ANIMATION
CS 448B | Fall 2023

MANEESH AGRAWALA
we discussed author driven vs. reader driven visualizations, in which author driven visualizations prescribe an ordering and convey stronger messaging, whereas reader driven visualizations can have multiple orderings and convey less messaging. I wonder which technique is better. I would think that it depends on the intended purpose and audience of a visualization – do you want to give the audience the freedom to generate their own conclusions, or do you want to ensure that they receive a specific message from your visualization?

I wondered if it is possible to produce a visualization that will easily be interpreted by everyone. In several other HCI classes, we have discussed how it is incredibly difficult to design a product that will fulfill the needs of every possible user, and I wonder if this same idea applies to creating visualizations as well.
FINAL PROJECT
Design Review Nov 27 and 29

Data analysis/explainer
   Analyze dataset in depth & make a visual explainer

Deliverables
   An article with multiple different interactive visualizations
     Short video (2 min) demoing and explaining the project

Schedule
   Project proposal: Mon 11/6
   Design Review and Feedback: 9th week of quarter, 11/27 and 11/29
   Final code and video: Sun 12/10 8pm

Grading
   Groups of up to 3 people, graded individually
   Clearly report responsibilities of each member

ANIMATION
QUESTION

The goal of visualization is to convey information

How does animation convey information?
**WHY USE MOTION?**

Visual variable to encode data
Direct attention
Understand system dynamics (changes in time)
Understand state transition
Increase engagement
Learning Objectives

1. Understand motion perception and cognitive interpretation
2. When to use animated transitions in visualization
3. How to implement animation

TODAY

MOTION PERCEPTION
MOTION AS A VISUAL CUE

Pre-attentive
   Stronger than color, shape, ...

Triggers an orientation response
Motion parallax provides 3D cue
More sensitive to motion at periphery

GROUPED DOTS COUNT AS 1 OBJECT

Dots moving together are grouped
GROUPING BASED ON BIOLOGICAL MOTION

[Johansson 1973]
VOLUME RENDERING [Lacroute 1995]

TRACKING MULTIPLE TARGETS

How many dots can we simultaneously track?

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4 to 6 - difficulty increases significantly at 6

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Can see change from one state to next
States are spatial layouts
Changes are simple transitions (translations, rotations, scale)

start

end
MOTIONS DIRECTLY SHOW TRANSITIONS

Can see change from one state to next
States are spatial layouts
Changes are simple transitions (translations, rotations, scale)

Shows transition better, but
Still may be too fast, or too slow
Too many objects may move at once

[Image of motion diagram]

DIMPVIS
[Kondo 2014]
https://vega.github.io/vega/examples/global-development/
COGNITIVE INTERPRETATION OF MOTION

CONSTRUCTING NARRATIVES [Heider & Simmel 1944]

Animation from:
An experimental study of apparent behavior.

Courtesy of:
Department of Psychology,
University of Kansas, Lawrence.
ATTRIBUTION OF CAUSALITY  [Michotte 1946]

Michotte demonstration 1. What do you see? Most observers report that "the red ball hit the blue ball." The blue ball moved "because the red ball hit it." Thus, the red ball is perceived to "cause" the blue ball to move, even though the balls are nothing more than color disks on your screen that move according to a programme.

http://cogweb.ucla.edu/Discourse/Narrative/Heider_45.html

Reprint from Ware [2004]
HOW DOES IT WORK?

Two-cylinder Stirling engine
http://www.keveney.com/Vstirling.html

PROBLEMS OF ANIMATION [Tversky 1992]

1. Difficult to estimate paths and trajectories
2. Motion is fleeting and transient
3. Cannot simultaneously attend to multiple motions
4. Trying to parse motion into events, actions and behaviors
5. Misunderstanding and wrongly inferring causality
6. Anthropomorphizing physical motion may cause confusion or lead to incorrect conclusions
**BREAK INTO STATIC STEPS**

1. **Expansion.** At this point, most of the gas in the system has just been driven into the hot cylinder. The gas heat and expands driving both pistons inward.

2. **Transfer.** At this point, the gas has expanded (about 3 times in this example). Most of the gas (about 2/3) is still located in the hot cylinder. The heat of combustion causes the crankshaft to turn 90 degrees.

3. **Contraction.** Now the majority of the expanded gas has been displaced to the cool cylinder. It cools and contracts, drawing both pistons outward.

4. **Transfer.** The new contracted gas is still located in the cool cylinder. The heat of combustion causes the crankshaft to turn 90 degrees, transferring the bulk of the gas to the hot cylinder to complete the cycle.

Choosing the set of steps

How to segment process into steps?

Tversky suggests

- Coarse level – segment based on objects
- Finer level – segment based on actions

Static depictions often do not show finer action-level segmentation
ANIMATED TRANSITIONS IN STATISTICAL GRAPHICS
SORTING

57

58
CHANGE ENCODINGS
CHANGE DATA FIELD

ADD DATA FIELD
CHANGE ENCODINGS + AXIS SCALE

DATA GRAPHICS & TRANSITIONS

<table>
<thead>
<tr>
<th>Category</th>
<th>Sales</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Visual Encoding

Change selected data fields or encodings

Animation to communicate changes?
During analysis and presentation it is common to transition between related data graphics

Can animation help?
How does this impact perception?

**TRANSITIONS BETWEEN CHARTS**

**PRINCIPLES FOR ANIMATION** [Tversky 2002]

**Congruence**
The structure and content of the external representation should correspond to the desired structure and content of the internal representation.

**Apprehension**
The structure and content of the external representation should be readily and accurately perceived and comprehended.
PRINCIPLES FOR ANIMATION  [Heer 2007]

Congruence
- Maintain valid data graphics during transitions
- Use consistent encodings
- Respect semantic correspondence
- Avoid ambiguity

Apprehension
- Group similar transitions
- Minimize occlusion
- Maximize predictability
- Use simple transitions
- Use staging for complex transitions
- Make transitions as long as needed, but no longer

Visual marks should always represent the same data tuple.
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Different actions should have distinct animations.

Objects are harder to track when occluded.

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Keep animation as simple as possible. If complicated, break into simple stages.
STUDY CONCLUSIONS [Heer 2007]

Appropriate animation improves graphical perception

Simple transitions beat “do one thing at a time”

Simple staging preferred and showed benefits but timing important and in need of study

Axis re-scaling hampers perception
  - Avoid if possible (use common scale)
  - Maintain landmarks better (delay fade out of gridlines)

Subjects preferred animated transitions

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ANIMATION IN TREND VISUALIZATION

Heer’s 2007 study found that animated transitions are better than static transitions for estimating changing values.

How does animation fare vs. static time-series depictions (as opposed to static transitions)?

Experiments by Robertson et al, IEEE InfoVis 2008
Animated Scatterplot [Robertson 2008]

Traces [Robertson 2008]
Small Multiples [Robertson 2008]

Which to prefer for analysis? Which for presentation?
STUDIED ANALYSIS & PRESENTATION

Subjects asked comprehension questions
Presentation condition included narration

Multiples 10% more accurate than animation

Presentation: Animation 60% faster than multiples
Analysis: Animation 82% slower than multiples

But, users prefer animation (even though less accurate and slower for analysis!)

IMPLEMENTING ANIMATION
**ANIMATION APPROACHES**

**Frame-based Animation**
Redraw scene at regular interval (e.g., 16ms)  
Developer defines the redraw function

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**FRAME-BASED ANIMATION**

- `circle(10,10)`  
- `circle(15,15)`  
- `circle(20,20)`  
- `circle(25,25)`

- `clear()`

1 2 3 4
**ANIMATION APPROACHES**

**Frame-based animation**
Redraw scene at regular interval (e.g., 16ms)
Developer defines the redraw function

**Transition-based animation** [Hudson & Stasko 1993]
Specify property value, duration & easing
Also called **tweening** (for in-betweening)

Typically computed via interpolation

\[
\text{step} (\text{fraction}) \{ \ x_{\text{now}} = x_{\text{start}} + \text{fraction} \times (x_{\text{end}} - x_{\text{start}}); \}
\]

Timing & redraw managed by UI toolkit

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**TRANSITION-BASED ANIMATION**

**from:** (10,10) **to:** (25,25) **duration:** 3sec

![Transition-Based Animation Diagram]
TRANSITION-BASED ANIMATION

from: (10,10) to: (25,25) duration: 3sec
Toolkit handles frame-by-frame updates and clearing screen

D3 TRANSITIONS

Any d3 selection can be used to drive animation.
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```
// Select SVG rectangles and bind them to data values.
var bars = svg.selectAll("rect.bars").data(values);
```

Static transition: update position and color of bars
```
bars
  .attr("x", (d) => xScale(d.foo))
  .attr("y", (d) => yScale(d.bar))
  .style("fill", (d) => colorScale(d.baz));
```
Any d3 selection can be used to drive animation.

// Select SVG rectangles and bind them to data values.
var bars = svg.selectAll("rect.bars").data(values);

// Animated transition: interpolate to target values using default timing
bars.transition()
  .attr("x", (d) => xScale(d.foo))
  .attr("y", (d) => yScale(d.bar))
  .style("fill", (d) => colorScale(d.baz));

// Animation is implicitly queued to run!
D3 TRANSITIONS, CONTINUED

bars.transition()
  .duration(500) // animation duration in ms
  .delay(0) // onset delay in ms
  .ease(d3.easeBounce) // set easing (or "pacing") style
  .attr("x", (d) => xScale(d.foo))
  ...

D3 TRANSITIONS, CONTINUED

bars.transition()
  .duration(500) // animation duration in ms
  .delay(0) // onset delay in ms
  .ease(d3.easeBounce) // set easing (or "pacing") style
  .attr("x", (d) => xScale(d.foo))
  ...

  bars.exit().transition() // animate elements leaving display
    .style("opacity", 0) // fade out to fully transparent
    .remove(); // remove from DOM upon completion
EASING FUNCTIONS

Goals: stylize animation, improve perception

Idea: warp time as duration goes from start (0%) to end (100%) and dynamically adjust the interpolation fraction using an easing function

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EASING FUNCTIONS
Extends CSS with Animated Transitions

```css
a {
    color: black;
    transition: color 1s ease-in-out;
}

a:hover {
    color: red;
}
```
CSS TRANSITIONS

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CSS TRANSITIONS

Extends CSS with Animated Transitions

a {
  color: black;
  transition: color 1s ease-in-out;
}

a:hover {
  color: red;
  Animate color transition upon mouse in / out.
SUMMARY

Animation is a salient visual phenomenon
Attention, object constancy, causality, timing
Design with care: congruence & apprehension
Step-by-step static images may be better for processes and for data analysis, but for presentation animation is preferred
For transitions, animation has some benefits, but consider task and timing