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Short Paper

TexTile: A Pixel-Based Focus+Context Tool For Analyzing Variants Across Multiple Text Scales

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Abstract

Before the advent of printed texts, text duplication was done primarily by hand. Errors, alterations, and erasures were common and varied widely across different copies of the same text. Classics scholars seek to reconstruct an "original" text by analyzing and merging variations across copies as "witnesses" to a conjectured original. Many scholars continue to use spreadsheets, sometimes as large sheets of actual paper, to visually collate variations across known versions. These approaches are generally well suited for collection of data about variations, a process that can take decades. However, they are poorly suited for analysis of variation above the level of individual words. Visualization techniques are needed to reveal patterns of variation at the level of lines, pages, and entire texts. We present TexTile, a new tool that integrates pixel-based and focus+context visualization techniques for analysis of reconstructed classical Latin texts. TexTile provides a comprehensive yet compact representation of variation at multiple levels over an entire text. The tool helps scholars validate the accuracy of textual variants and analyze similarities between different contributing copies. The integrated visualization design allows exploration of variation across textual scales while preserving continuity of browsing, much like when examining a physical manuscript. We conducted a mixed quantitative-qualitative user study to assess the usability of the integrated design.

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [Information Interfaces and Presentations]: User Interfaces-Graphical user interfaces (GUI)—Interaction Styles

1. Introduction

Classics is a wide-ranging humanities discipline that involves a wide variety of text analysis activities. Its diverse topics of study include literature, art, and the history of ancient languages like Latin and Greek. Of the numerous activities that classics scholars engage in today, *philology* remains a central focus. It is a critical analysis process in which scholars compare two or more versions of text, record their similarities, observe interesting patterns and outliers, and construct an annotated version that they believe reflects the structure, content, and meaning of the original.

The Digital Latin Library project [DLL] works in close collaboration with several of the world's most prominent classical Latin scholars to support this process. We interviewed them extensively to determine their digital information activities [ABHW16]. Essential capabilities include browsing entire texts with their footnotes, interacting with text structure at different scales, searching and filtering on variation information, highlighting interesting features, and formulating and verifying hypotheses about variation. A major goal of the DLL project is to support these capabilities through integration of text and other visualization techniques in a full-featured, cross-platform desktop application. Toward this goal, we built *TexTile*, a novel tool for visualizing variation in hierarchical text. TexTile integrates pixel-based, focus+context, and coordinated interaction techniques to create a single, continuous display.

We previously described evaluation of a prototype design in which these techniques were isolated in distinct views [AEA*16]. The design was effective for reading variation at a single level, whether of words, lines, or pages. However, participants' feedback reflected difficulty in scanning and navigating across levels of text. Repeatedly moving between views to change the level of focus made for slow, tedious, and error-prone navigation. This had the effect of inhibiting both scanning to find patterns of variation and drilling down to examine details about particular text elements.

To overcome these limitations, TexTile uses a single 2-D layout. It displays text hierarchy horizontally and sources of variation vertically. This design is inspired by the Perspective Wall [MRC91] visualization of file system structure. TexTile's integrated design provides an overview of an entire text while simultaneously aggregating variations into line and page tiers around a chosen focal word and its neighbors. We ran a new user study to evaluate the design in terms of key domain-independent tasks (Wehrend, et al. [WL90]). We found that locate, comparison, and distribution tasks are relatively easy to perform. Cluster and correlation tasks remain difficult, but improvable through features to filter and sort witnesses.

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2. Related Work

TexTile draws on the well-established techniques of pixel-based encoding, focus+context representation, and direct manipulation interaction for navigation and selection. Integration of these features aims to overcome limitations of the user interface tools currently used to analyze variation in classical texts.

Pixel-based visualization is a technique popularized by Keim [Kei00]. It efficiently represents large amounts of data in limited screen space by displaying each data point as a single pixel or a small region of pixels. Each pixel's color is calculated from a color map that covers the range of data values being represented. Notable techniques that use pixel-based visual encoding of data include Literature Fingerprinting [KO07], Sequence Surveyor [ADG11], and Poetry Visualization [ARLC*13].

Exploration in a single view typically involves paging, scrolling, or panning and zooming to navigate an information space. In contrast, exploration using multiple views encounters discontinuities through the need to navigate both within and between multiple views of often different information spaces. Overview+detail and focus+context are two well-known approaches to layout and coordinate views to facilitate transitions during navigation. In their review of these approaches, Cockburn, et al. [CKB09] described several advantages of focus+context techniques. Placing the focus within contextual views helps users maintain a sense of context while investigating details of data. This allows traversal over data scales/levels to happen more smoothly and continuously. In many cases all views/scales can be presented and explored in a single coherent display. Prominent examples include the Perspective Wall [MRC91] for visualizing document file systems, VarifocalReader [KJW*14] for intra-document exploration, and TreeJuxtaposer [MGT*03] for comparing hierarchical data sets.

To date there has been relatively little application of visualization techniques to variant analysis in classical language studies. The complexity of the collation process and the resulting data may be one reason for this. Collating a manuscript for a new scholarly edition of a text involves idiosyncratic comparison of a myriad of variations spread throughout tens of historical copies as well as the information contains in earlier editions. This process frequently calls for switching between distant reading [Mor13] through an evolving spreadsheet/paper collation table and (very) close reading of these *witnesses* directly. Juxta [WJ13], TRAViz [JGF*15], and ShakerVis [GCL*15] are some of the tools available for comparing and visualizing variant information. Although these tools help in recognizing density patterns in different text metrics, they generally lack features for navigating and querying text itself at the scales of pages, lines, and words. Moreover, they tend to scale poorly, both visually and interactively, for more than a few text versions, which can number 50 or more in many cases. TexTile readily scales to this number both representationally and interactively. The results of our user study suggests that in TexTile the bottleneck is instead user perception, calling for features to search and filter versions.

3. Design and Implementation

Through our evaluation of the prototype tool [AEA*16], we identified two key features for incorporation into TexTile. First, TexTile implements a tiered hierarchy of views to provide an integrated focus+context display similar to Perspective Wall [MRC91]. The Perspective Wall has a front-facing center view that displays the details of a filesystem, such as documents in a folder. On either side of the central view are walls that display context to the left and right, shrinking to the horizon. These walls display files aggregated into their corresponding folders. In TexTile, the center view displays a column for each word and its variants, with the centermost column as focal point. The side views aggregate variation in cascading levels of lines and pages. This approach allows continuous exploration of tiered hierarchies such as in textual (book, chapters, pages, lines, words, characters) and geographical (country, state, county) data. Second, pixel color is mapped to an analogous, higher contrast yellow-orange-red color scheme based on user feedback. The tool is implemented using Improvise [Wea04], a visualization environment to design and implement highly-coordinated visualizations.

3.1. Tiered Layout

The central *Lemma View* (Fig. 1A) represents the annotated text of an edition at its lowest level of granularity, the *lemma*. A lemma is an editing choice, usually of a word and its spelling, informed by variation across witnesses. Horizontally, lemmata appear in order of their occurrence in the *apparatus* (footnotes). This is almost always natural reading order. Vertically, witnesses appear in their order (usually by influence) in the *conspectus*. The central view (@) always has one lemma, at position w in the lemma sequence, as its focus. A colored pixel at a column-row intersection indicates the presence of variation for that lemma-witness combination.

To the left ("<Lemmata") and right ("Lemmata>") side of the focus are 13 columns, showing trailing and following lemmata. The ranges of lemmata displayed in the left and right Lemma Views are [w-13, w-1] and [w+1, w+13]. If there are fewer than 13 lemmata prior to or following the lemma in focus, only the lemmata present are displayed, and some columns appear blank.

On both sides of the Lemma Views are *Line Views* (Fig. 1B). Columns show witness-variant co-occurrence for entire lines. The left ("<<Lines") and right ("Lines>>") Line Views display 9 columns (lines) each. For line number L, the ranges of line numbers displayed in the left and right Line Views are [L(w-14)-8, L(w-14)] and [L(w+14), L(w+14)+8]. The innermost column of each Line View sometimes shows a partially aggregated line. This happens when that line still has lemmata visible in the Lemma View.

On both sides of the Line Views are *Page Views* (Fig. 1C). Columns show witness-variant counts aggregated at the level of entire pages. The left ("<<<Pages") and right ("Pages>>>") Page Views display 5 columns (pages) each. For page number P, the ranges of page numbers in the left and right Page Views are [P(L(w-14)-8)-4, P(L(w-14))] and [P(L(w+14)+4), P(L(w+14)+8)+4]. The innermost column of each Page View aggregates only the portion of a page not visible as lines in the adjacent Line View.

On the outside of each Page View, one additional column aggregates witness-variant counts for the entire text (Fig. 1D). Both sides are identical and serve to anchor navigation. Both views effectively show average edit distance for each witness (using the same pixel color encoding as the other views).

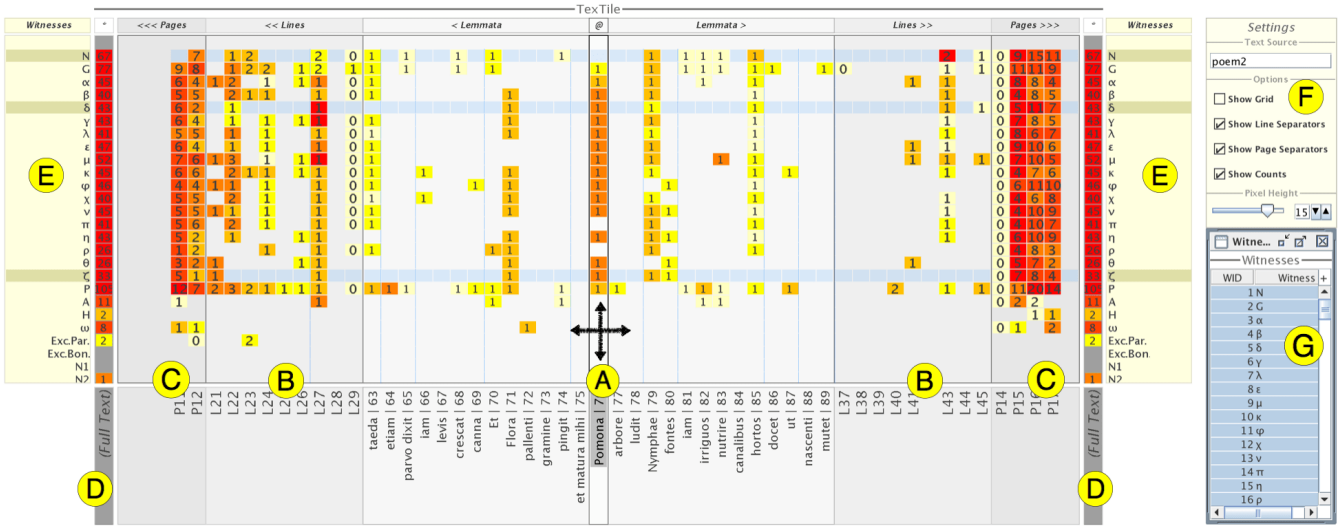

Figure 1: *Focus+context layout in TexTile. Pixels are at the intersections of rows (versions/witnesses) and columns (words/lemmata). A central Lemma View (A) focuses on a single lemma and can be dragged horizontally over the text and vertically over witnesses. Moving outward, succeeding tiers display neighboring lemmata, lines, and pages to the left (earlier in the text) and right (later). Line Views (B) count and color variants for each witness over entire lines. Page Views (C) do the same for entire pages. Full Text Views (D) do the same for an entire edition. Each row is labeled with its corresponding witness symbol (E). Interactive options (F) let the user select an edition by name, show separators between lines and/or pages (light blue vertical lines), and display of counts as digits or only color. The results of the user study prompted trial addition of a new list view (G) to allow dynamic filtering of the layout on a selected subset of witnesses.*

3.2. Pixel Coloring

The presence of a variant for a lemma-witness combination is indicated by a rectangular "pixel". We calculate pixel color using a case-sensitive version of the Levenshtein edit distance [Lev66]. For scholars, edit distance is a simple, reasonable measure of similarity between a lemma and a variant. We use a six-level, yellow-to-red color scheme to represent increasing string dissimilarity in the ranges 0, 1, 2–3, 4–9, 10–27, and 28+. For instance, consider lemma "Pomona" in the primary text. The variants "pomena" in witness P and "per amoena" in witness τ have edit distances 2 (yellow) and 6 (pale orange), respectively. In the Line and Page Views, the individual edit distances are summed over the entire line or page, then mapped into the same color scheme. Scholars care about the amount of lexical variation contributed by each witness, and want to compare variation at different levels, but express more interest in local than global variation. The color scheme uniformly depicts aggregate variation across levels while providing increased dynamic range to differentiate small aggregate distances at local levels. Color also accumulates in a sensible manner in the innermost columns of the Line and Page Views during navigation.

3.3. Interaction

Panning in both directions (left-right and top-bottom) is enabled in the central focus column (@). (Panning in the other views is straightforward but was not implemented in time for the user study.) When a user uses the mouse or keyboard to move horizontally in this column, pages and lines shift correspondingly in the Line and Page Views. For example, consider the usage scenario depicted in Fig. 1, of a user visualizing the second poem in a collection [TC10]. The user drags to shift the central focus to lemma "Pomona". The 13 lemmata prior to and following "Pomona" are displayed in the two Lemma Views. Using the modular arithmetic described in section 3.1, the left and right Line Views display lines 21–29 and 37–45, respectively. The left and right Page Views display pages 11–12 and 14–17, spanning the entire poem as originally printed in 1910.

TexTile uses XPath to extract simple witness and lemma tables, with page and line numbers, from the input XML file. In response to navigation, the lemma table is repartitioned using the above modulus formulas. Each view receives an appropriately filtered subset of lemmata to display. In the Line, Page, and Full Text Views, these subsets are aggregated. The witness-variant pairs are then counted and colored for each pixel. To provide additional context, line and page separators can be turned on in the Lemma and Line Views, respectively (Fig. 1F). These lines are intended to help keep track of one's reading location in the text including when panning over lemmata, even when colored pixels are very sparse. Enabling the "Show Counts" checkbox displays the precise number of variants above each pixel, aggregated at the corresponding tier. As the user traverses from one lemma to another, lines shift and variant counts are updated, with counts filling or draining in the rightmost and leftmost columns of the left and right Line Views, respectively. The corresponding calculation is applied in the Page views.

The data set can be filtered to view a subset of witnesses and their variants using a multi-select witnesses list (Fig. 1G). This querying feature allows users to view only those witnesses required for their analytic needs. In addition, the outermost Witness Views (Fig. 1E)

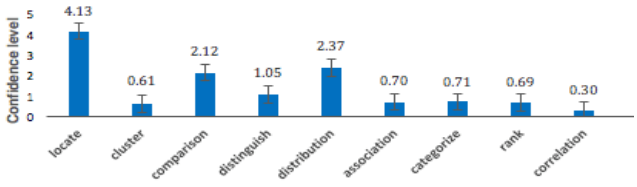

Figure 2: *Study participants performed a variety of common operational tasks [WL90] in TexTile. Confidence level varied widely.*

bracket the Full Text views. The Witness Views can be brushed to highlight witnesses. For each selected witness, the entire row is highlighted with a darker blue background. This feature helps the user scan the rows for witnesses of particular interest.

4. User Study and Evaluation

The experimental setting of this user study was similar to the earlier study conducted to assess the prototype tool [AEA*16]. The present study consisted of a set of 13 user tasks and 10 qualitative questions. User tasks were designed based on discussion with Latin scholars to compare Giarratano's 1910 edition of *Calpurnius Siculus* [TC10] with other important editions. The qualitative questions were derived from the domain-independent operations listed by Wehrend, et al. [WL90], which are suitable to assess usability of user-centered systems such as TexTile.

The main goal of the user study was to assess the broad usability of TexTile as an interactive graphical alternative to the static footnotes of printed editions. We ran a grounded evaluation based primarily on task performance observations and user rating of individual features. The study was conducted over several days with 15 participants. All were undergraduate or graduate students with little to no prior experience with visualization tools. Given the short training duration of ∼15 minutes, all were surprisingly quick to learn the hierarchical visual design and the navigation method needed to perform the tasks. (Future work could look at whether longer training sessions improve efficiency of task performance.)

Following the evaluation guidelines discussed in [IZCC08] and [Sta14], we encouraged participants to follow a think-aloud protocol, in part to facilitate recording their comments about design features that they found helpful or in need of improvement. Accuracy level and confidence in performing each task were recorded. User tasks were grouped into four types that cover the significant capabilities that we targeted TexTile to support:

- Differentiating and identifying patterns using pixel color tasks. (*"Select the first 20 witnesses. Compare lines 63 and 66. Do you see a common pattern in the witness list?"*)
- Finding the number of text variants present for a particular lemma. (*"Select witness N. In poem 2, page 12, line 35, how many lemmas with a variant are present?"*)
- Identifying common witnesses for a lemma, and vice-versa. (*"On page 11, which witness has the most variants?"*)
- Locating pages, lines, and words in the focus+context views. (*"Find the start and end line numbers on page 13."*)

We performed logistic regression to check statistical significance in mean difference of accuracy between task groups (a binary variable). The results did not show any significant difference in means ($\tilde{\chi}^2$ = 1.1, df = 3, p = 0.7746). In the case of confidence (an ordinal variable), a non-parametric Kruskal-Wallis test was performed. The results do not show any significant difference ($\tilde{\chi}^2$ = 5.534, df = 3, p-value = 0.1366). Hence we conclude that performance of all four task groups are the same.

Additional qualitative questions were designed to probe confidence in basic visualization task operations: locate, cluster, compare, distinguish, distribute, associate, categorize, rank, correlate [WL90]. Responses were recorded on a Likert scale from 1 (easy) to 5 (difficult). For example, one question to prompt a comparison task was *Do you think this visual representation helps you to make comparison between variants?*. Responses showed a non-normal distribution. We performed a Friedman test and identified that there is a significant difference in means ($\tilde{\chi}^2$ = 29.73, df = 8, p = 0.0002). Applying a Bonferroni adjustment to avert any chances of type I error, the new significance level is set to 0.0014. A post-hoc analysis was performed using Wilcoxon signed rank test that helped us to categorize the nine tasks based on the difficulty level. Fig. 2 shows confidence by task, with error bars.

The user study led to several important observations and insights. As for difficulty, we observed that locate, comparison, and distribution tasks are relatively easy to perform in TexTile. In contrast, cluster and correlation tasks are significantly difficult to accomplish. We attribute the difficulty to tasks involving large vertical distances between witness rows. This suggests future work to improve TexTile by adding features to filter, sort, and group witnesses/rows (either automatically or interactively). An additional feature could display a summary of variant count and similarity along the horizontal to help users more readily identify the most contentious lemmata. Our qualitative observations also reinforced design tradeoffs. Lemma strings are harder to read vertically than horizontally, but witness labels (*sigla*) are strings too, and while fewer are sometimes longer. Page and line separators are unobtrusive but are confusingly similar, and could be more visually distinct. Lastly, users asked to see variant details when hovering. We are building a full application to complement TexTile with rich text viewing features.

5. Conclusion

In this paper we described TexTile, a new tool that integrates pixel-based and focus+context visualization techniques for analysis of variation across scales in scholarly reconstructions of classical Latin texts. The results of a user study served to verify its overall usability for several kinds of common visualization tasks. It also identified features needed to make it more effective for several other kinds of tasks including grouping and correlating witnesses based on variant similarity. Moving forward we will incorporate these features into a production version of the tool and perform a summative evaluation in practical application by Latin scholars. Visualization tools like TexTile can facilitate ongoing study of the historical documents that give us a precious window onto ancient knowledge and culture.

References

[ABHW16] ABBAS J., BAKER S. R., HUSKEY S. J., WEAVER C.: How I Learned to Love Classical Studies: Information Representation Design of the Digital Latin Library. In *Proceedings of the Annual Meeting of the Association for Information Science and Technology (ASIS&T)* (Copenhagen, Denmark, October 2016). 1

[ADG11] ALBERS D., DEWEY C., GLEICHER M.: Sequence Surveyor: Leveraging Overview for Scalable Genomic Alignment Visualization. *Visualization and Computer Graphics, IEEE Transactions on 17*, 12 (Dec 2011), 2392–2401. 2

[AEA*16] ASOKARAJAN B., ETEMADPOUR R., ABBAS J., HUSKEY S., WEAVER C.: Visualization of Latin Textual Variants using a Pixel-Based Text Analysis Tool. In *EuroVis Workshop on Visual Analytics (EuroVA)* (2016), The Eurographics Association. 1, 2, 4

[ARLC*13] ABDUL-RAHMAN A., LEIN J., COLES K., MAGUIRE E., MEYER M., WYNNE M., JOHNSON C. R., TREFETHEN A., CHEN M.: Rule-based Visual Mappings - with a Case Study on Poetry Visualization. *Computer Graphics Forum 32*, 3pt4 (2013), 381–390. 2

[CKB09] COCKBURN A., KARLSON A., BEDERSON B. B.: A Review of Overview+Detail, Zooming, and Focus+Context Interfaces. *ACM Comput. Surv. 41*, 1 (Jan. 2009), 2:1–2:31. 2

[DLL] Digital Latin Library. http://digitallatin.org/. Accessed: 2017-02-27. 1

[GCL*15] GENG Z., CHEESMAN T., LARAMEE R. S., FLANAGAN K., THIEL S.: ShakerVis: Visual analysis of segment variation of German translations of Shakespeare's Othello. *Information Visualization 14*, 4 (2015), 273–288. 2

[IZCC08] ISENBERG P., ZUK T., COLLINS C., CARPENDALE S.: Grounded Evaluation of Information Visualizations. In *Proceedings of the 2008 Workshop on BEyond Time and Errors: Novel evaLuation Methods for Information Visualization* (New York, NY, USA, 2008), BELIV '08, ACM, pp. 6:1–6:8. 4

[JGF*15] JÄNICKE S., GESSNER A., FRANZINI G., TERRAS M., MAHONY S., SCHEUERMANN G.: TRAViz: A Visualization for Variant Graphs. *Digital Scholarship in the Humanities 30*, suppl 1 (2015), i83–i99. 2

[Kei00] KEIM D.: Designing Pixel-oriented Visualization Techniques: Theory and applications. *IEEE Transactions on Visualization and Computer Graphics 6*, 1 (Jan 2000), 59–78. 2

[KJW*14] KOCH S., JOHN M., WÖRNER M., MÜLLER A., ERTL T.: VarifocalReader - In-Depth Visual Analysis of Large Text Documents. *IEEE Transactions on Visualization and Computer Graphics 20*, 12 (Dec 2014), 1723–1732. 2

[KO07] KEIM D., OELKE D.: Literature Fingerprinting: A New Method for Visual Literary Analysis. In *VAST07: IEEE Symposium on Visual Analytics Science and Technology* (Oct 2007), pp. 115–122. 2

[Lev66] LEVENSHTEIN V.: Binary Codes Capable of Correcting Deletions, Insertions and Reversals. In *Soviet Physics Doklady* (1966), vol. 10, p. 707. 3

[MGT*03] MUNZNER T., GUIMBRETIÈRE F., TASIRAN S., ZHANG L., ZHOU Y.: TreeJuxtaposer: Scalable Tree Comparison Using Focus+Context with Guaranteed Visibility. *ACM Trans. Graph. 22*, 3 (July 2003), 453–462. 2

[Mor13] MORETTI F.: *Distant Reading*. Verso, June 2013. 2

[MRC91] MACKINLAY J. D., ROBERTSON G. G., CARD S. K.: The Perspective Wall: Detail and Context Smoothly Integrated. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (1991), CHI '91, pp. 173–176. 1, 2

[Sta14] STASKO J.: Value-driven Evaluation of Visualizations. In *Proceedings of the Fifth Workshop on Beyond Time and Errors: Novel Evaluation Methods for Visualization* (New York, NY, USA, 2014), BELIV '14, ACM, pp. 46–53. 4

[TC10] TITUS CALPURNIUS SICULUS, CAESAR GIARRATANO: *Calpurnii Et Nemesiani Bucolica*. 1910. 3, 4

[Wea04] WEAVER C.: Building Highly-Coordinated Visualizations in Improvise. In *Information Visualization, 2004. INFOVIS 2004. IEEE Symposium on* (2004), pp. 159–166. 2

[WJ13] WHEELES D., JENSEN K.: JuxtaCommons. In *Proceedings of the Digital Humanities* (2013), Journal of Digital Humanities. 2

[WL90] WEHREND S., LEWIS C.: A Problem-oriented Classification of Visualization Techniques. In *Proceedings of the 1st Conference on Visualization '90* (Los Alamitos, CA, USA, 1990), VIS '90, IEEE Computer Society Press, pp. 139–143. 1, 4