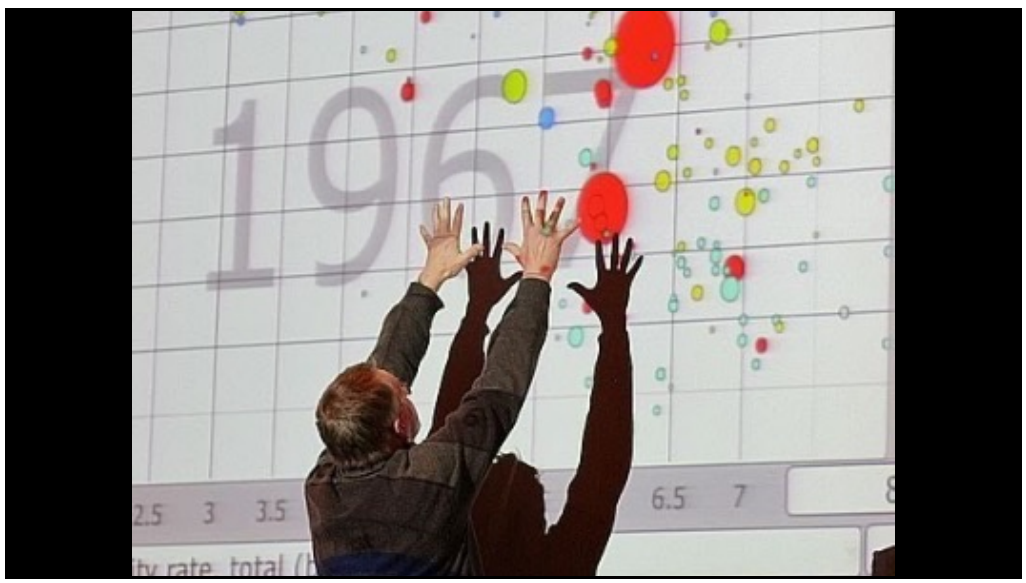
ANIMATION

CS 448B | Fall 2024

MANEESH AGRAWALA

1



2

READING RESPONSE: QUESTIONS/THOUGHTS

A critique about their [Cleveland & McGIll on Graphical Perception] argument is that by purely focusing on accuracy could limit the creative possibilities in creating visualizations. In some things like narrative visualizations engagement is almost just as important as precision. ***Could there be a more flexible approach that can balance accuracy and creativity in order to make visualizations precise and engaging?***

This question then leads me to ask how we should amend preattentive processing to be more inclusive — for example, ***how do the preattentive cues we rely on in communicating data need to adapt to ensure inclusive design?*** The article specifies how color, size, and shape are detected almost instantly and thus commonly used in visualization, but how can we account for viewers that may have difficulty distinguishing between the colors we use or micro-differences in size or shape?

3

ANIMATION

4

QUESTION

The goal of visualization is to convey information

How does animation convey information?

5

CONE TREES

[Robertson 1991]

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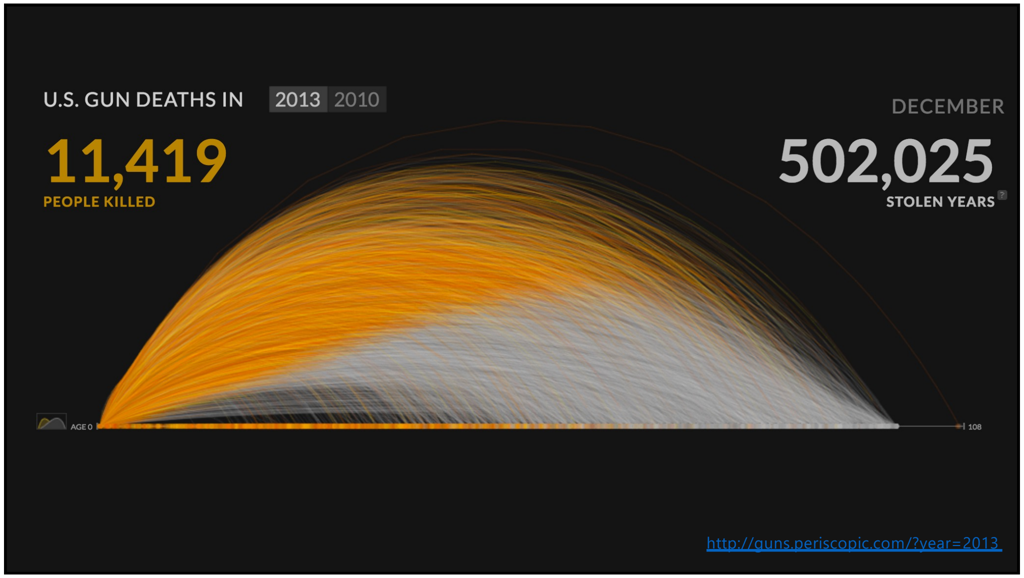

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WHY USE MOTION?

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

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TODAY

Learning Objectives

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

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MOTION PERCEPTION

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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

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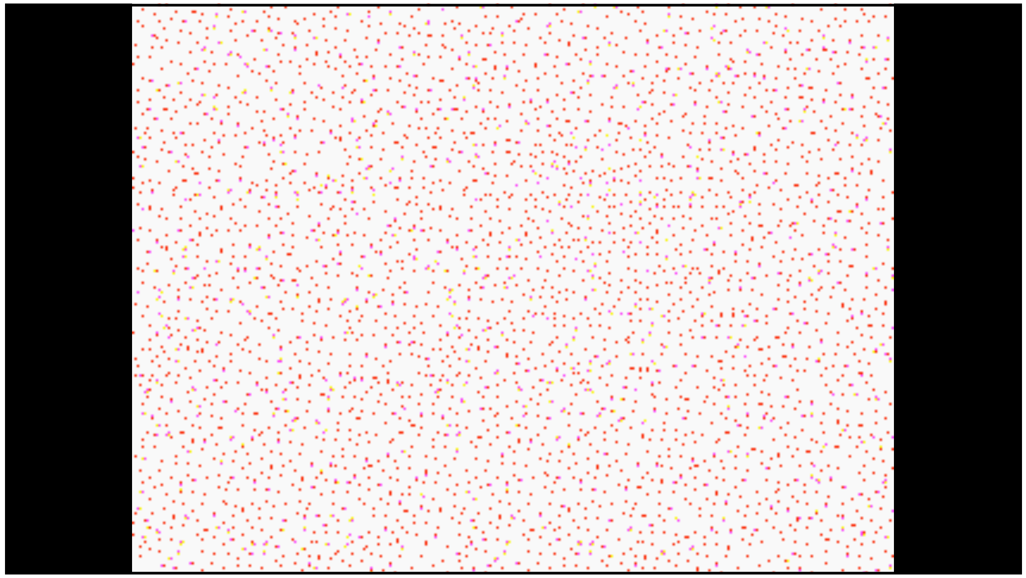
GROUPED DOTS COUNT AS 1 OBJECT

Dots moving together are grouped

12



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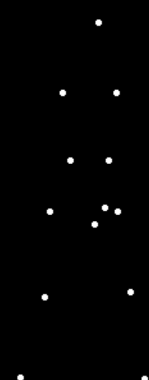
GROUPING BASED ON BIOLOGICAL MOTION



[Johansson 1973]

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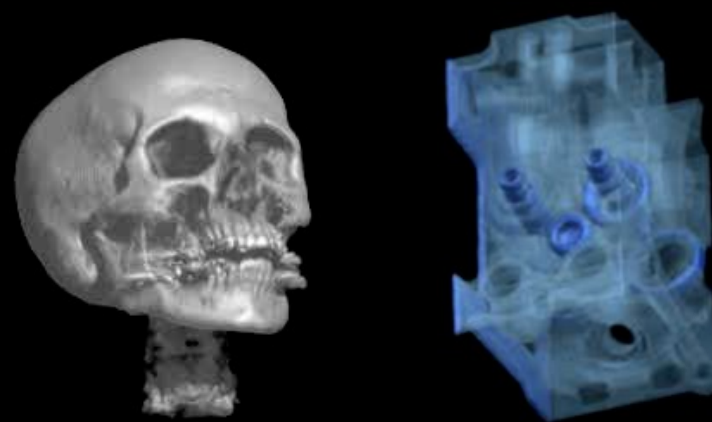
VOLUME RENDERING [Lacroute 1995]



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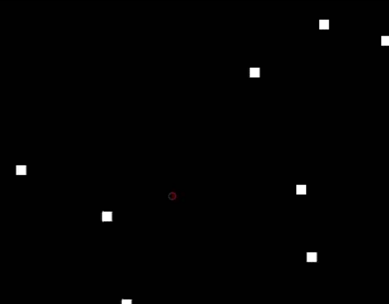
TRACKING MULTIPLE TARGETS



How many dots can we simultaneously track?

[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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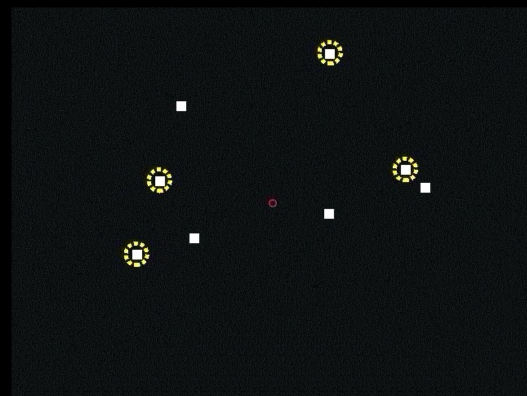
TRACKING MULTIPLE TARGETS



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[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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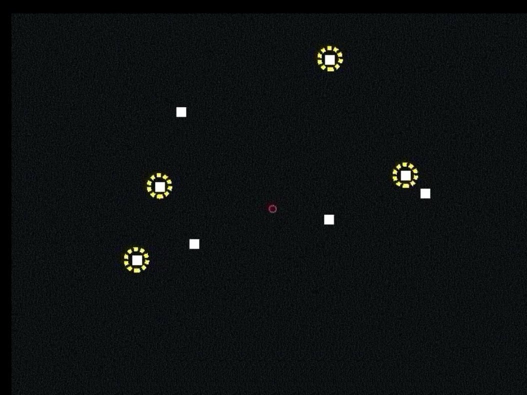
TRACKING MULTIPLE TARGETS



How many dots can we simultaneously track?

4 to 6 - difficulty increases significantly at 6

[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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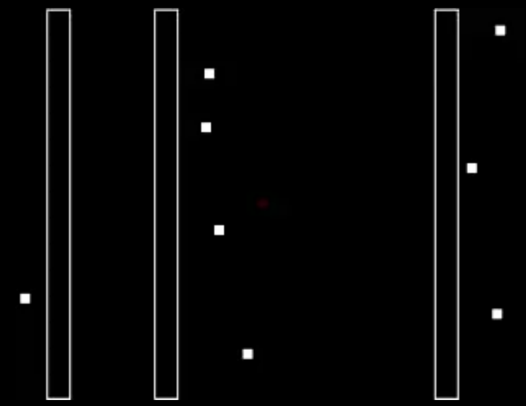
TRACKING MULTIPLE TARGETS



How many dots can we simultaneously track?

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[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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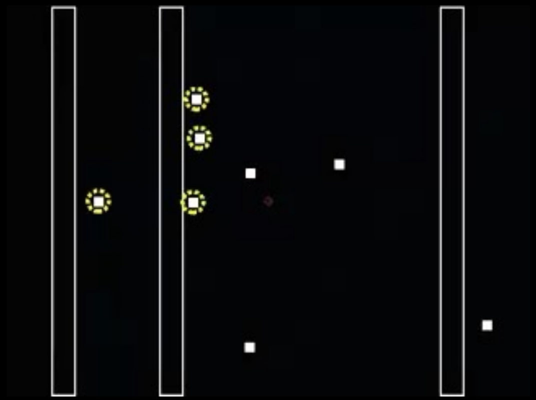
TRACKING MULTIPLE TARGETS



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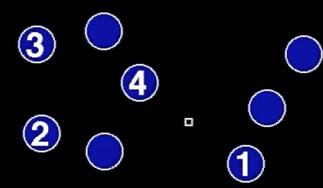
TRACKING MULTIPLE TARGETS



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[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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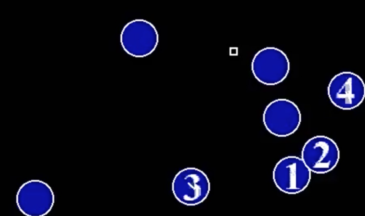
TRACKING MULTIPLE TARGETS



How many dots can we simultaneously track?

4 to 6 - difficulty increases significantly at 6

[Yantis 1992, Pylyshn 1988, Cavanagh 2005]

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STATE TO STATE TRANSITIONS

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (translations, rotations, scale)

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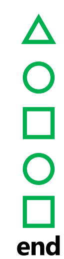
STATE TO STATE TRANSITIONS

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (translations, rotations, scale)



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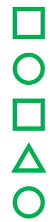
MOTIONS DIRECTLY SHOW TRANSITIONS

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (translations, rotations, scale)



start **end**

Shows transition better, but

- Still may be too fast, or too slow
- Too many objects may move at once

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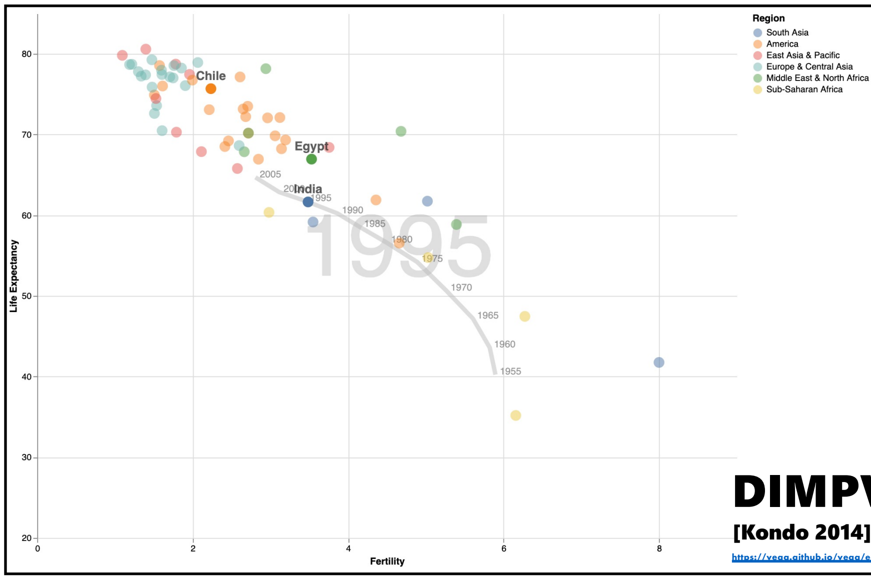

DIMPVIS

[Kondo 2014]

https://vega.github.io/vega/examples/global-development/

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ANNOUNCEMENTS

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FINAL PROJECT

Proposal due 11/4 10:30am

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 11/4
- Design Review and Feedback: 10th week of quarter
- Final code and video: Sun 12/8 8pm

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

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COGNITIVE INTERPRETATION OF MOTION

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CONSTRUCTING NARRATIVES [Heider & Simmel 1944]

Animation from:
Heider, F. & Simmel, M. (1944).
An experimental study of apparent behavior.
American Journal of Psychology, 57, 243-259.

Courtesy of:
Department of Psychology,
University of Kansas, Lawrence

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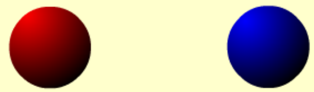
ATTRIBUTION OF CAUSALITY [Michotte 1946]

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

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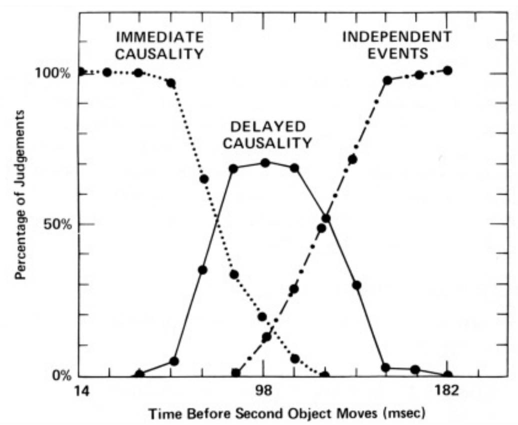
ATTRIBUTION OF CAUSALITY [Michotte 1946]



Reprint from Ware [2004]

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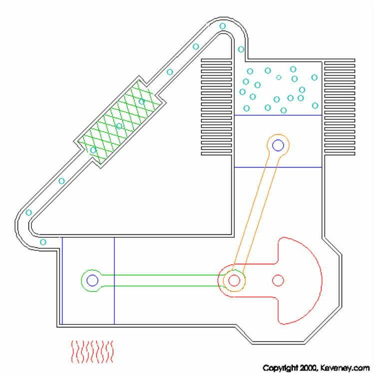
HOW DOES IT WORK?



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

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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

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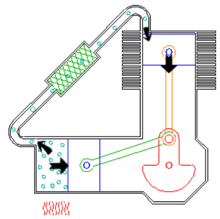
BREAK INTO STATIC STEPS

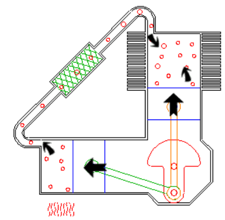
1

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



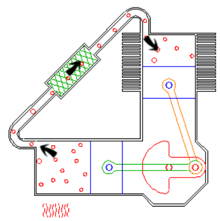
3

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



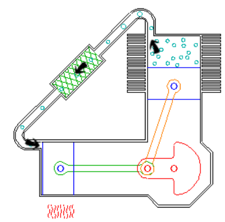
2

Transfer. At this point, the gas has expanded (about 3 times in this example). Most of the gas (about 2/3rds) is still located in the hot cylinder. Flywheel momentum carries the crankshaft the next 90 degrees, transferring the bulk of the gas to the cool cylinder.



4

Transfer. The now contracted gas is still located in the cool cylinder. Flywheel momentum carries the crank another 90 degrees, transferring the gas to back to the hot cylinder to complete the cycle.



Two-cylinder Stirling engine

http://www.keveney.com/Vstirling.html

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CHALLENGES

Choosing the set of steps

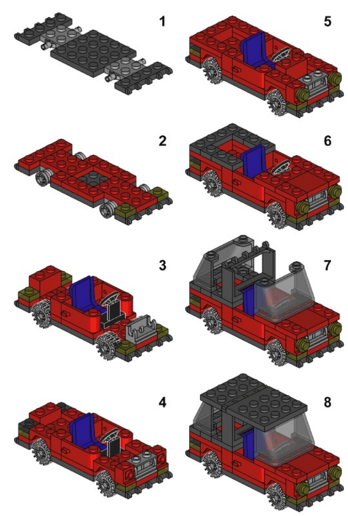
How to segment process into steps?

Tversky suggests

Coarse level – segment based on objects

Finer level – segment based on actions

Static depictions often do not show finer action-level segmentation



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ANIMATED TRANSITIONS IN STATISTICAL GRAPHICS

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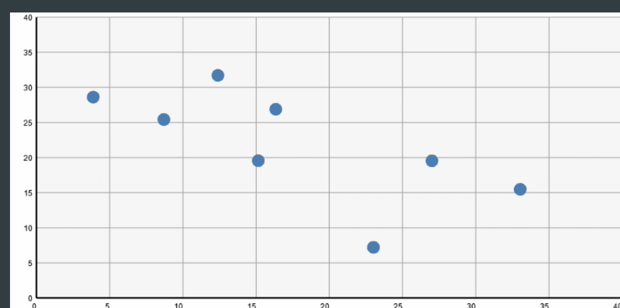

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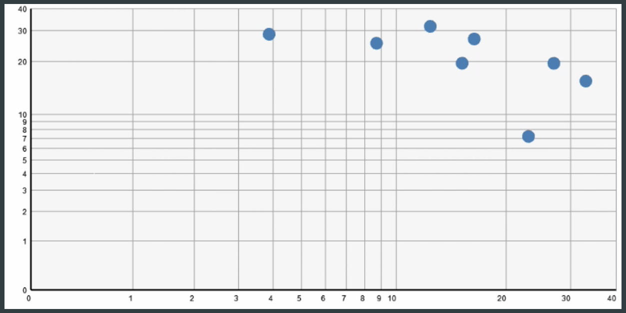
LOG TRANSFORM



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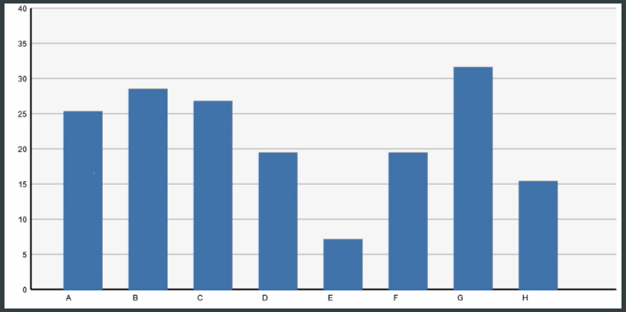

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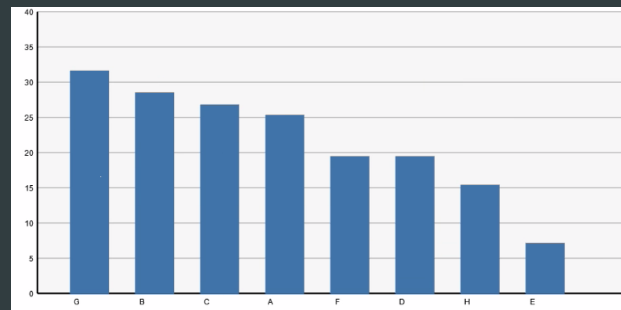
SORTING



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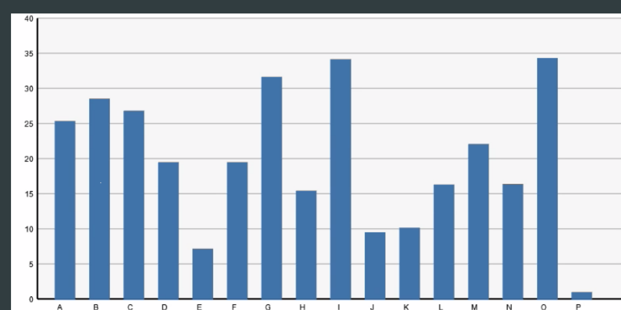

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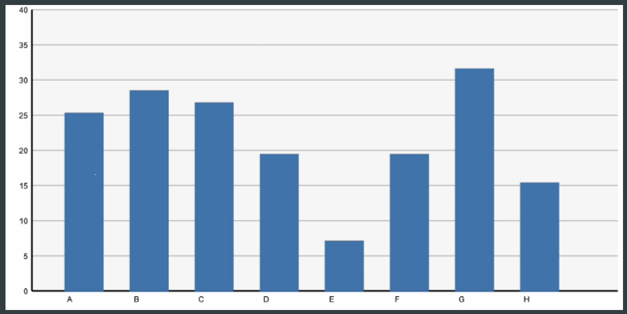
FILTERING



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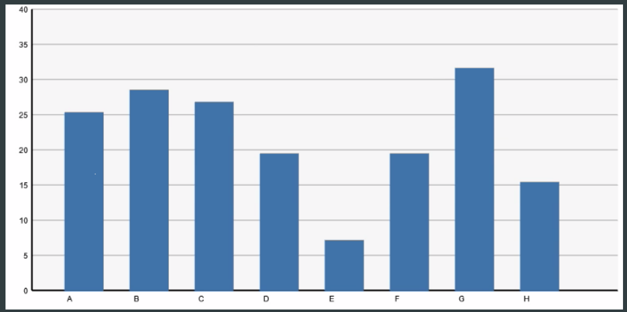

Month 1

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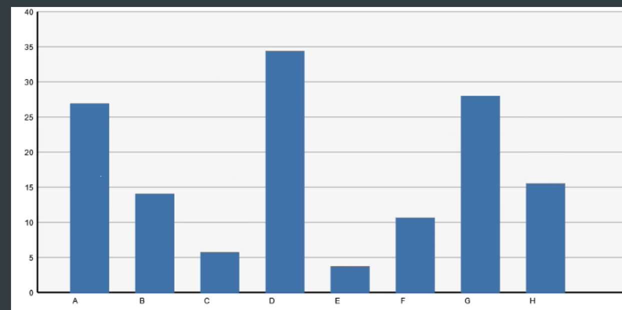
TIMESTEP



Month 2

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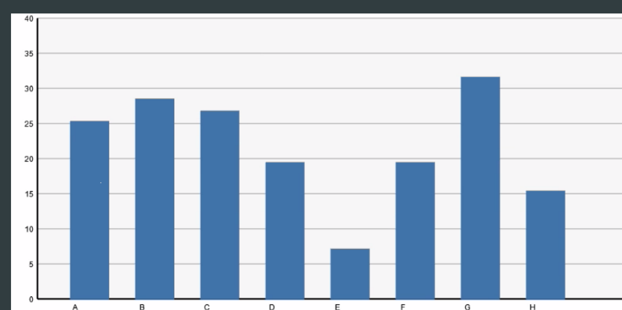

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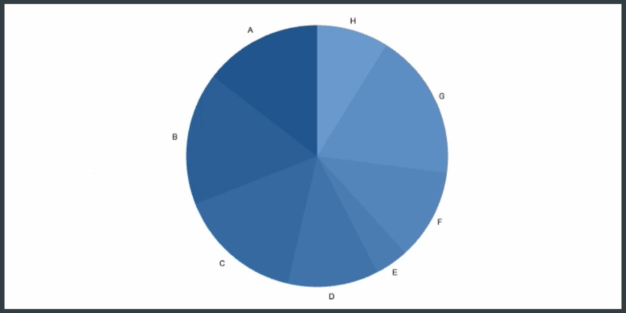
CHANGE ENCODINGS



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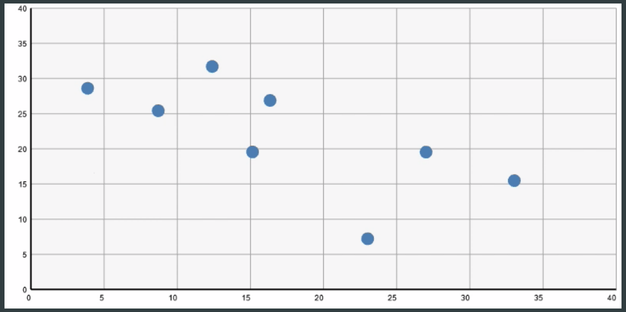

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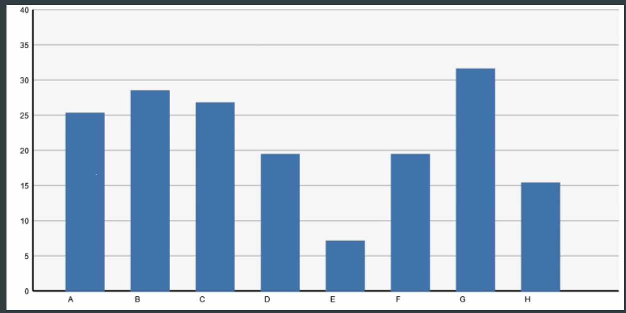
CHANGE DATA FIELD



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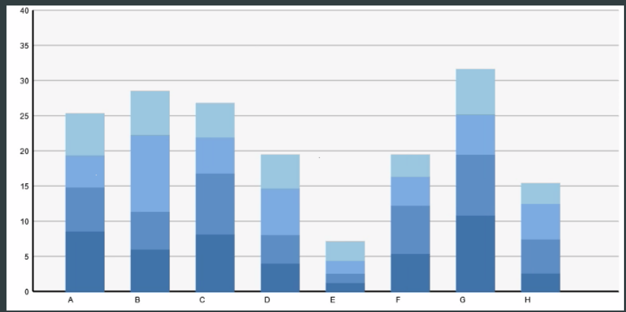
ADD DATA FIELD



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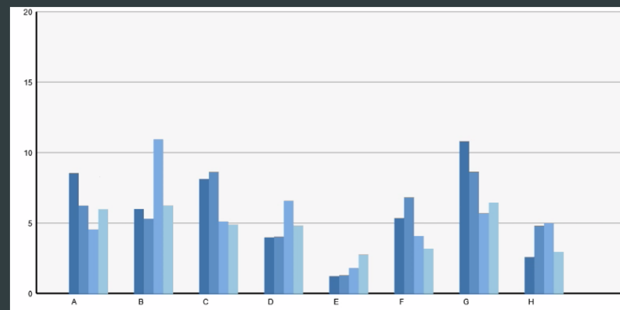
CHANGE ENCODINGS + AXIS SCALE



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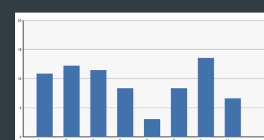
DATA GRAPHICS & TRANSITIONS

Category	Sales	Profit
A	11	7
B	13	10
C	12	6
D	8	5
E	3	1

Visual Encoding

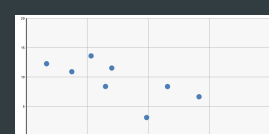


Change selected data fields or encodings

Animation to communicate changes?

Category	Sales	Profit
A	11	7
B	13	10
C	12	6
D	8	5
E	3	1

Visual Encoding



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TRANSITIONS BETWEEN CHARTS

During analysis and presentation it is common to transition between *related* data graphics

Can animation help?
How does this impact perception?

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PRINCIPLES FOR ANIMATION **[Tversky 2002]**

Congruence *Expressiveness?*

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

Apprehension *Effectiveness?*

The structure and content of the external representation should be readily and accurately perceived and comprehended.

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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

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PRINCIPLES FOR ANIMATION [Heer 2007]

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

Visual marks should always represent the same data tuple.

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

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PRINCIPLES FOR ANIMATION [Heer 2007]

Congruence

Maintain valid data graphics during transitions
Use consistent encodings
Respect semantic correspondence
Avoid ambiguity → **Different actions should have distinct animations.**

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

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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 → **Objects are harder to track when occluded.**
Maximize predictability
Use simple transitions
Use staging for complex transitions
Make transitions as long as needed, but no longer

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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

Keep animation as simple as possible. If complicated, break into simple stages.

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Animated Transitions in Statistical Data Graphics

Jeffrey Heer
George G. Robertson

Microsoft Research

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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

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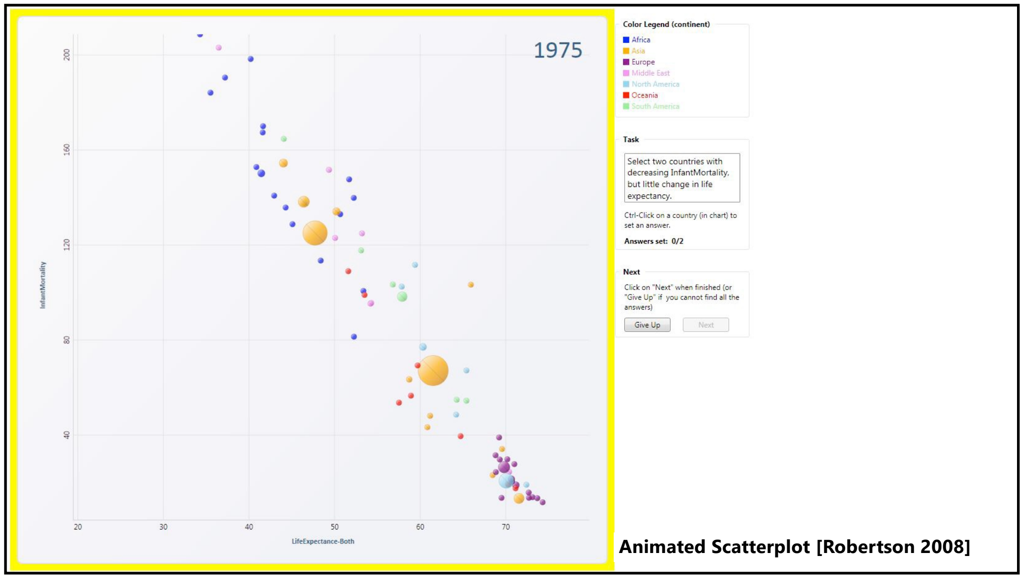
1975
InfantMortality
LifeExpectance-Both
Color Legend (continent)
Africa
Asia
Europe
Middle East
North America
Oceania
South America
Task
Select two countries with decreasing InfantMortality, but little change in life expectancy.
Ctrl-Click on a country (in chart) to set an answer.
Answers set: 0/2
Next
Click on "Next" when finished (or "Give Up" if you cannot find all the answers)
Give Up
Next
Animated Scatterplot [Robertson 2008]

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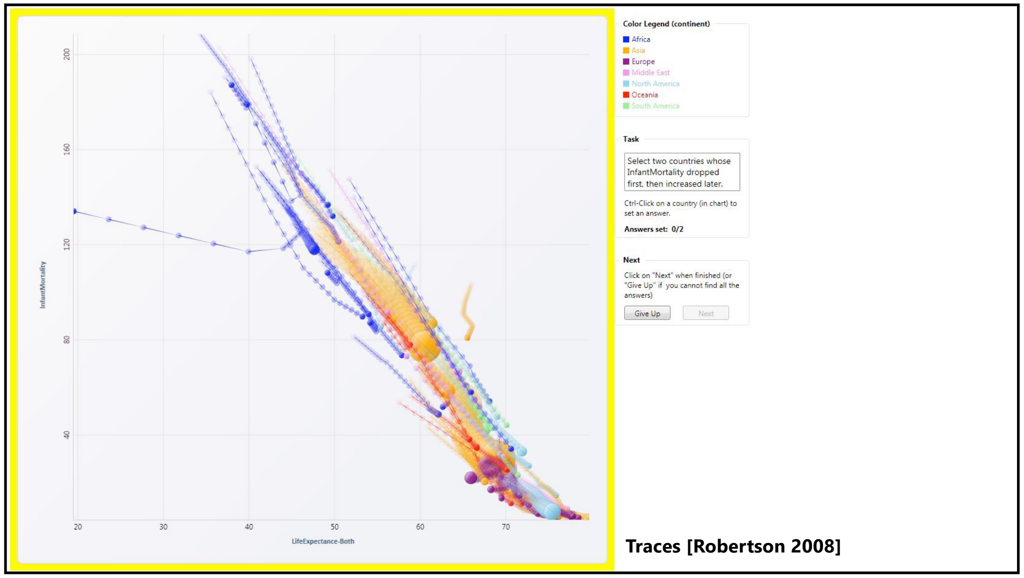
InfantMortality
LifeExpectance-Both
Color Legend (continent)
Africa
Asia
Europe
Middle East
North America
Oceania
South America
Task
Select two countries whose InfantMortality dropped first, then increased later.
Ctrl-Click on a country (in chart) to set an answer.
Answers set: 0/2
Next
Click on "Next" when finished (or "Give Up" if you cannot find all the answers)
Give Up
Next
Traces [Robertson 2008]

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Small Multiples [Robertson 2008]

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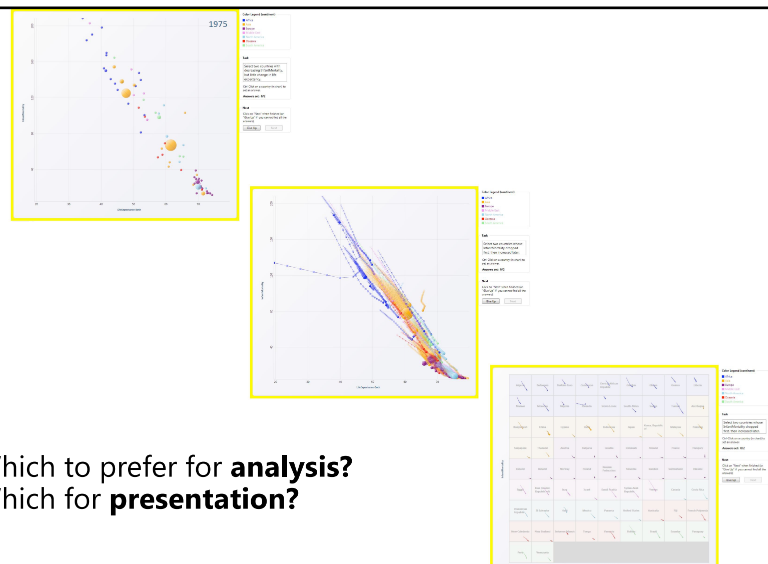

Which to prefer for **analysis?**
Which for **presentation?**

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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!)

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IMPLEMENTING ANIMATION

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ANIMATION APPROACHES

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

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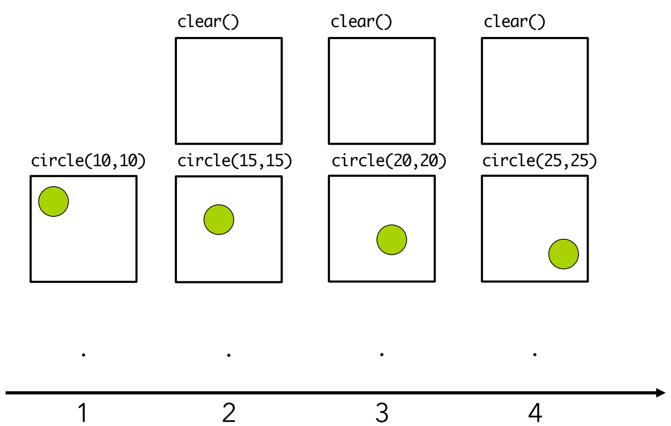
FRAME-BASED ANIMATION



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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

step(*fraction*) { $x_{now} = x_{start} + fraction * (x_{end} - x_{start})$; }

Timing & redraw managed by UI toolkit

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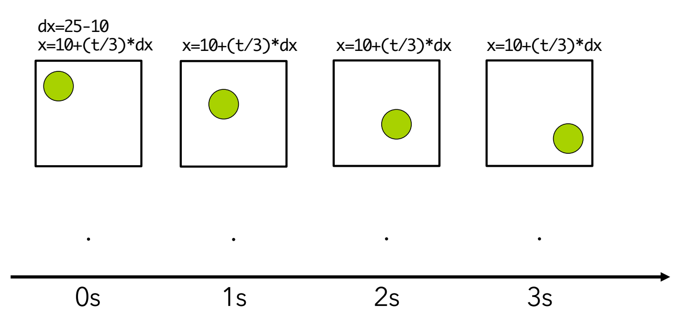
TRANSITION-BASED ANIMATION

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



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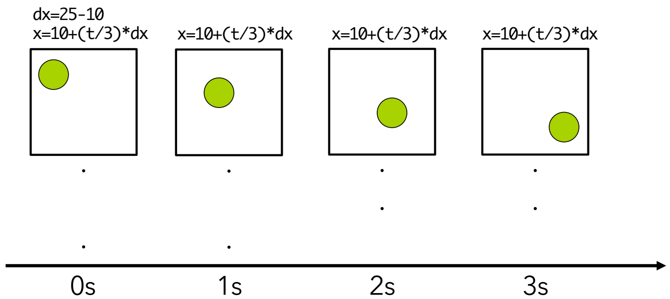
TRANSITION-BASED ANIMATION

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



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D3 TRANSITIONS

Any d3 ***selection*** can be used to drive animation.

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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);
```

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D3 TRANSITIONS

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);

// 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));
```

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D3 TRANSITIONS

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));
```

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D3 TRANSITIONS

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!
```

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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))
  …
```

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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
```

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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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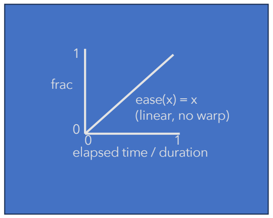

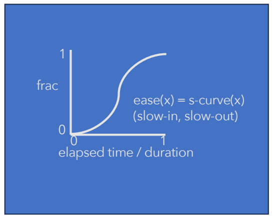

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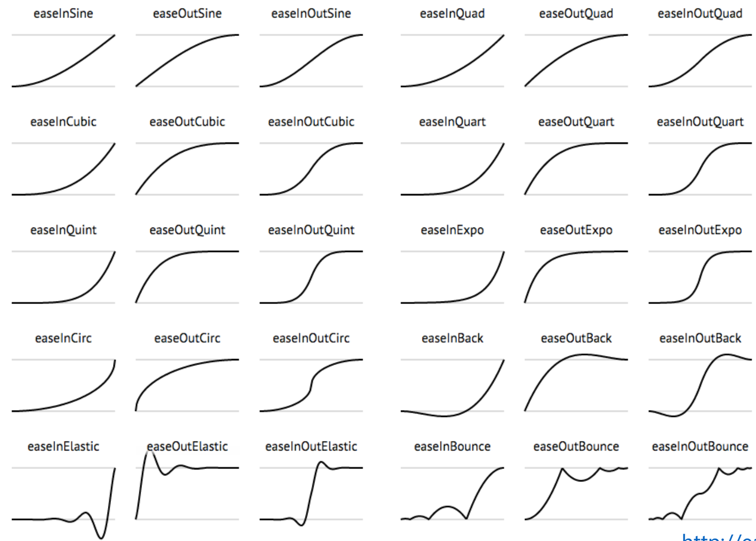

http://easings.net/

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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**

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Summary

- Animations convey motion, action, story, process
- Problems
  - Divided attention
  - Transient
- Techniques
  - Aid segmentation into events, actions, sequences, story
  - Relies on our ability to fill in temporal gaps (closure)
  - More research required on principles for creating effective animated visualizations

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