Improving Engagement of Animated Visualization with Visual Foreshadowing

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ABSTRACT
Animated visualization is becoming increasingly popular as a compelling way to illustrate changes in time series data. However, maintaining the viewer’s focus throughout the entire animation is difficult because of its time-consuming nature. Viewers are likely to become bored and distracted during the ever-changing animated visualization. Informed by the role of foreshadowing that builds the expectation in film and literature, we introduce visual foreshadowing to improve the engagement of animated visualizations. In specific, we propose designs of visual foreshadowing that engage the audience while watching the animation. To demonstrate our approach, we built a proof-of-concept animated visualization authoring tool that incorporates visual foreshadowing techniques with various styles. Our user study indicates the effectiveness of our foreshadowing techniques on improving engagement for animated visualization.

Index Terms: Human-centered computing—Visualization—Visualization design and evaluation methods; Computing methodologies—Computer graphics—Animation

1 INTRODUCTION
In recent years, animated visualization has been widely adopted to show changes in time series data, because of its inherent nature of presenting temporal evolution over time [11, 25]. When used appropriately, animated visualization can be attractive and effective to convey information [18, 29]. A well-known example is Hans Rosling’s Gapminder presentation using the animated bubble chart to review the financial and physical well-being changes of different countries over 200 years [26]. This work has garnered more than 8 million views from all over the world [21] and has drawn considerable public attention toward data visualization. Since then, more and more animated visualizations have emerged to present changes in data. For example, Top 15 Best Global Brands Ranking [27] and The History of the World’s Best Go Players [2] use an animated bar chart to show changes in rankings.

However, without additional guidance from a presenter, general audience might feel difficult to pay attention to key information and reluctant to consume an entire animation. Although animated visualizations are visually appealing, people are not sure where to focus when multiple changes simultaneously occur. Moreover, the ever-changing nature of animated visualization makes it hard for people to retain their attention for a long time.

In film and literature, foreshadowing is widely adopted as an important narrative tactic to engage viewers and readers [8]. This narrative tactic uses implications early in a story to indicate the subsequent emergence of a relevant occurrence in the plot [24, 32]. Therefore, we propose to adopt visual foreshadowing for data storytelling to improve the engagement of animated visualization. Visual foreshadowing guides audience’s attention to significant changes in data and raise expectations for forthcoming events.

In this study, we formulate and apply visual foreshadowing on animated bar chart, which is a common animated visualization for ranking changes. We demonstrate four examples of visual foreshadowing that can be categorized into two major types: explicit foreshadowing (that openly suggests the outcome) and implicit foreshadowing (that leaves subtle clues by hinting the relevant items). To learn the efficacy of engagement enhancement of our approach, we implement a proof-of-concept system that generates animated bar charts with diverse visual foreshadowing techniques. With this new animated visualization authoring tool, we support the easy creation of visual foreshadowing effects for specific item(s). Our system facilitates adding, previewing, and editing visual foreshadowing for the selected items with different temporal ranking data. Our user study results suggest that the proposed visual foreshadowing techniques are useful to engage the audience of animated visualization.

2 RELATED WORK
A large variety of animations being applied to different domains. Thus, the need for emphasizing crucial parts of animation has motivated researchers to study attention guidance for dynamic visualization [10, 15, 22, 31]. For example, in the education domain, De Koning et al. [13] attempted to transfer successful cueing approaches from static visualization to animation for instructional design. The authors proposed a framework that classifies three cueing functions, selection, organization, and integration. This work suggested developing visual cues for animation instead of borrowing the effective ones for static representations. The more recent work of De Koning et al. [12], summarized visual cues to direct learner attention to key information, including basic arrows, colored circles, and other visual cues embedded within graphical entities of dynamic visualization. In an effort to locate task-relevant information, Etemadpour et al. [16] and Chen et al. [9] applied motions to data points, and De Koning et al. [14] studied the role of presentation speed in attention cueing. In dynamic narrative visualization, Waldner et al. [30] studied the flicker effect and found a good trade-off between attraction effectiveness and the subjective annoyance caused by flickering. Many of the considerations from these works informed the design of our visual foreshadowing.

Despite the availability of existing studies, the topic of how visual cues help improve engagement in animation or dynamic visualization is still under exploration. The work by Wang et al. [32] is the most relevant to our approach. The authors first adopted the term “foreshadowing” to help enhance the narratives of clickstream data visualization. However, their techniques are employed in the timeline, and the visual effects are limited to animated stacked graph. In the current research, we formally define visual foreshadowing and propose design examples for animated visualization.
3 **Visual Foreshadowing**

Foreshadowing is a narrative tactic that is widely used in film and literature. It often appears in the early stages of a plot because it can subtly create tension and set viewers’ expectations regarding how the story will unfold. We conduct an extensive literature review of the foreshadowing techniques used in the literature, film, and video games domains [1, 4, 6, 20, 23, 28], analyze the existing visual cues in data visualization [19, 30, 32], and formally define visual foreshadowing. Taking bar chart race as an example, we initialize visual foreshadowing designs for animated visualization.

### 3.1 Definition

We see visual foreshadowing as a new form of animation effect that appears before the critical events during the playback of animated visualization to set the viewer’s expectations. Basing from previous research on animation [17], we define visual foreshadowing for animated visualization from three perspectives, namely, *visual effect*, *timing*, and *duration*. Accordingly, visual foreshadowing can be formalized as a 3-tuples:

\[
\text{Visual Foreshadowing} := (\text{visual effect}(s), \text{timing}(s), \text{duration}(s)).
\]

Visual foreshadowing can have one or multiple *visual effects*. The visual effects in visual foreshadowing can be a textual statement or the ones that are attached to specific visual elements. Under the framework, different visual cues (e.g., flickering or pointing with arrows) can be easily introduced to extend the foreshadowing effects.

Foreshadowing can be achieved implicitly or explicitly [5, 32]. Following this taxonomy, the *visual effects* adopted in visual foreshadowing should also have two categories. *Explicit foreshadowing* occurs when an outcome is directly indicated, which explicitly gives viewers a piece of information to entice them to want more. Therefore, the audience is directly informed of the key information or the final outcome. *Implicit foreshadowing* appears when an outcome is indirectly hinted, which leaves subtle clues about a future event by suggesting related items. The upcoming event is only apparent to viewers after it has occurred. On the basis of prior work on visual cue preference and highlighting interventions for static visualizations [7], the visual effects for indicating relevant visual elements in indirect foreshadowing can include adding a contour and setting the transparency. By using the visual cues, the author can draw viewers’ attention to the target items.

Given the specified visual effect, *timing* is used to specify when the visual effects start, while *duration* is to control the time length of the visual effects. Timing and duration should be chosen for each foreshadowing visual effect. The author can define when to start building the viewer’s expectations and when to stop before the crucial event occurs.

### 3.2 Example Foreshadowing Effects

The design of foreshadowing can be numerous. Considering the design space of possible visual cues [19], we strategically select the common cueing methods to ease the burden of understanding the visual designs. We demonstrate two explicit and two implicit foreshadowing techniques to enhance animated visualization with two different datasets.

- **Prologue**. Prologue is an explicit foreshadowing example. Inspired by the study of Kong et al. [20] that the perceived main message of a visualization can be influenced by the slant of the title, the foreshadowing design is to insert additional text description to suggest the forthcoming events (see Fig. 1(a)). After noticing the caption, the audience’s focus is guided to the target bar so that they can see how the bar animates to meet their expectation.

- **Pre-scene**. Pre-scene is an explicit foreshadowing example. The goal of the design is to arouse the viewer’s interest to see how the selected bar would change to the final state. This direct foreshadowing design builds the expectation visually, where the final ranking and the length of the bar are directly visualized. As illustrated in Fig. 1(b), the final state of the iSpy item is directly shown in the animated visualization. People may be curious about how the suggested item of the current state turns out.

- **Contour**. Contour is an implicit foreshadowing example. The visual effect of the foreshadowing technique is drawing a contour around the target bar to attract the audience’s attention before important change occurs. In contrast to the explicit foreshadowing techniques, this type of visual foreshadowing only highlights the relevant items without disclosing what will happen in the future. As shown in Fig. 2(a), the bar with contour is suggesting some interesting change will happen to it.

- **De-emphasis**. De-emphasis is an implicit foreshadowing example. Similar to the Contour effect, interesting items will be highlighted before key events occur. As shown in Fig. 2(b), the De-emphasis effect is implemented by setting transparency. The relevant items hold the original transparency, whereas the transparency of those irrelevant bars is set to 20%.

### 4 Visual Foreshadowing Authoring

To evaluate the visual foreshadowing design, we built a proof-of-concept system for animated visualization authoring. The user interface of the prototyping system consists of a foreshadowing configuration panel (Fig. 3(a)), a basic animation setting widget (Fig. 3(b)),...
To apply the visual foreshadowing to the animated bar chart, the underlying data can be updated by editing the data table. As shown in Fig. 3(e), each row of the data table represents a ranking item, while the columns show the temporal dimension. After loading the CSV data file of the chart, an initial static bar chart will be displayed in the preview panel (Fig. 3(c)), and the animated visualization illustrating the ranking changes can be played. To apply the visual foreshadowing to the animated bar chart, the user needs to select the specific items and create the associated visual foreshadowing effect in the foreshadowing editing widget (Fig. 3(a)).

Future Extensions of Visual Foreshadowing Designs  

The goal of the visual foreshadowing in our work is to entice the viewer to consume the entire animation instead of the one with tedious visual effects. For instance, a user wants to add an explicit foreshadowing effect to suggest the rank of the Coca-Cola company in 2019. The user can obtain the corresponding bar by choosing the item in the item list. Then, the user needs to specify the settings for explicit foreshadowing by selecting the effect type, providing relevant words, and choosing the time range to show the visual effects. Finally, the resulting foreshadowing effect with time range is indicated in the timeline widget (Fig. 3(d)). The user can preview the synthesized animated visualization with additional visual foreshadowing effects.
Table 1: Average ratings of the user engagement survey questions (1 = strongly disagree, 7 = strongly agree).

| Assessment          | Foreshadowing | Mean  | SD   |
|---------------------|---------------|-------|------|
| Enjoyment Without   | 4.13          | 0.61  |
|                    | With          | 6.54  | 0.54 |
| Focused Attention   | 3.71          | 1.03  |
|                    | 6.17          | 0.72  |
| Cognitive Involvement Without | 4.50         | 1.04  |
|                     | 6.04          | 0.58  |

In-depth Investigation on Effectiveness

In our user study, we investigated visual foreshadowing with several visual effects generally. Interestingly, participants had a stronger preference on the foreshadowing designs that only leaves subtle clues rather than the ones that openly suggest the events was empirically observed. For instance, compared with participants that tested with the Pre-scene effect, participants that tested with the De-emphasis effect were more willing to wait until the end of an animated transition to obtain the final outcome. However, which visual foreshadowing design and which foreshadowing setting (e.g., timing, and duration) are the most effective ones remain unclear. What about the combinations of visual foreshadowing for engagement improvement? In addition, we studied general engagement improvement on a rather small tested data. Whether or not viewers will behave differently in more complicated data is also interesting to study. Examining these ideas requires further investigation, which is outside the scope of this work. We encourage follow-up studies to explore the different aspects of visual foreshadowing used in animated visualization.

7 Conclusion

In this work, we introduced visual foreshadowing, a design that enhances animated visualization with effective visual cues ahead of time. The visual cues with proper timing prepare the audience with critical patterns of temporal data and enhance temporal change recognition. We build a proof-of-concept system to support foreshadowing authoring and further investigation. We demonstrate our visual foreshadowing approach with a qualitative evaluation. Results show that our method can guide participants’ preparation for the upcoming events in the generated animated ranking visualization. The subjective preference ratings reveal that animated visualization with visual foreshadowing are engaging to show temporal data changes. In the future, we plan to investigate other design choices (e.g., the design of visual cues) with different levels of data complexities. We will also integrate visual foreshadowing into other forms of animated visualization, such as dynamic line chart and scatter plot, to provide effective animated narrative visualizations.

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REFERENCES

[1] E. Aarseth. A narrative theory of games. In M. S. El-Nasr, M. Consalvo, and S. K. Feiner, eds., *International Conference on the Foundations of Digital Games, FDG ’12, Raleigh, NC, USA, May 29 - June 01, 2012*, pp. 129–133. ACM, 2012.

[2] Abacaba. The history of the world’s best go players. Available at https://www.youtube.com/watch?v=o8vLyEpOQ-8.

[3] F. Amini, N. H. Riche, B. Lee, J. Leboe-McGowan, and P. Irani. Hooked on data videos: assessing the effect of animation and pictographs on viewer engagement. In *Proceedings of the 2018 International Conference on Advanced Visual Interfaces, AVI 2018*, Castiglione della Pescaia, Italy, May 29 - June 01, 2018, pp. 21:1–21:9, 2018. doi: 10.1145/3206505.3206552

[4] B. Bae, Y. Cheong, and D. Vella. Modeling foreshadowing in narrative comprehension for sentimental readers. In H. Koenitz, T. I. Sezen, G. Ferri, M. Haahr, D. Sezen, and G. Catak, eds., *Interactive Storytelling - 6th International Conference, ICIDS 2013, Istanbul, Turkey, November 6-9, 2013, Proceedings*, vol. 8230 of Lecture Notes in Computer Science, pp. 1–12. Springer, 2013.

[5] B.-C. Bae and R. M. Young. A use of flashback and foreshadowing for surprise arousal in narrative using a plan-based approach. In *Joint international conference on interactive digital storytelling*, pp. 156–167. Springer, 2008.

[6] D. Bordwell. *Narration in the Fiction Film*. University of Wisconsin Press, 1985.

[7] G. Carenini, C. Conati, E. Hoque, B. Steichen, D. Toker, and J. T. Enns. Highlighting interventions and user differences: informing adaptive information visualization support. In *CHI Conference on Human Factors in Computing Systems, CHI’14, Toronto, ON, Canada - April 26 - May 01, 2014*, pp. 1835–1844, 2014.

[8] S. B. Chatman. *Story and discourse: Narrative structure in fiction and film*. Cornell University Press, 1980.

[9] H. Chen, S. Engle, A. Joshi, E. D. Ragan, B. F. Yuksel, and L. Harrison. Using animation to alleviate overdraw in multiclass scatterplot matrices. In R. L. Mandryk, M. Hancock, M. Perry, and A. L. Cox, eds., *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, CHI 2018, Montreal, QC, Canada, April 21-26, 2018*, p. 417. ACM, 2018.

[10] F. Chevalier, P. Dragicevic, and S. Franchonari. The not-so-staggering effect of staggered animated transitions on visual tracking. *IEEE Trans. Vis. Comput. Graph.*, 20(12):2241–2250, 2014.

[11] F. Chevalier, N. H. Riche, C. Plaisant, A. Chalbi, and C. Hurter. Animations 25 years later: New roles and opportunities. In *Proceedings of the International Working Conference on Advanced Visual Interfaces, AVI 2016*, Bari, Italy, June 7-10, 2016, pp. 280–287, 2016.

[12] B. B. de Koning and H. Jarodzka. Attention guidance strategies for supporting learning from dynamic visualizations. In *Learning from dynamic visualization*, pp. 255–278. Springer, 2017.

[13] B. B. De Koning, H. K. Tabbers, R. M. J. P. Rikers, and F. Paas. Towards a framework for attention cueing in instructional animations: Guidelines for research and design. *Educational Psychology Review*, 21(2):113–140, 2009.

[14] B. B. de Koning, H. K. Tabbers, R. M. J. P. Rikers, and F. Paas. Attention cueing in an instructional animation: The role of presentation speed. *Computers in Human Behavior*, 27(1):41–45, 2011.

[15] F. Du, N. Cao, J. Zhao, and Y. Lin. Trajectory bundling for animated transitions. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, CHI 2015, Seoul, Republic of Korea, April 18-23, 2015*, pp. 289–298, 2015.

[16] R. Etemadpour and A. G. Forbes. Density-based motion. *Information Visualization*, 16(1):3–20, 2017.

[17] T. Ge, Y. Zhao, B. Lee, D. Ren, B. Chen, and Y. Wang. Canis: A high-level language for data-driven chart animations. *Comput. Graph. Forum*, 39(3):607–617, 2020.

[18] J. Heer and G. G. Robertson. Animated transitions in statistical data graphics. *IEEE Trans. Vis. Comput. Graph.*, 13(6):1240–1247, 2007.

[19] H. K. Kong, Z. Liu, and K. Karahalios. Internal and external visual cue preferences for visualizations in presentations. *Comput. Graph. Forum*, 36(3):515–525, 2017.

[20] H. K. Kong, Z. Liu, and K. Karahalios. Frames and slants in titles of visualizations on controversial topics. In R. L. Mandryk, M. Hancock, M. Perry, and A. L. Cox, eds., *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, CHI 2018, Montreal, QC, Canada, April 21-26, 2018*, p. 438. ACM, 2018.

[21] R. Kosara and J. D. Mackinlay. Storytelling: The next step for visualization. *IEEE Computer*, 46(5):44–50, 2013.

[22] J. Lu, J. Wang, H. Ye, Y. Gu, Z. Ding, M. Xu, and W. Chen. Illustrating changes in time-series data with data video. *IEEE Computer Graphics and Applications*, 40(2):18–31, 2020.

[23] P. Martin. The Writer’s Guide to Fantasy Literature: From Dragon’s Lair to Hero’s Quest : how to Write Fantasy Stories of Lasting Value. Writer Books, 2002.

[24] G. Moura. What is foreshadowing? Available at http://www.elementsofcinema.com/screenwriting/foreshadowing.html.

[25] G. G. Robertson, R. Fernandez, D. Fisher, B. Lee, and J. T. Stasko. Effectiveness of animation in trend visualization. *IEEE Trans. Comput. Graph.*, 14(6):1325–1332, 2008.

[26] H. Rosling. Gapminder. Available at http://www.gapminder.org.

[27] TheRankings. Top 15 best global brands ranking. Available at https://www.youtube.com/watch?v=BQovQUga0VE.

[28] S. Turner. The Creative Process: A Computer Model of Storytelling and Creativity. L. Erlbaum, 1994.

[29] B. Tversky, J. B. Morrison, and M. Bétrancourt. Animation: can it facilitate? *Int. J. Hum.-Comput. Stud.*, 57(4):247–262, 2002.

[30] M. Waldner, M. L. Muzic, M. Bernhard, W. Purgathofer, and I. Viola. Attractive flicker - guiding attention in dynamic narrative visualizations. *IEEE Trans. Vis. Comput. Graph.*, 20(12):2456–2465, 2014.

[31] Y. Wang, D. Archambault, C. E. Scheidegger, and H. Qu. A vector high-level language for data-driven chart animations. *IEEE Trans. Vis. Comput. Graph.*, 24(9):2487–2500, 2018. doi: 10.1109/TVCG.2017.2750689.

[32] Y. Wang, Z. Chen, Q. Li, X. Ma, Q. Luo, and H. Qu. Animated narrative visualization for video clickstream data. In *SIGGRAPH ASIA 2016, Macao, December 5-8, 2016 - Symposium on Visualization*, pp. 11:1–11:8, 2016.