Ph.D. Qualifying Exam

A Survey on Animation in Visual Data Storytelling

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Outline

Introduction

Visual Data Storytelling

Animation in Visual Data Storytelling

Conclusion and Future Work

Outline
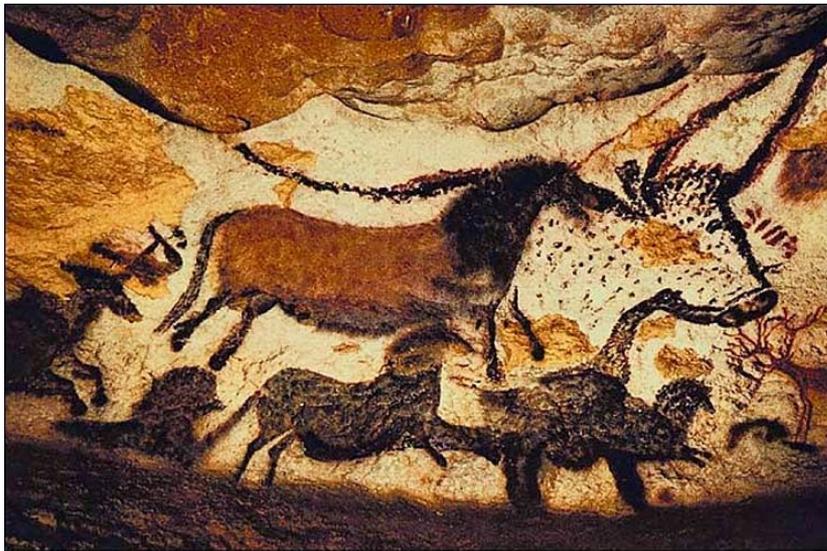
Introduction

Background and Motivation

Concepts

Why Storytelling?

For thousands of years, storytelling has been an essential part of our humanity.

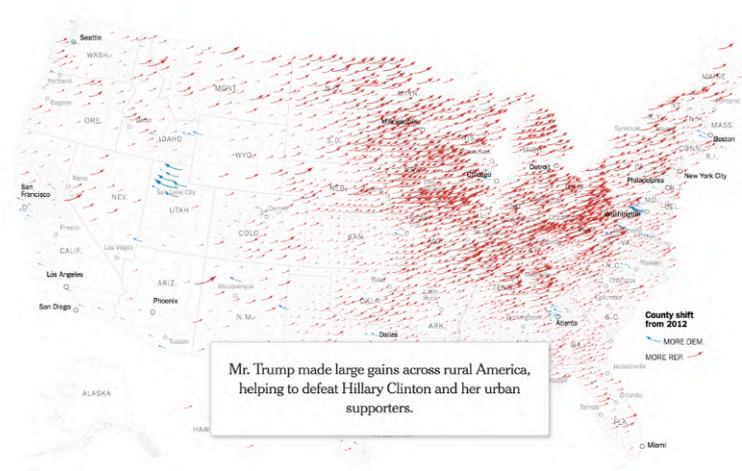Ancient storytelling

Why Storytelling?

Modern storytelling

Analysis of the most popular 500 TED Talk presentations found that **stories made up at least 65% of their content**.

Background and Motivation

Why Data Storytelling?

Storytelling can be used to improve the understandability and engagement of data visualizations.

Enterprise

Journalism

Why Animation?

Animation is an effective means of **showing changes** in data visualization due to its inherent nature of presenting **temporal evolution over time**.

Hans Rosling's
Gapminder presentation

https://www.youtube.com/watch?v=jbkSRLYSojo

Animation in Visual Data Storytelling

- Visual Data Storytelling
- **Animation techniques**

Concepts

- Narrative

Narrative is **a series of connected events** transmitted in the form of spoken words, written words, or graphical representations.

- Data story

The data stories we focus on in this survey generally **incorporate data visualization** or **data dynamics**, display information, and enhance abstract data with capabilities to clarify salient differences, provide insights, and engage the audience.

Concepts

- Visual data storytelling

Visual data storytelling is a method of telling a data story to aid understanding, describe relationships, and convey insights of **abstract data** through **visual representations**.

Outline

# Visual Data Storytelling

Brief History

Taxonomy

Brief History

In 2001, Gershon and Page were the first to notice the valuable contribution that storytelling could give to information visualization.

Nevertheless, their **strategies** for storytelling are **unclear** because they are based on map views and did not provide a description of actual visualization.

Gershon, Nahum, and Ward Page. "What storytelling can do for information visualization." *Communications of the ACM* 44.8 (2001): 31-37.

Brief History

Later, in 2010, the theme sparked again when Segel and Heer reinvented the notion of using storytelling in visualizations and named it narrative visualization.
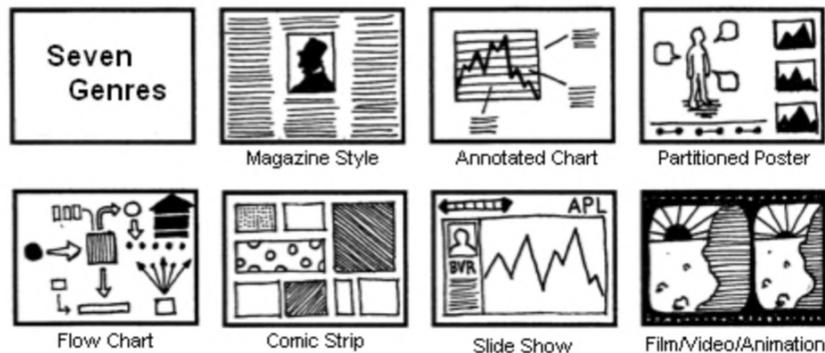
Genres of Narrative Visualization

Visual narrative tactics
- Visual Structuring
- Highlighting
- Transition guidance

Their work is valuable for communicating an intended message by using visualization techniques, but it failed to **establish clear definitions of visual data stories** and their compositions.

Segel, Edward, and Jeffrey Heer. "Narrative visualization: Telling stories with data." *IEEE transactions on visualization and computer graphics* 16.6 (2010): 1139-1148.

Brief History

In 2013, Kosara et al. provided a general review of story-telling research. However, they only **simply discussed a working model of story construction** that is based on the working methods of journalists.

Lee et al. (2015) stated the use of attractive visualization as a storytelling medium has become increasingly prevalent in the visualization community. Nevertheless, the visualization community has yet to reach a clear consensus on the essential content of data stories.

Kosara, Robert, and Jock Mackinlay. "Storytelling: The next step for visualization." Computer 46.5 (2013): 44-50.

Lee, Bongshin, et al. "More than telling a story: Transforming data into visually shared stories." IEEE computer graphics and applications 35.5 (2015): 84-90.

Brief History

Therefore, Lee et al. (2015) propose three characteristics that have to be present in visual data stories:

- A set of story pieces to support facts
- Annotations or narration to clearly highlight and emphasize the data
- A meaningful sequence of story pieces to reach the author's communication goal
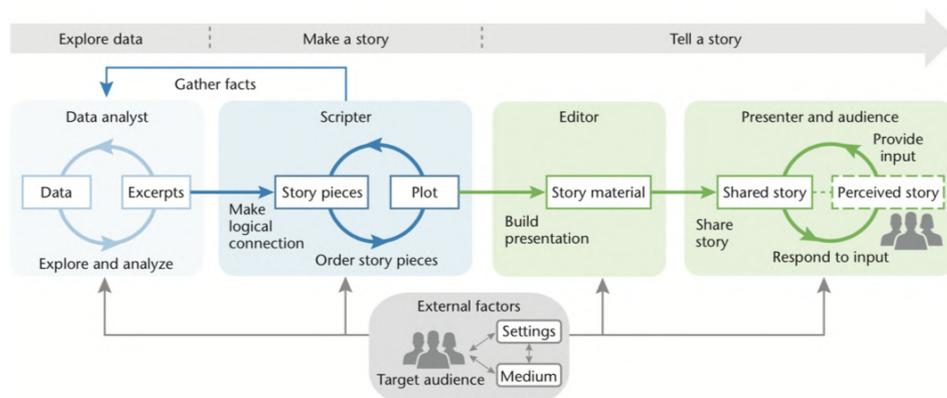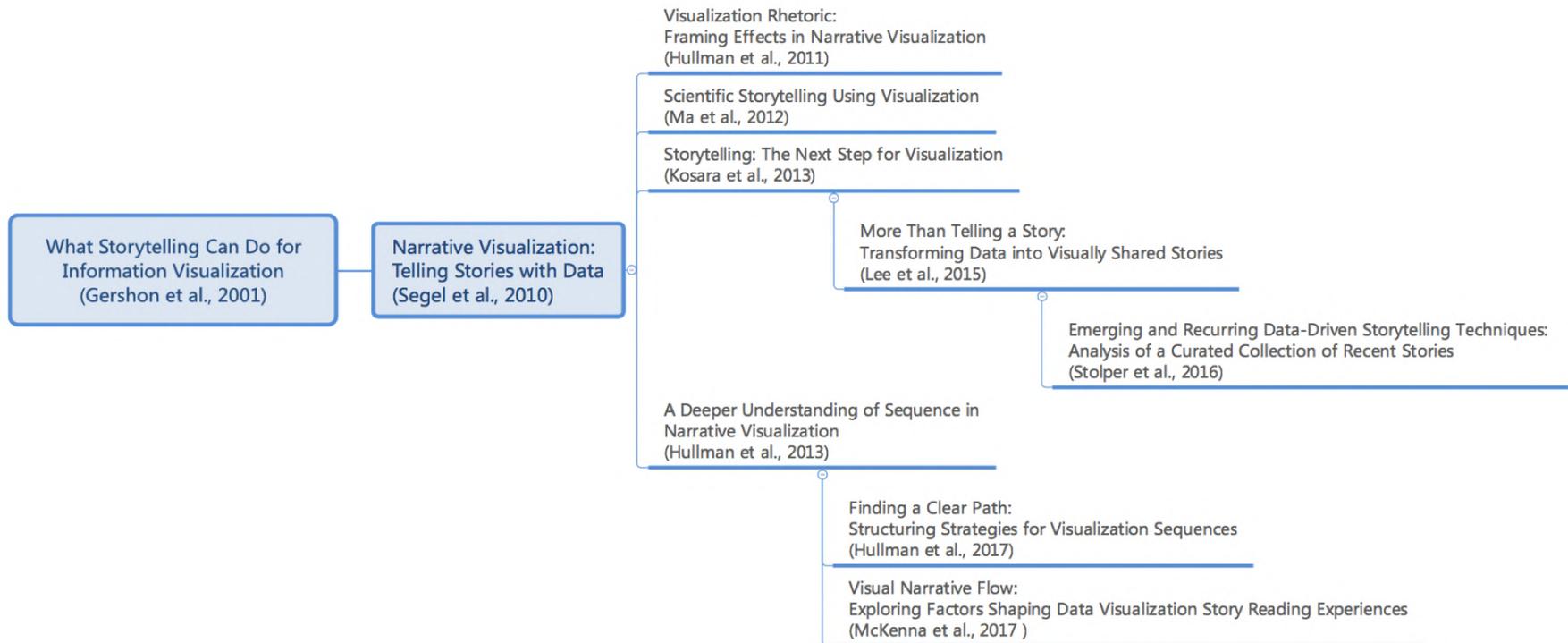

The visual data storytelling process

Lee, Bongshin, et al. "More than telling a story: Transforming data into visually shared stories." IEEE computer graphics and applications 35.5 (2015): 84-90.

Brief History

More recently, Stolper et al. (2016) identify and describe the storytelling techniques applied in the recent online data-driven stories. They classify 20 data-driven storytelling techniques into four high-level categories.

This paper **extends** the taxonomy by Segal et al. (2010) and consider **newly emerging** genres.

Stolper, Charles D., et al. "Emerging and recurring data-driven storytelling techniques: Analysis of a curated collection of recent stories." Microsoft Research, April 3 (2016): 2016.

Brief History

Visualization Rhetoric:
Framing Effects in Narrative Visualization
(Hullman et al., 2011)

Scientific Storytelling Using Visualization
(Ma et al., 2012)

Storytelling: The Next Step for Visualization
(Kosara et al., 2013)

What Storytelling Can Do for
Information Visualization
(Gershon et al., 2001)

Narrative Visualization:
Telling Stories with Data
(Segel et al., 2010)

More Than Telling a Story:
Transforming Data into Visually Shared Stories
(Lee et al., 2015)

Emerging and Recurring Data-Driven Storytelling Techniques:
Analysis of a Curated Collection of Recent Stories
(Stolper et al., 2016)

A Deeper Understanding of Sequence in
Narrative Visualization
(Hullman et al., 2013)

Finding a Clear Path:
Structuring Strategies for Visualization Sequences
(Hullman et al., 2017)

Visual Narrative Flow:
Exploring Factors Shaping Data Visualization Story Reading Experiences
(McKenna et al., 2017)

Development of visual data storytelling

Taxonomy by Segel et al.

- **Visual Structuring**
  (e.g., Progress Bar, and "Checklist" Progress Tracker)
- **Highlighting**
  (e.g., Close-Ups, Motion, and Zooming)
- **Transition Guidance**
  (e.g., Viewer Motion, and Animated Transitions)

Although Segal et al. (2010) provided a nice framework that nevertheless **misses several essential dimensions** given that some aspects of data storytelling have changed (e.g., Scrollytelling).

Segel, Edward, and Jeffrey Heer. "Narrative visualization: Telling stories with data." *IEEE transactions on visualization and computer graphics* 16.6 (2010): 1139-1148.

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Taxonomy by Stolper et al.

1. Communicating narrative and explaining data
- Textual Narrative
- Audio Narration
- Flowchart Arrows
- Labeling
- Text Annotations on Visualizations
- Tooltips
- Element Highlighting

2. Linking separated story elements
- Linking Through Interaction
- Linking Through Color
- Linking Through Animation

3. Enhancing structure and navigation
- Next/Previous Buttons
- Scrolling
- Section Header Buttons
- Menu Selection
- Timeline
- Geographic Map

4. Providing controlled exploration
- Dynamic Queries
- Embedded Exploratory Visualizations
- Separate Exploratory Visualizations

- A wider range of genres (e.g., scrollers)
- Extending limited interaction to a high-level category

Stolper, Charles D., et al. "Emerging and recurring data-driven storytelling techniques: Analysis of a curated collection of recent stories." Microsoft Research, April 3 (2016): 2016.
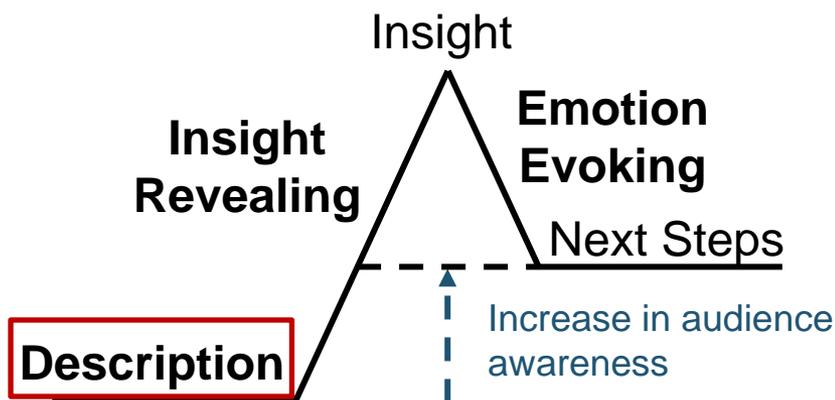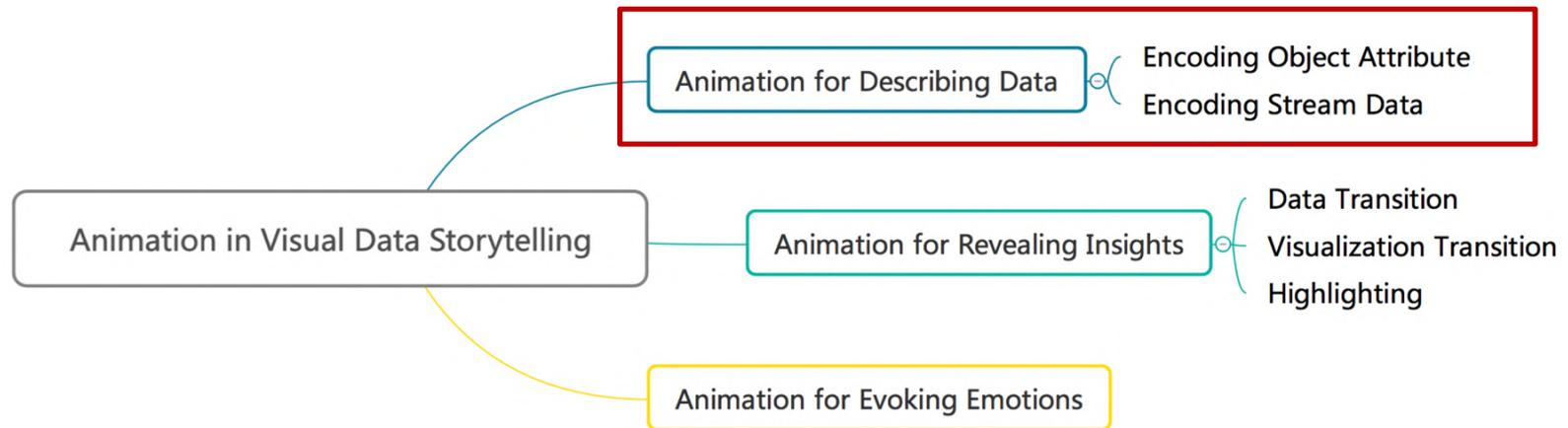
Taxonomy based on the Data Story Model

Climax

Rising Action   Falling Action

Exposition   Denouement
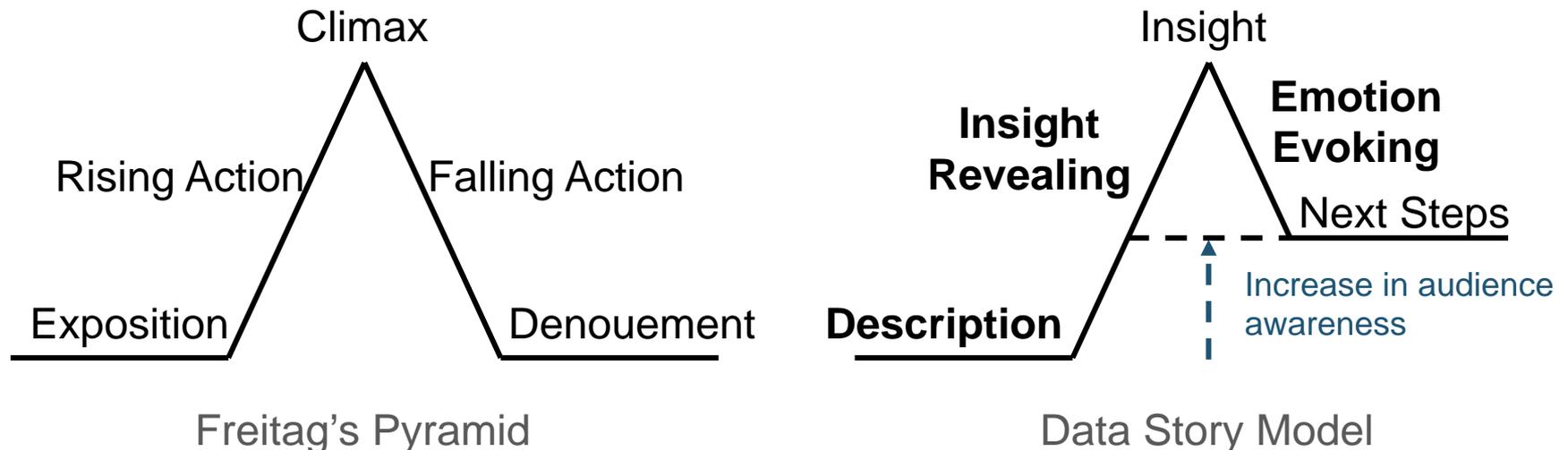
Freitag's Pyramid
(adapted from Gustav Freytag's Technik des Drams (1863))

Insight

Insight Revealing   **Emotion Evoking**

Next Steps

Description
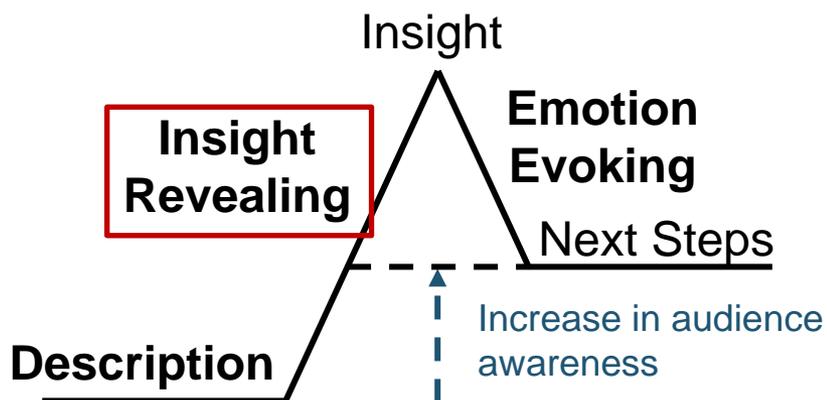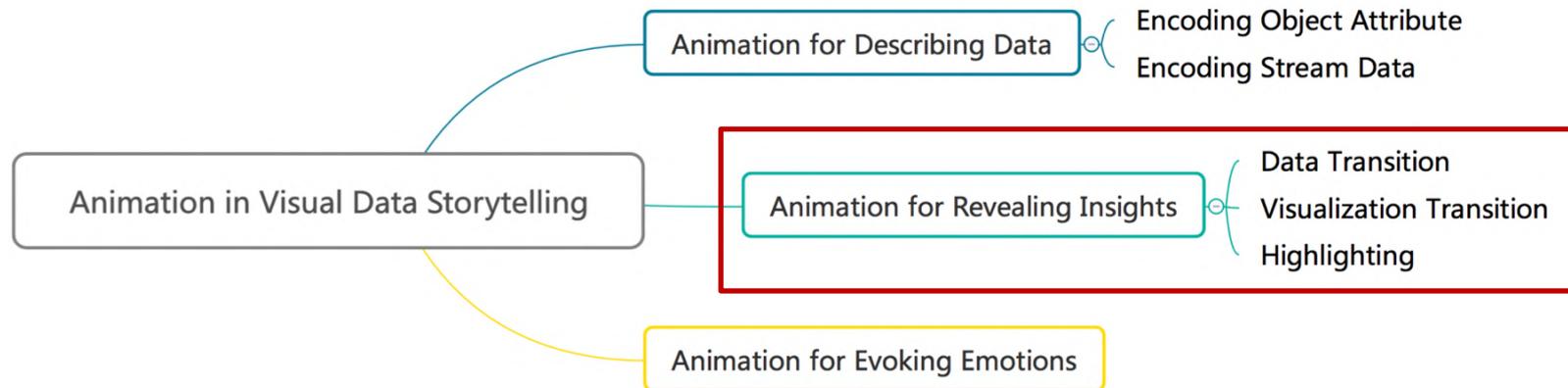
Increase in audience awareness

Data Story Model

- Exposition provides important **background information** to the audience.
- Rising action is series of events build **toward** the point of **greatest interest**.
- Climax is the greatest intensity of the **conflict**.
- Falling action makes its way **towards the resolution**.
- Denouement comprises events from the resolution to the actual ending scene.
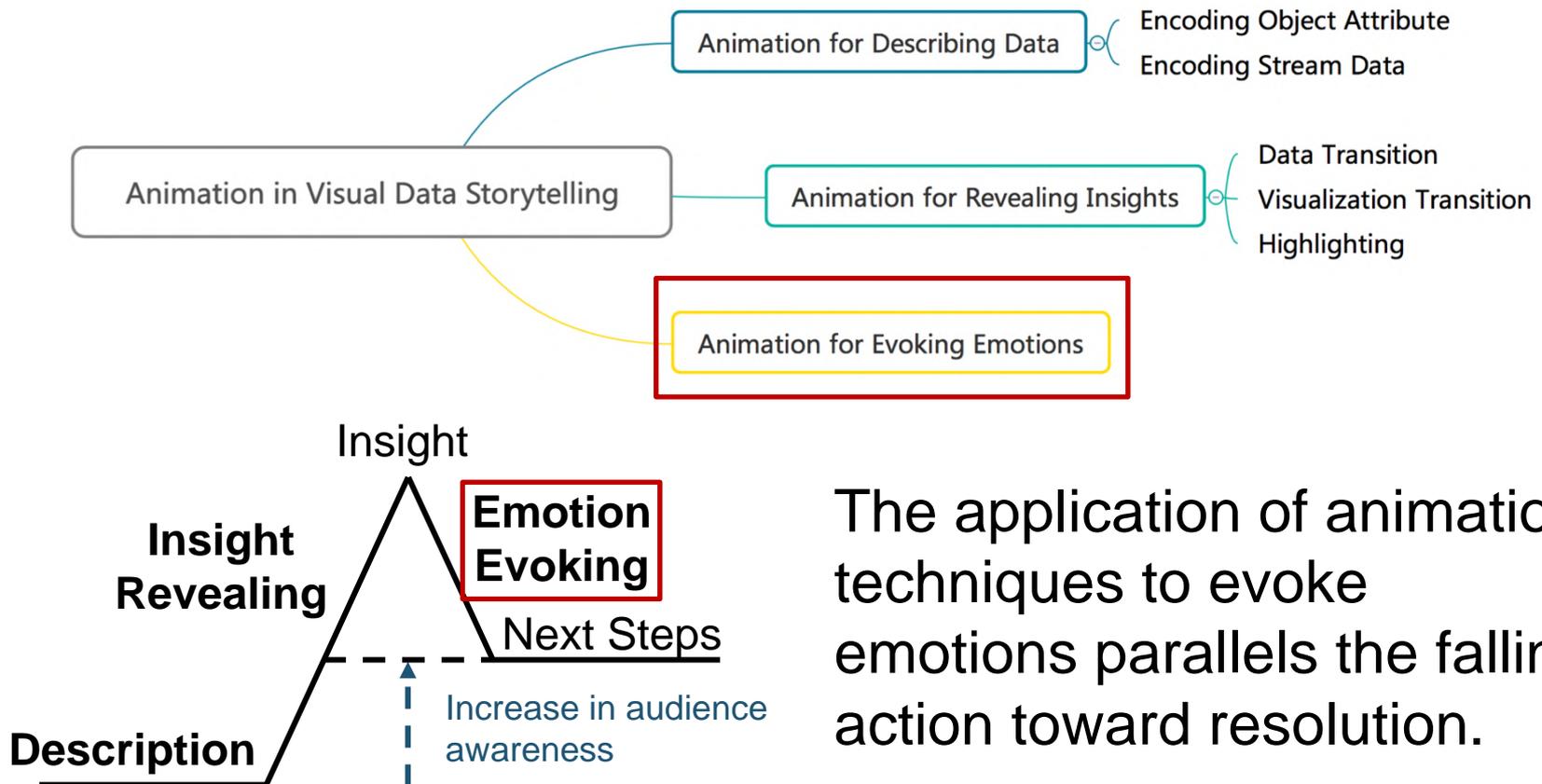
Taxonomy based on the Data Story Model

Animation can be used to describe the data in the exposition stage.

Taxonomy based on the Data Story Model
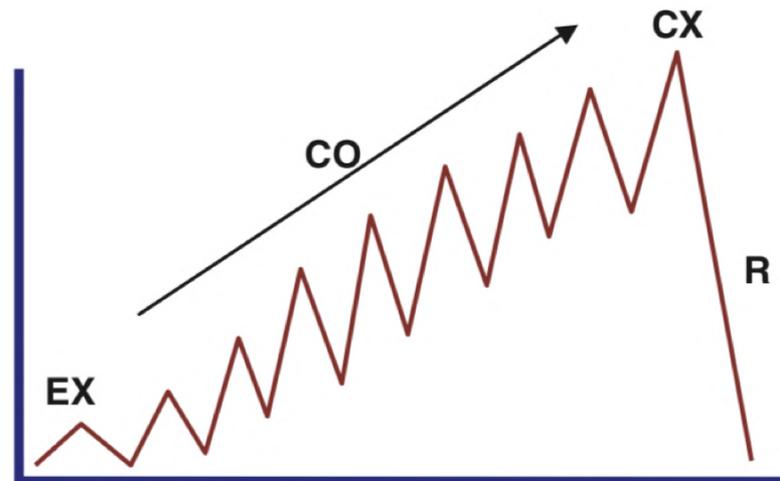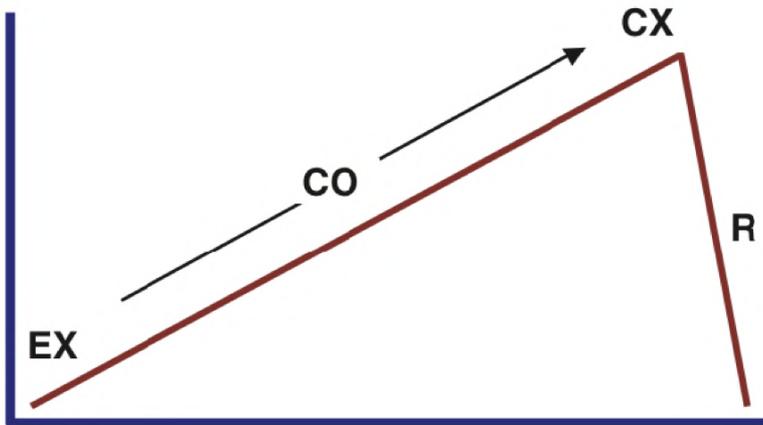
Animation in Visual Data Storytelling

Animation for Describing Data
- Encoding Object Attribute
- Encoding Stream Data

Animation for Revealing Insights
- Data Transition
- Visualization Transition
- Highlighting

Animation for Evoking Emotions

Insight

Insight Revealing

Emotion Evoking

Next Steps

Description

Increase in audience awareness

Animation techniques in this category refer to visual strategies that build toward key findings.

Taxonomy based on the Data Story Model

Animation in Visual Data Storytelling

- Animation for Describing Data
  - Encoding Object Attribute
  - Encoding Stream Data
- Animation for Revealing Insights
  - Data Transition
  - Visualization Transition
  - Highlighting
- **Animation for Evoking Emotions**

Insight

Insight Revealing

Emotion Evoking

Next Steps

Description

Increase in audience awareness

The application of animation techniques to evoke emotions parallels the falling action toward resolution.

Variation of the Data Story Model

Taxonomy

Taxonomy based on the Data Story Model

Category		Related Papers	Remarks
Animation for Describing Data	Encoding Data Attribute	(Huber & Healey, 2005), (Akiba et al., 2010), (Scheepens et al., 2016), (Romat et al., 2018)	static data
	Encoding Stream Data	(Huron et al., 2013), (Wang et al., 2016), (Lin & Vuillemot, 2013), (Liu et al., 2016)	dynamic data
Animation for Revealing Insights	Data Transition	(Dragicevic et al., 2011), (Chevalier et al., 2014)	temporal aspect
		(Du et al., 2015), (Wang et al., 2017)	spatial aspect
	Visualization Transition	(Elmqvist et al., 2008), (Bezerianos et al., 2010)	view change
		(Heer & Robertson, 2007), (Drucker & Fernandez, 2015)	chart change
	Highlighting	(Ware & Bobrow, 2004)	position change
		(Waldner et al., 2014)	appearance change
Animation for Evoking Emotion		(Peng et al., 2018)	personal data

Outline

Animation in Visual Data Storytelling

Animation for Describing Data

Animation for Revealing Insights

Animation for Evoking Emotions

Describing Data

Two types of animation techniques used to describe data:

- Encoding **object attribute**

- Encoding **stream data**

Research goal:

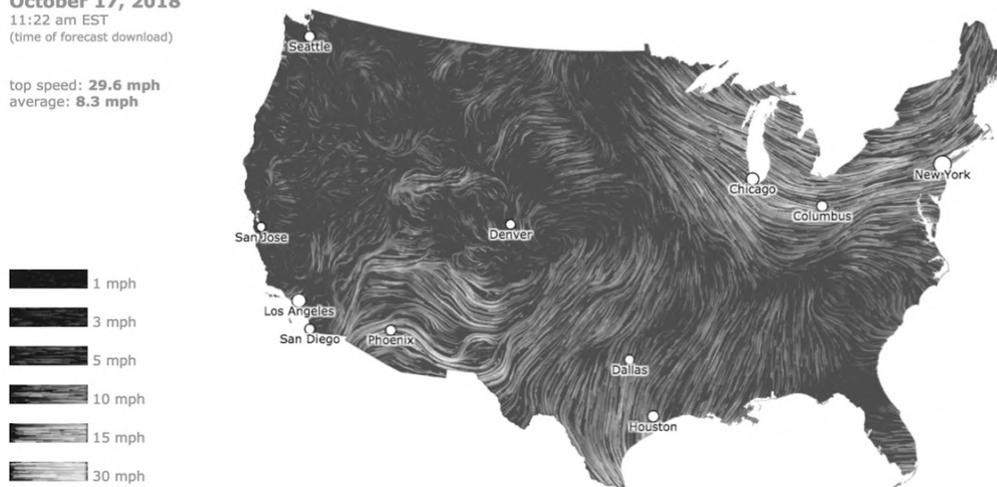Applying animation **intuitively** to **present data**.

Introduction

Visual Data
Storytelling

Animation in Visual
Data Storytelling

Conclusion and
Future Work

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Encoding Object Attribute

wind map

October 17, 2018
11:22 am EST
(time of forecast download)

top speed: **29.6 mph**
average: **8.3 mph**

1 mph
3 mph
5 mph
10 mph
15 mph
30 mph

Seattle · San Jose · Los Angeles · San Diego · Phoenix · Denver · Dallas · Houston · Chicago · Columbus · New York

Animation is usually applied to help scientists in observing the objects' **complicated changes and interactions**.

http://hint.fm/wind/

Encoding Object Attribute

Romat et al. (2018) provides a systematic design space for generating animated network edge textures and applies dynamic particles to the network edges to increase the mapping capacity.

Romat, Hugo, et al. "Animated Edge Textures in Node-Link Diagrams: a Design Space and Initial Evaluation." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

Encoding Object Attribute

Particle Pattern | Pattern Frequency | Particle Speed

The three variables defining for dynamic behavior

Previous methods:
- Using static properties
- Animated texture in ad hoc manner

Romat, Hugo, et al. "Animated Edge Textures in Node-Link Diagrams: a Design Space and Initial Evaluation." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

Encoding Object Attribute

No delay   Departure delay   Arrival delay
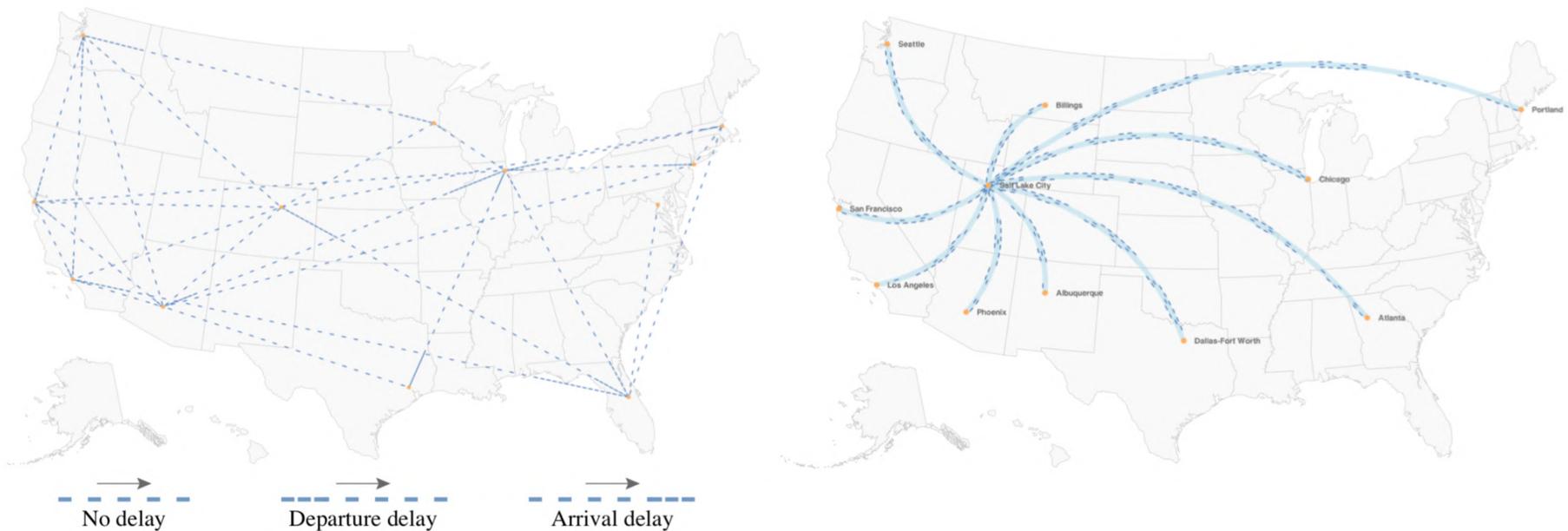
Contribution: Widens encoding space
Limitation: Unclear interaction between variables

Romat, Hugo, et al. "Animated Edge Textures in Node-Link Diagrams: a Design Space and Initial Evaluation." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

Encoding Stream Data
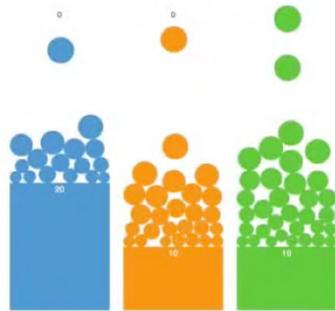
Bar Chart   Pie Chart   Bubble Chart

Huron et al. (2013) used the physical process of sedimentation as a metaphor and invented a visualization method to create data stream narration.

Huron, Samuel, Romain Vuillemot, and Jean-Daniel Fekete. "Visual sedimentation." *IEEE Transactions on Visualization and Computer Graphics* 19.12 (2013): 2446-2455.

Encoding Stream Data
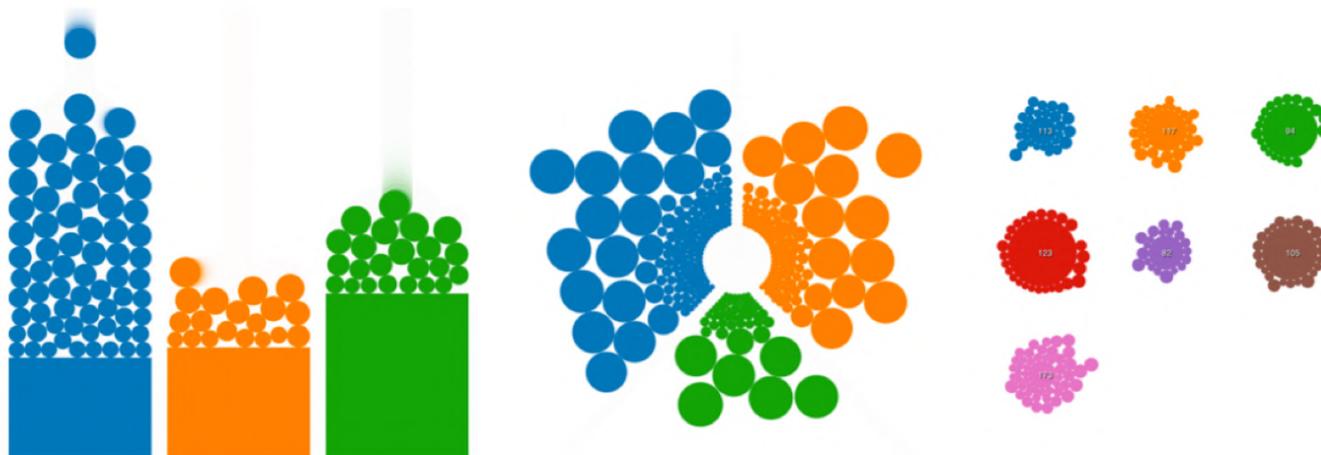
However, it may have some visual effect problems when dealing with bursty data streams because tokens aggregate depending only on the heuristic buffering strategy.

Huron, Samuel, Romain Vuillemot, and Jean-Daniel Fekete. "Visual sedimentation." *IEEE Transactions on Visualization and Computer Graphics* 19.12 (2013): 2446-2455.

Encoding Stream Data
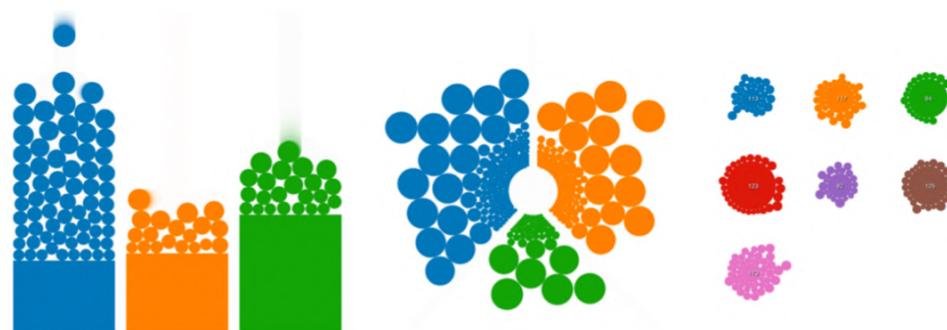
(Huron et al., 2013)
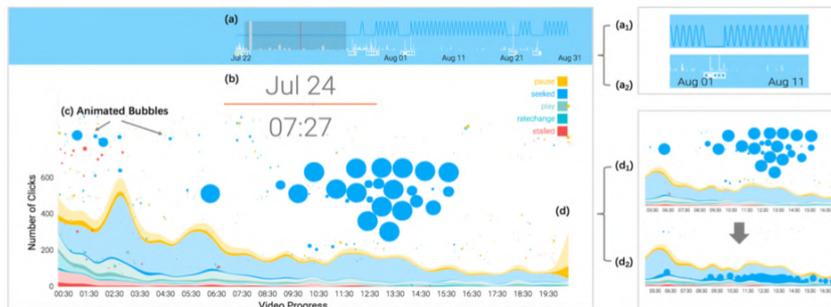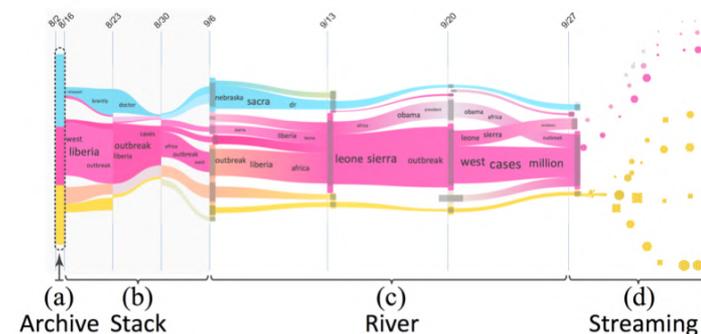
(Wang et al., 2016)

(Liu et al., 2016)

Wang, Yun, et al. "Animated narrative visualization for video clickstream data." *SIGGRAPH Asia 2016 Symposium on Visualization.* ACM, 2016.
Liu, Shixia, et al. "Online visual analytics of text streams." *IEEE transactions on visualization and computer graphics* 22.11 (2016): 2451-2466.

Describing Data

Two types of animation techniques used to describe data:

- Encoding object attribute (**static** data)

- Encoding stream data (**dynamic** data)

Three types of animations that aim at revealing insights:

- Animation for **visualization transition**

- Animation for **highlighting**

- Animation for **data transition**

Animation for visualization transition
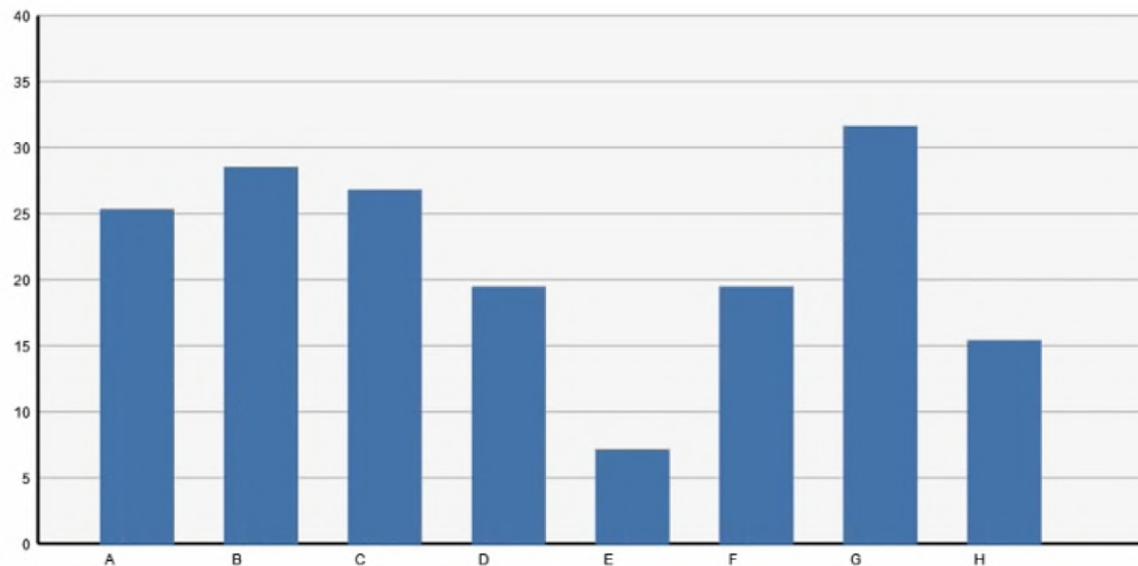
Heer et al. (2007) proposed a framework, DynaVis, for creating animated visualizations between different charts.

Heer, Jeffrey, and George Robertson. "Animated transitions in statistical data graphics." *IEEE transactions on visualization and computer graphics* 13.6 (2007): 1240-1247.

Animation for visualization transition
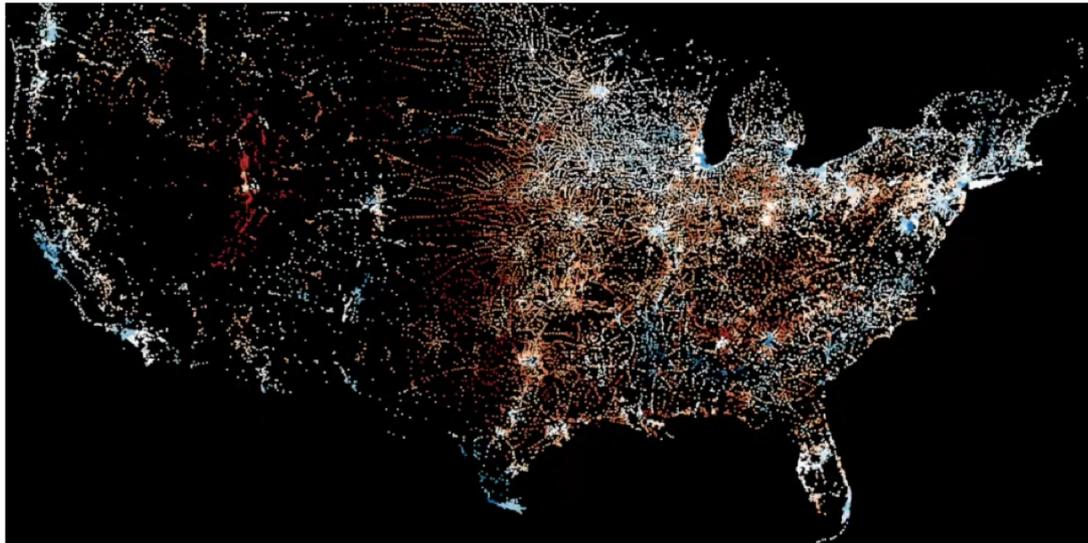
Drucker et al.(2015) proposed a unifying framework and implemented the SandDance system for generating unit visualizations (e.g., unit charts, and scatterplots) and smooth transitions between different layouts.

Drucker, Steven, and Roland Fernandez. "A unifying framework for animated and interactive unit visualizations." *Microsoft Research, Aug*(2015).

Animation for visualization transition
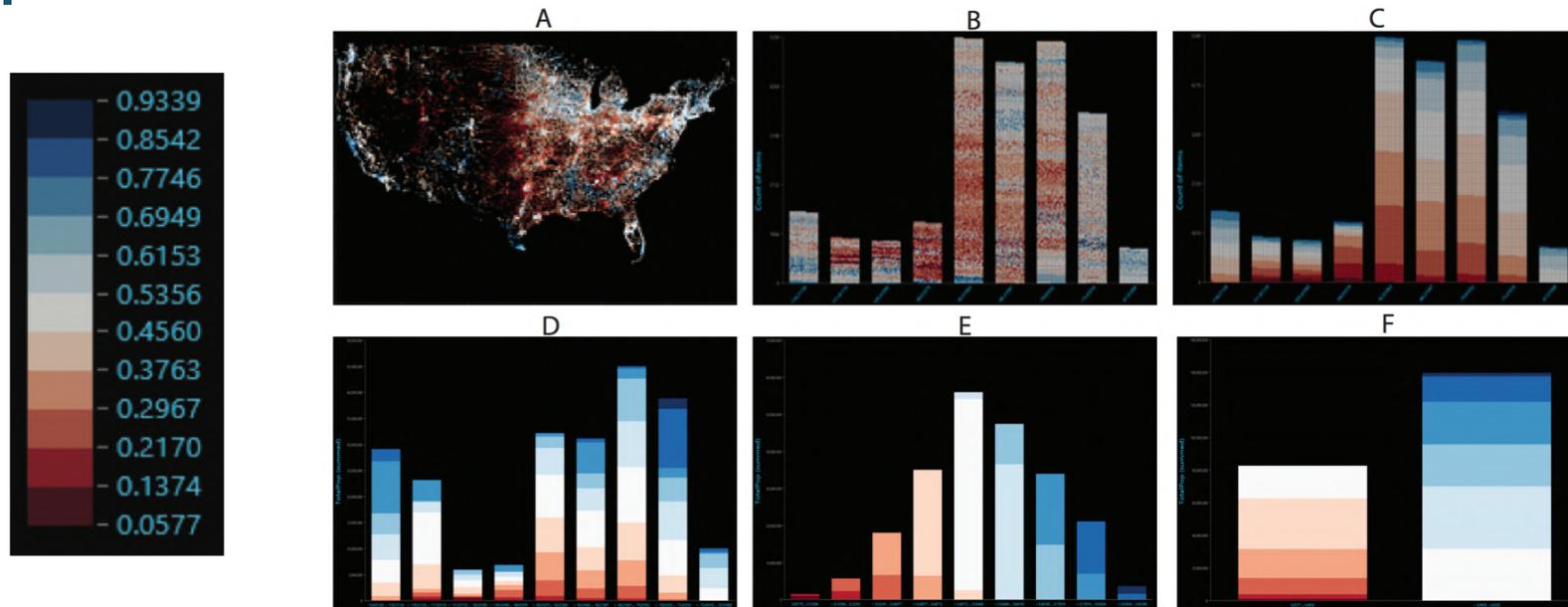
Exploring the 2010 election. A: Colored by voting percent; B: Binned by longitude; C: Sorted by voting percent; D: Summed by total population; E: Binned by voting percent; F: Changed to 2 bins.

Drucker, Steven, and Roland Fernandez. "A unifying framework for animated and interactive unit visualizations." *Microsoft Research, Aug*(2015).

Animation for visualization transition
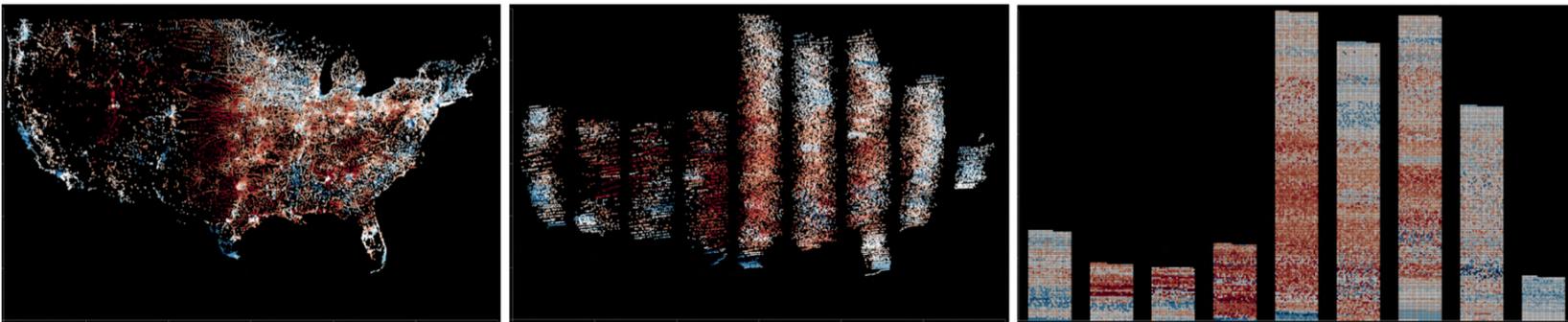
As the volume of data increases, the animated transitions will become **incomprehensible without more sophisticated bundling** techniques. Moreover, the units will become hard to display since the pixels of the screen are limited.

Drucker, Steven, and Roland Fernandez. "A unifying framework for animated and interactive unit visualizations." *Microsoft Research, Aug*(2015).

Animation for Highlighting

Waldner et al. (2014) considered human perception when designing a flickering effect, which is the cyclical variation of an objects appearance and disappearance that catches viewers' attention.

Waldner, Manuela, et al. "Attractive flicker—Guiding attention in dynamic narrative visualizations." *IEEE Transactions on Visualization & Computer Graphics* 12 (2014): 2456-2465.

Animation for data transition

Different temporal distortion strategies for animated transitions

Dragicevic et al. (2011) are the first to perform an empirical study and confirm that the slow-in/slow-out pacing is easier to follow than other temporal distortions in animations.

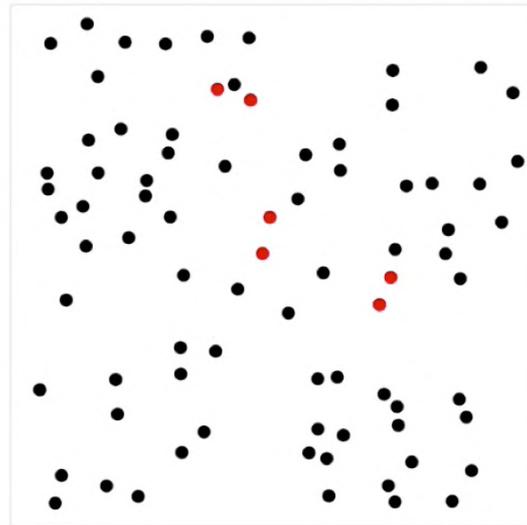However, their conclusion is only suitable for single-object tracking.

Dragicevic, Pierre, et al. "Temporal distortion for animated transitions." *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* ACM, 2011.

# Animation for data transition
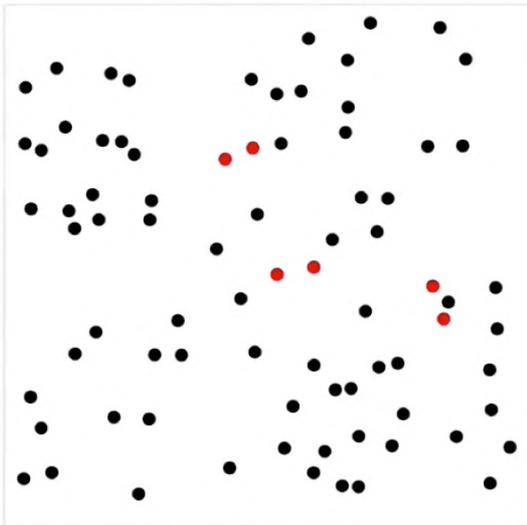
Task with **straight** ...   Task with **bundled** ...

Du et al. (2015) proposed a trajectory bundling approach for a group of adjacent objects that move in a similar direction.

Du, Fan, et al. "Trajectory bundling for animated transitions." *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2015.

Animation for data transition
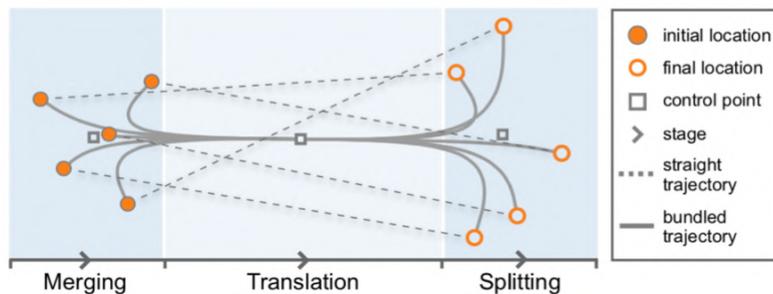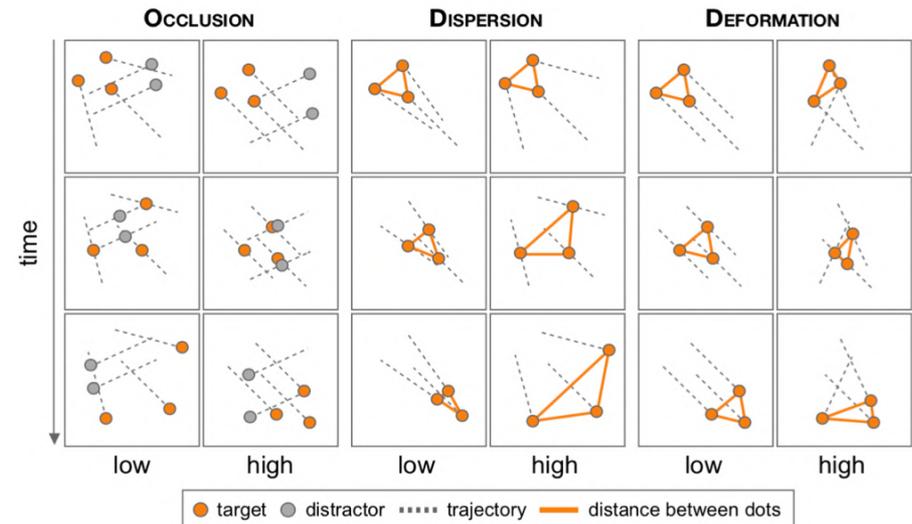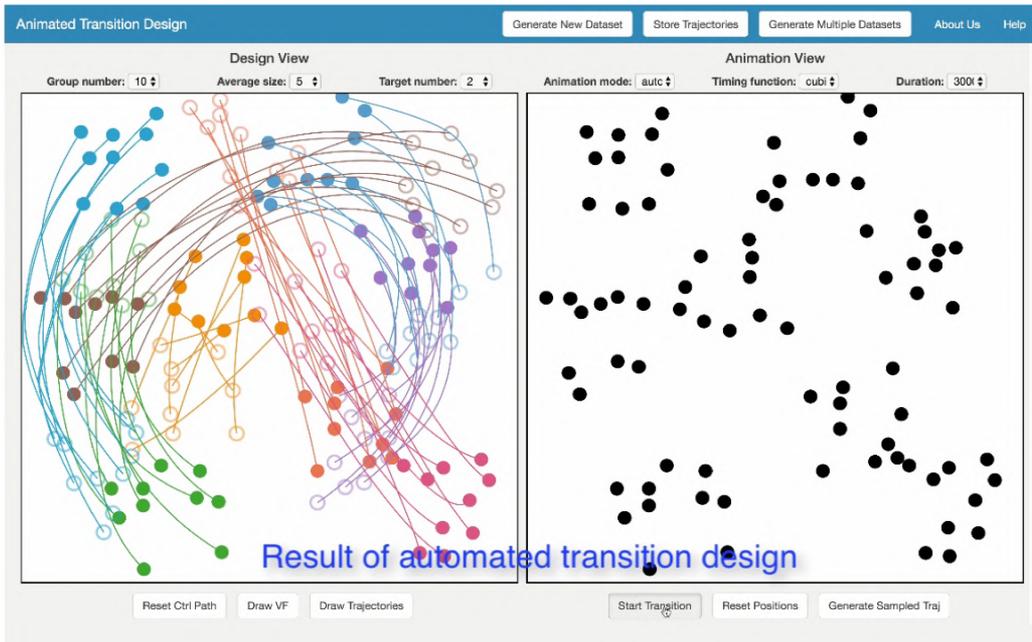

The movement trajectories

Illustration of the complexity metrics

Before this work, little has been done for improving animated transitions from the spatial aspect.

Du, Fan, et al. "Trajectory bundling for animated transitions." *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2015.

Revealing Insights

Animation for data transition


Result of automated transition design

However, the vector field design in their work relies on the clustering of moving points with similar spatial positions and motions, which is a strong constraint of the proposed technique.

Wang et al. (Wang et al., 2017) proposed a framework for creating animated transition of points along nonlinear paths with collision avoidance.

Wang, Yong, et al. "A Vector Field Design Approach to Animated Transitions." *IEEE transactions on visualization and computer graphics* (2017).

Evoking Emotions

- Emotion is one of the **key differences** between data story and data visualization.
- Emotive data stories are often more **memorable** and **enjoyable**.
- Evoking the audience's emotions can also **help convey** the storytellers' desired **messages**.
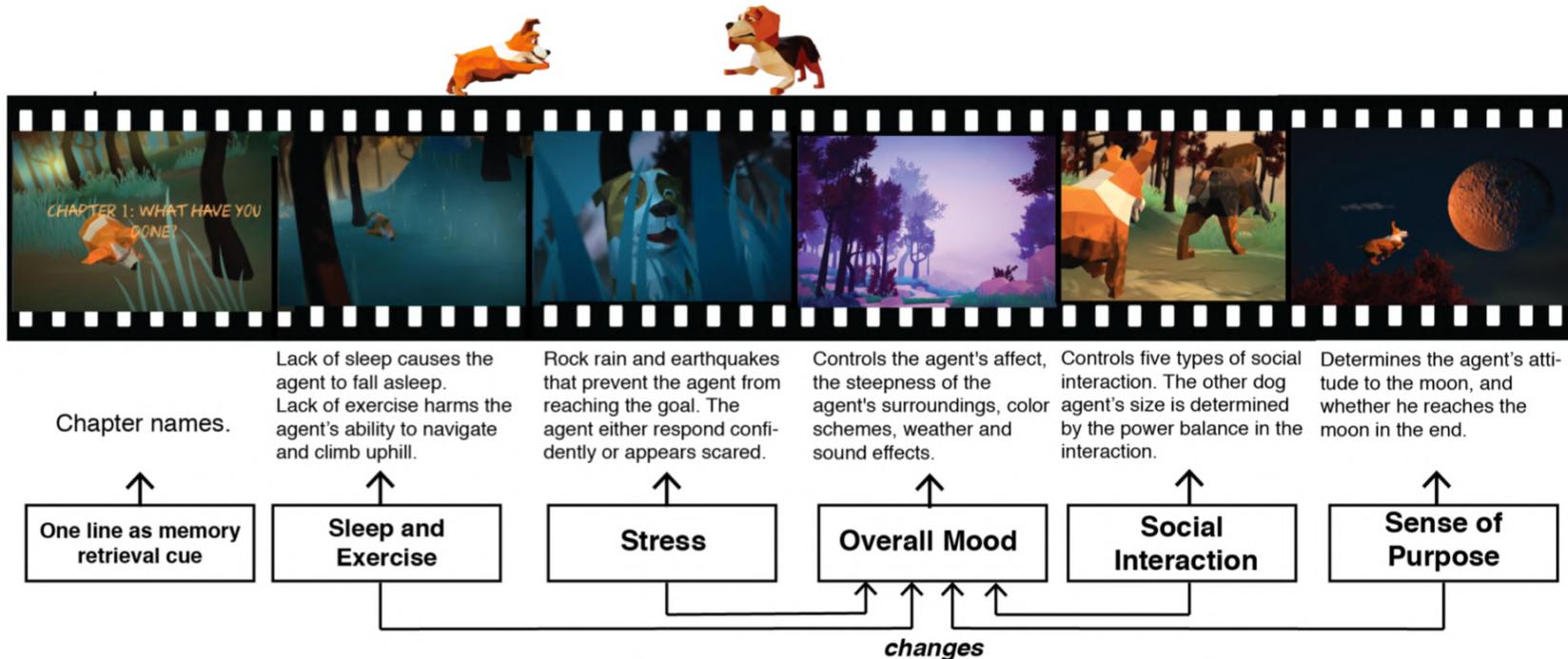
Evoking Emotions

U.S. GUN DEATHS IN   2013 2010

0
PEOPLE KILLED

0
STOLEN YEARS

AGE 0   108
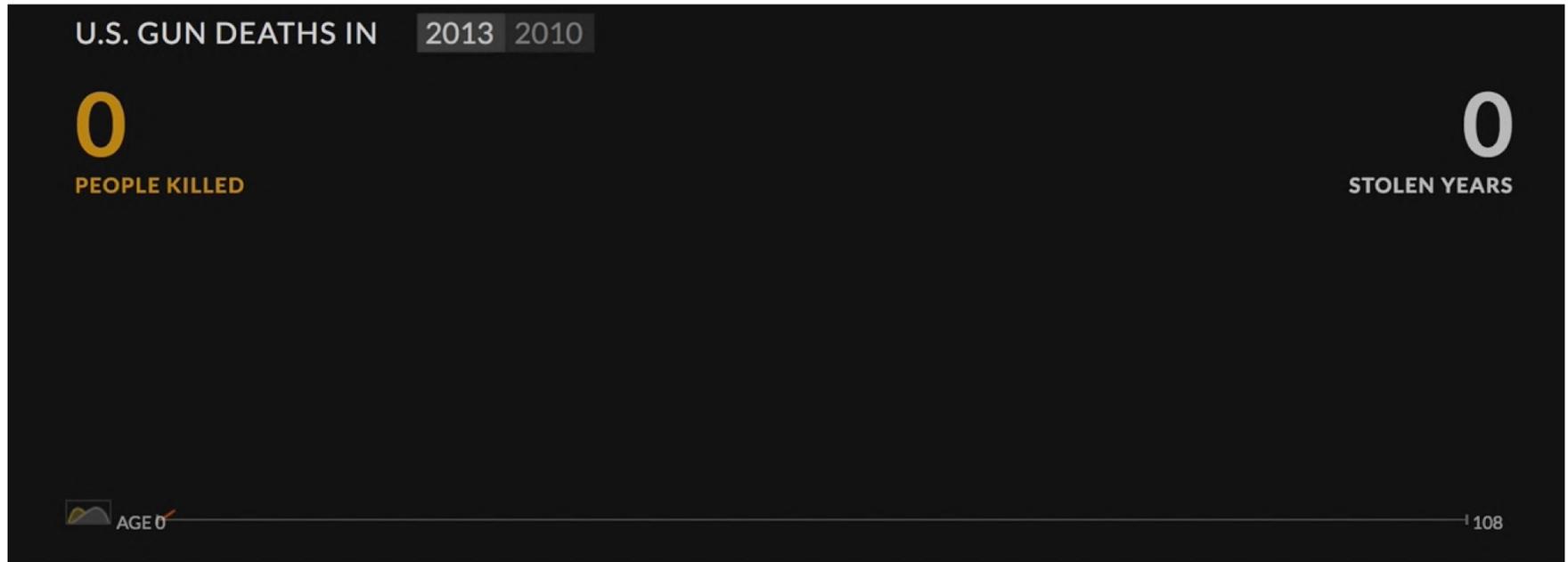
The animation produces an emotional data story with intense anxiety owing to the metaphor and the speed-up effect.

https://guns.periscopic.com/?year=2013

Evoking Emotions

By considering the viewer's mood and behavior data, Peng et al. (2018) opened up the design space and generated personalized animations that are emotionally engaging and motivated.
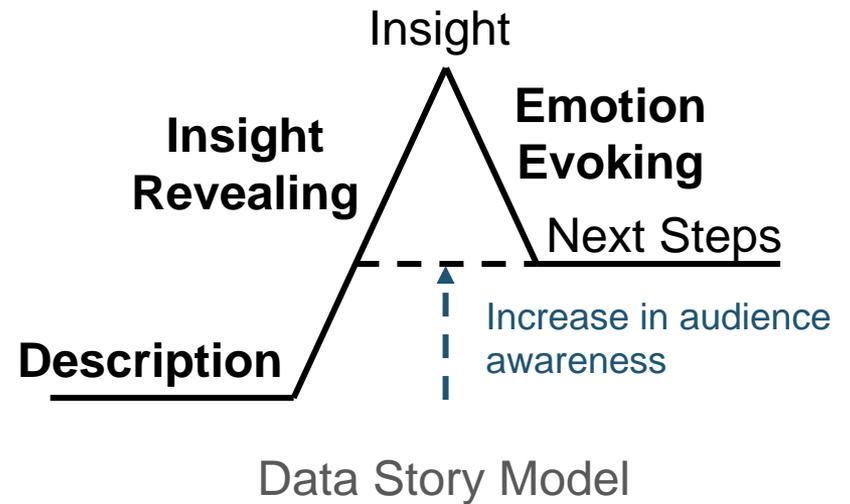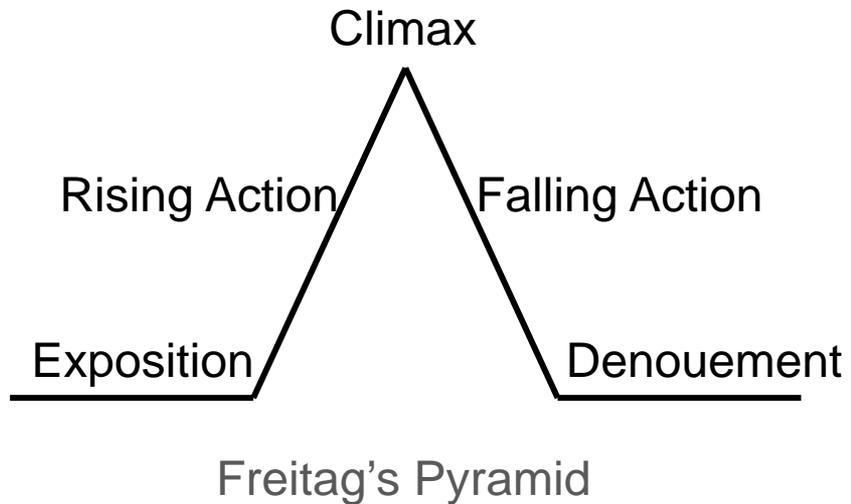
Peng, Fengjiao, et al. "A Trip to the Moon: Personalized Animated Movies for Self-reflection." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

Outline

Conclusion and Future Work

Conclusion

Future Work

Data Story Model

Freitag's Pyramid

Data Story Model

Conclusion

Animation in Visual Data Storytelling

Category		Related Papers	Remarks
Animation for Describing Data	Encoding Data Attribute	(Huber & Healey, 2005), (Akiba et al., 2010), (Scheepens et al., 2016), (Romat et al., 2018)	static data
	Encoding Stream Data	(Huron et al., 2013), (Wang et al., 2016), (Lin & Vuillemot, 2013), (Liu et al., 2016)	dynamic data
Animation for Revealing Insights	Data Transition	(Dragicevic et al., 2011), (Chevalier et al., 2014)	temporal aspect
		(Du et al., 2015), (Wang et al., 2017)	spatial aspect
	Visualization Transition	(Elmqvist et al., 2008), (Bezerianos et al., 2010)	view change
		(Heer & Robertson, 2007), (Drucker & Fernandez, 2015)	chart change
	Highlighting	(Ware & Bobrow, 2004)	position change
		(Waldner et al., 2014)	appearance change
Animation for Evoking Emotion		(Peng et al., 2018)	personal data

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Challenges

Crafting good data stories is not easy. Data sometimes seems to be the **antithesis** of stories because stories are usually related to **affectivity**, while data are associated with **objectivity**.
Moreover, a lot of **contradictions** have been found in animation research.

Emotion of Data Story

Advantages:
- Memorability
- Persuasiveness
- Engagement

Challenges:
- Human's mental states are hard to measure and evaluate

Opportunities:
- Personal data
- Speed

Effectiveness of Animation

Advantages:
- Comprehensible
- Engaging

Challenges:
- Findings have indicated that similar and opposing opinions always exist

Opportunities:
- Techniques from cinematography