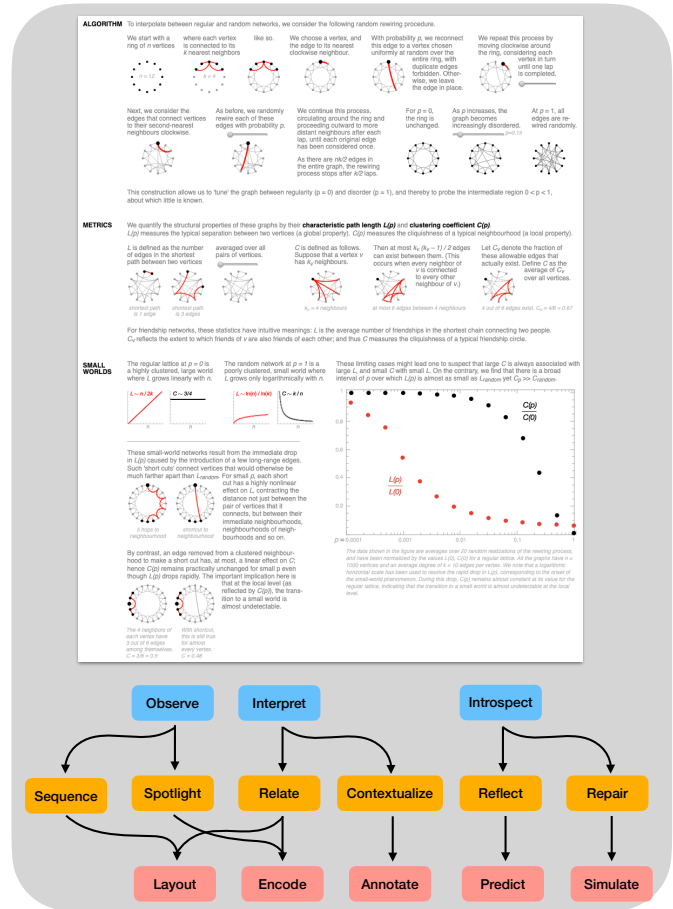
Annotations accomplish four goals: Sequencing and spotlighting with verbal phrasing and left-to-right text placement to observe the weakening correlation over time; adding context to help interpret the relationship between unemployment and inflation; and relating the annotated text with their respective time periods. By also using encoding to relate these items, we can interpret the annotation as referring to the entire time period rather than the single point it connects with. Finally, footnotes, title and subtitle/caption serve as guides for additional context about the chart's message and data sources.

F. Example 4



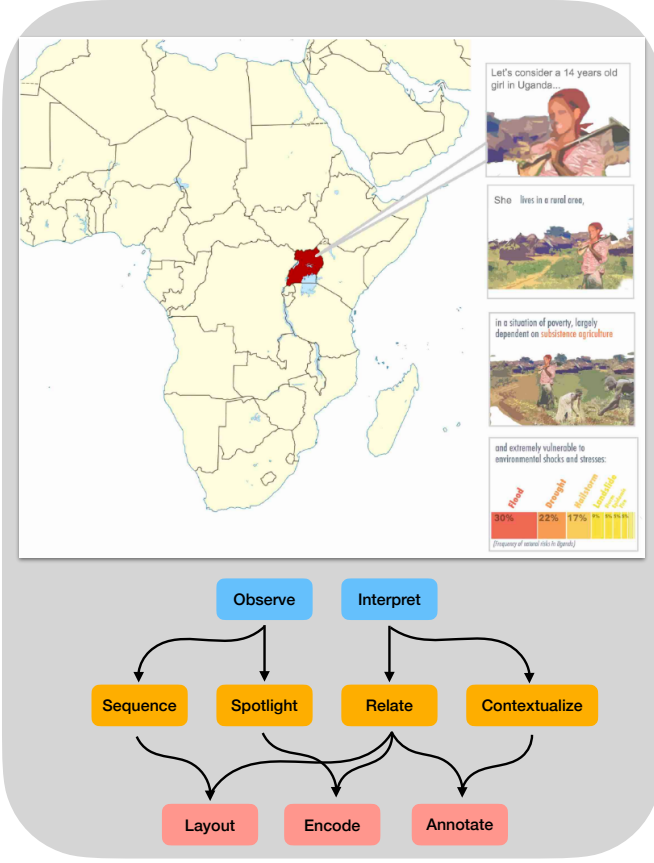
This visualization was used by Hullman et al. [11] (originally from The New York Times [58]) to analyze forms of sequencing in data journalism. In this example, **layout** is used to not only **sequence** a set of insights for the reader to **observe**, but also **relate** these insights and better **interpret** the overall narrative through parallelism (i.e., walking through general-to-specific transitions for each region). **Annotations** are used in each frame to provide **context** about the current view, as well as **spotlight** specific countries near the end of a general-to-specific transition (black cut-out).

G. Example 5



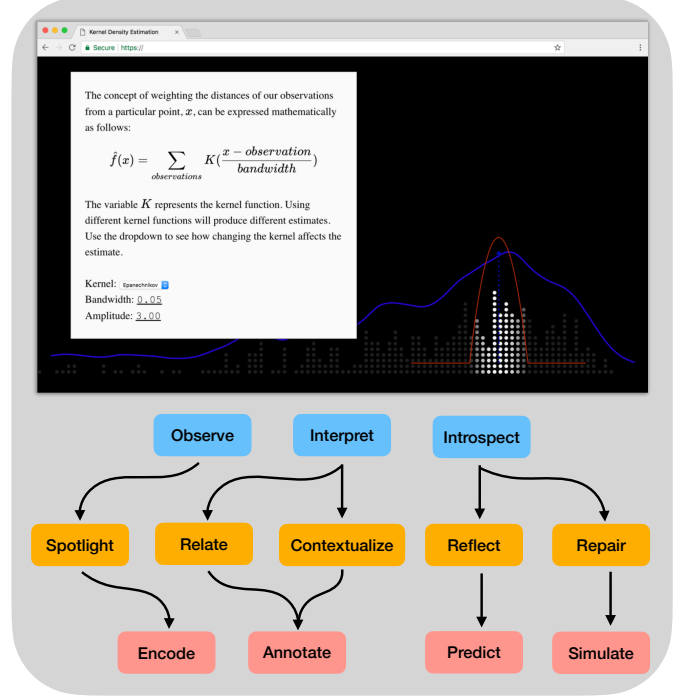
This illustration was authored by Victor [36] to demonstrate the benefits of sequential art for communicating 'small-world' networks [59]. **Layout** helps **sequence** sections of content (algorithm, metrics, small worlds) and to help **observe** the overall organization. This **layout** also **relates** the ordering of algorithmic steps to **interpret** its process. Red hue and bold font **encoding** **spotlights** structural graph properties and **relates** their meaning (red hue to represent paths and bold font to represent clustering coefficients). **Annotations** (in light gray color) are also placed below some of the visuals to provide helpful **context**. Finally, interactive sliders **simulate** certain steps of the algorithm (to **repair** understanding), enabling the reader to **introspect** and **reflect** by making tacit **predictions** about the algorithm's functionality.

H. Example 6



This visualization was used by Bach et al. [21] to demonstrate the use of data comics, narrating conditions of poverty in Uganda. A **layout** of four frames on the right **sequence** a narrative for **observation**, helping **relate** events of the story and data (last frame at the bottom). A bright red hue **encoding** **spotlights** Uganda on the map, with a tapered **annotation** that **relates** it to the narrative sequence. **Annotations** are also provided in each of the narrative frames for additional **context**. Finally, orange hue **encoding** **relates** the third and fourth frames, indicating that the dependency on “subsistence agriculture” is affected by droughts.

I. Example 7



This visualization [60] was created by Matt Conlen using Idyll [35] to explain kernel density estimation (KDE). **Annotated** text in the white box provides important **context** to help the reader **interpret** KDE parameters and their effect on the background visualization. Underlined text **annotations** (bandwidth and amplitude) serves to **relate** interactive parameters throughout the entire document. Based on the selected parameters, data inside the KDE bandwidth is **spotlit** with opacity **encoding**. Finally, readers can **reflect** via **predictions** about the effect of different parameters on the background visualization by changing their values directly, which then **simulate** the KDE algorithm to provide visual feedback and **repair** comprehension.

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