Animation

Maneesh Agrawala

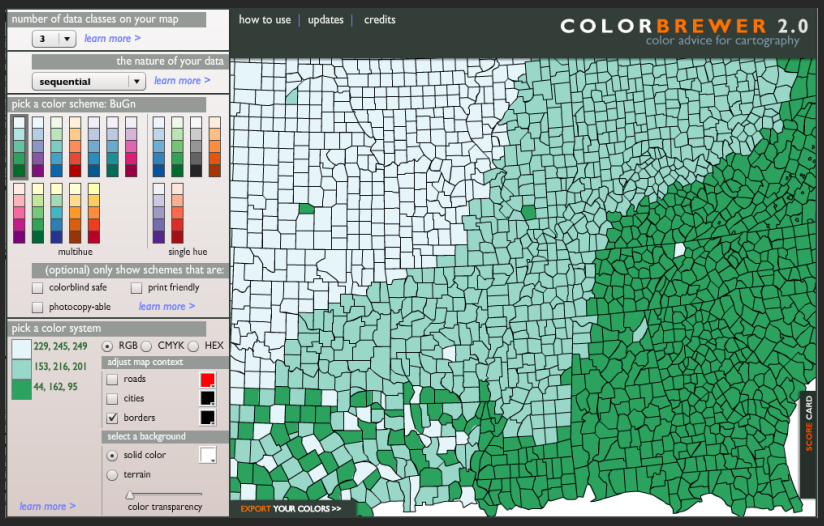
CS 448B: Visualization
WInter 2020

1

Last Time: Color

2

Color Brewer



www.colorbrewer.org

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Announcements

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Final project

New visualization research or data analysis project

- **Research**: Pose problem, Implement creative solution
- **Data analysis**: Analyze dataset in depth & make a visual explainer

Deliverables

- **Research**: Implementation of solution
- **Data analysis/explainer**: Article with multiple interactive visualizations
- 6-8 page paper

Schedule

- Project proposal: Wed 2/19
- Design review and feedback: 3/9 and 3/11
- Final presentation: 3/16 (7-9pm) Location: TBD
- Final code and writeup: 3/18 11:59pm

Grading

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

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Animation

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Question

The goal of visualization is to convey information

How does *animation* help convey information?

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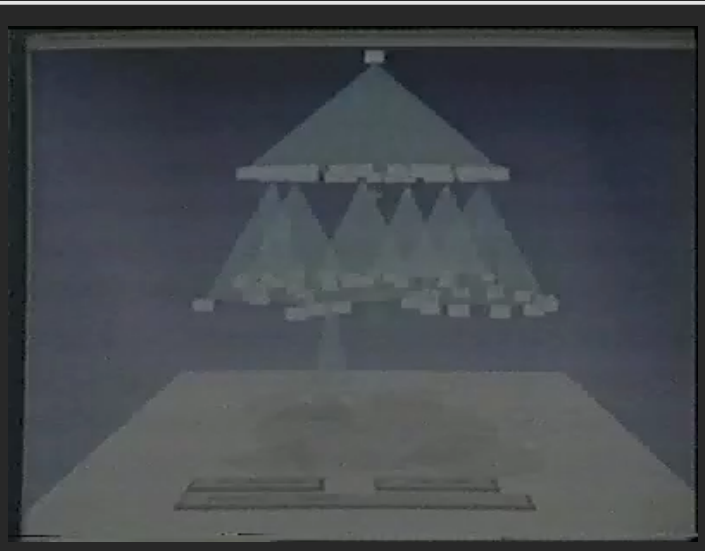
Cone Trees [Robertson 91]



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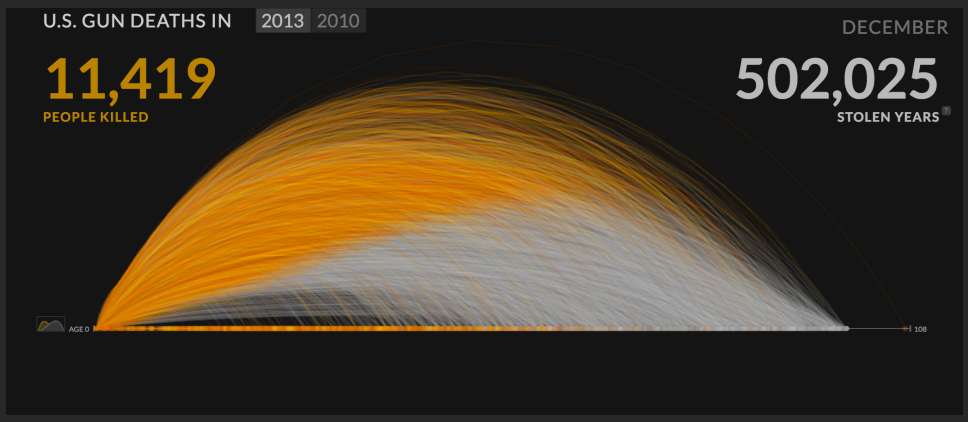
U.S. Gun Deaths [Periscopic 2013]



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

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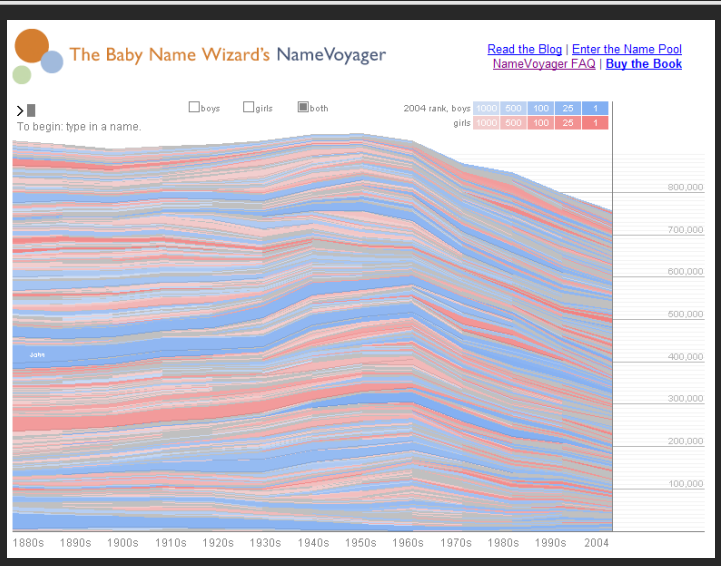
NameVoyager [Wattenberg 04]



http://www.babynamewizard.com/namevoyager/lnv0105.html

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Why Use Motion?

Visual variable to encode data
Direct attention
Understand system dynamics
Understand state transition
Increase engagement

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Topics

Understanding motion
Animated transitions in visualization
Implementing animation

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Understanding Motion

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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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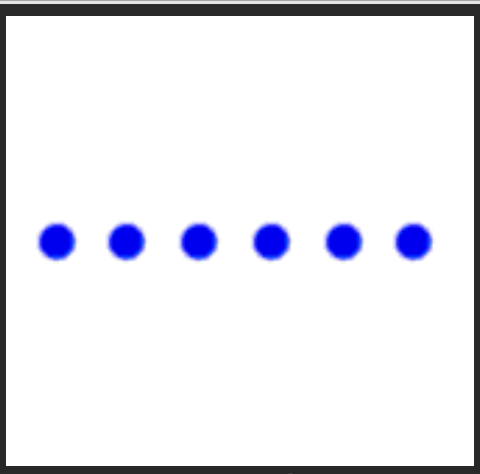
Grouped dots count as 1 object



Dots moving together are grouped

http://coe.sdsu.edu/eet/articles/visualperc1/start.htm

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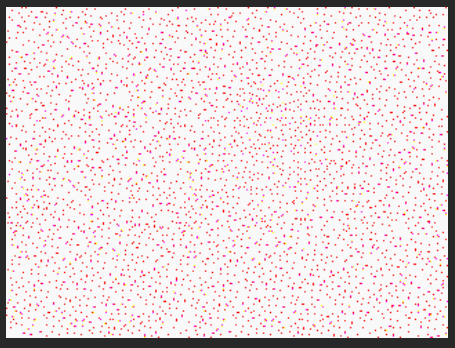
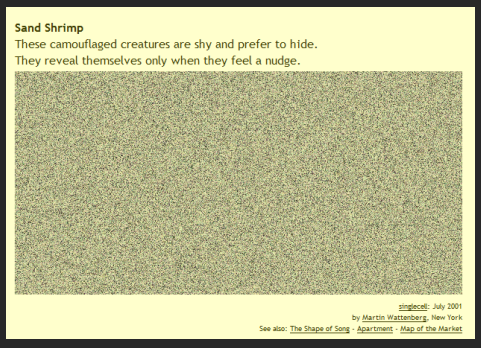
Segment by common motion (fate)



http://dragon.uml.edu/psych/commfate.html



http://www.singlecell.org/july/index.html

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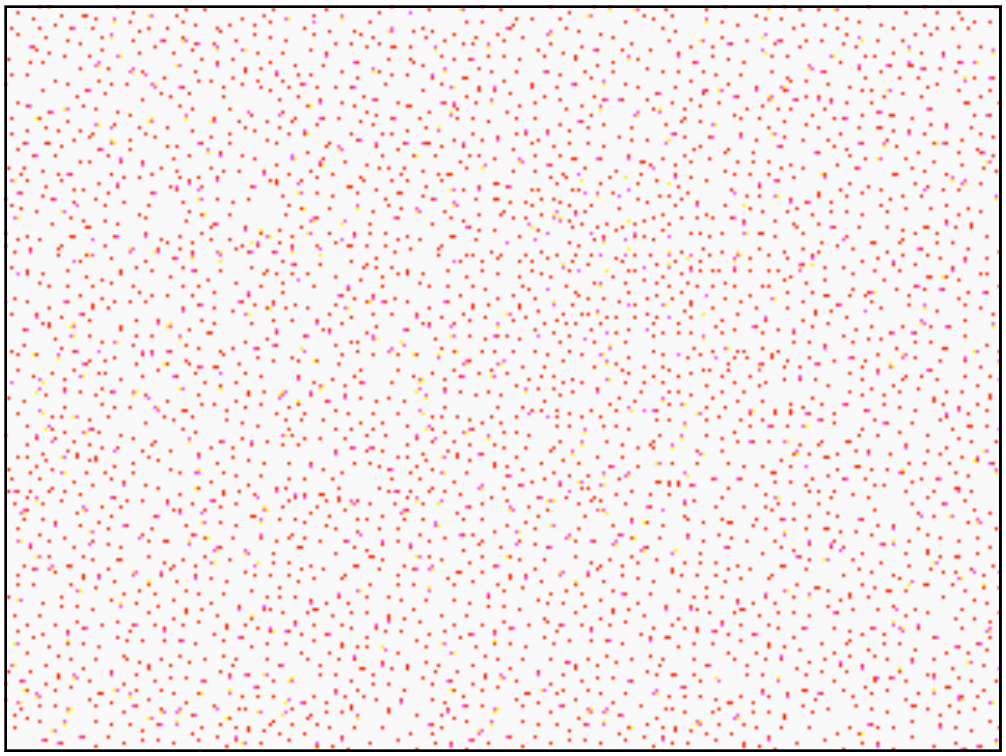

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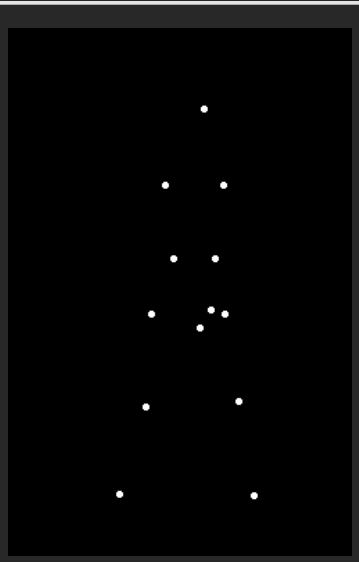
Grouping based on biological motion



[Johansson 73]

http://www.lifesci.sussex.ac.uk/home/George_Mather/Motion/

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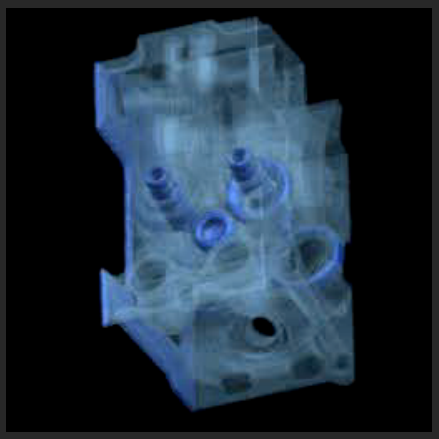
Volume rendering [Lacroute 95]



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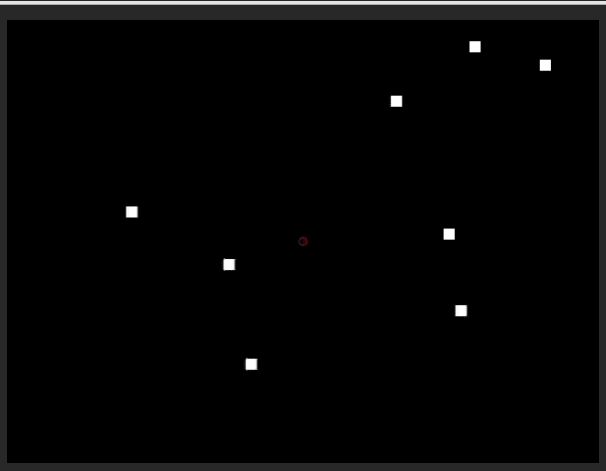
Tracking multiple targets



How many dots can we simultaneously track?

[Yantis 92, Pylyshn 88, Cavanagh 05]

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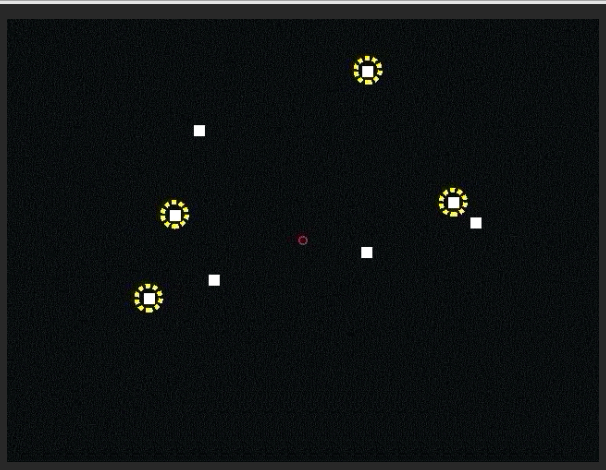
Tracking multiple targets



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21

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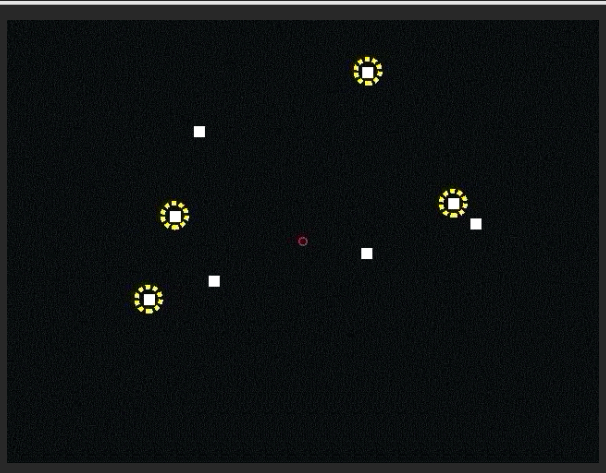

How many dots can we simultaneously track?

- **4 to 6 - difficulty increases significantly at 6**

[Yantis 92, Pylyshn 88, Cavanagh 05]

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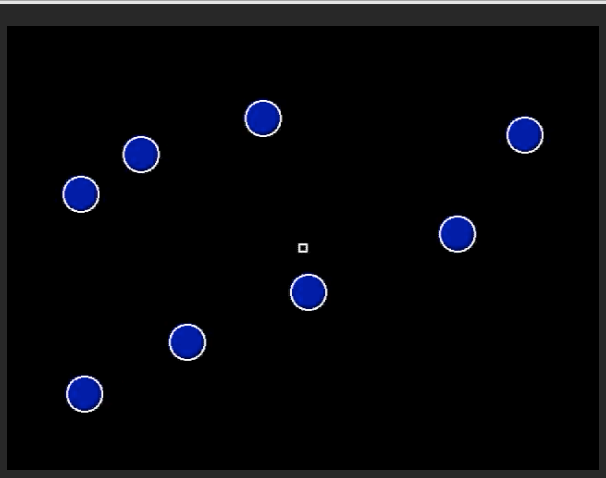
Tracking multiple targets



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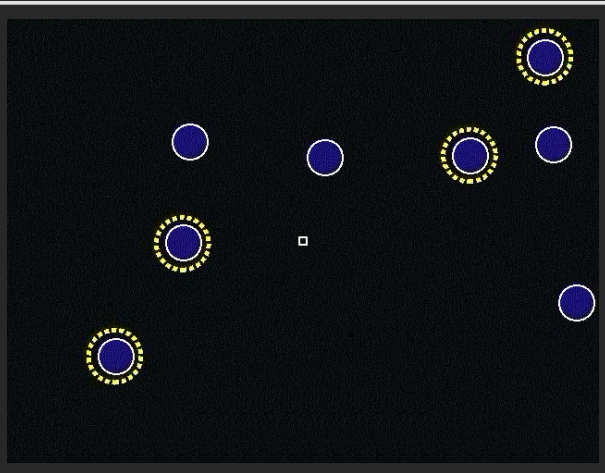

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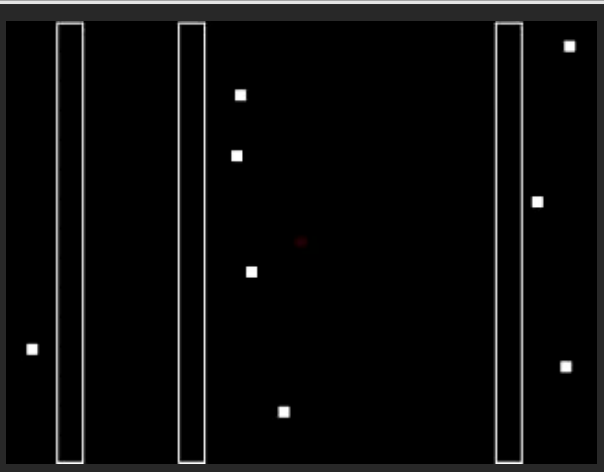

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[Yantis 92, Pylyshn 88, Cavanagh 05]

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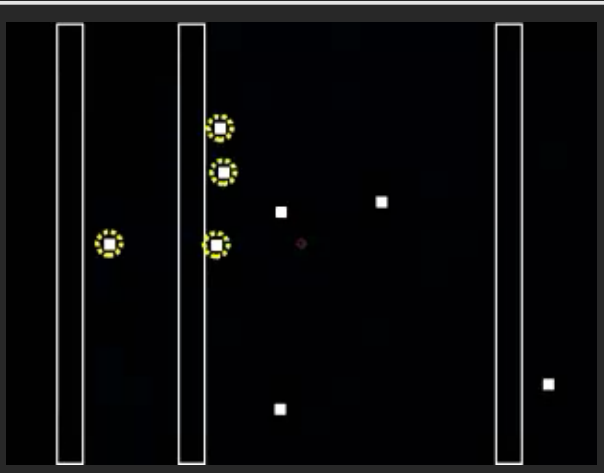
Tracking multiple targets



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[Yantis 92, Pylyshn 88, Cavanagh 05]

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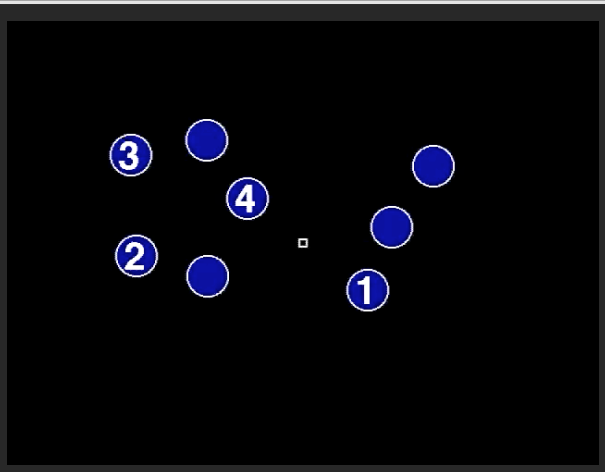
Tracking multiple targets



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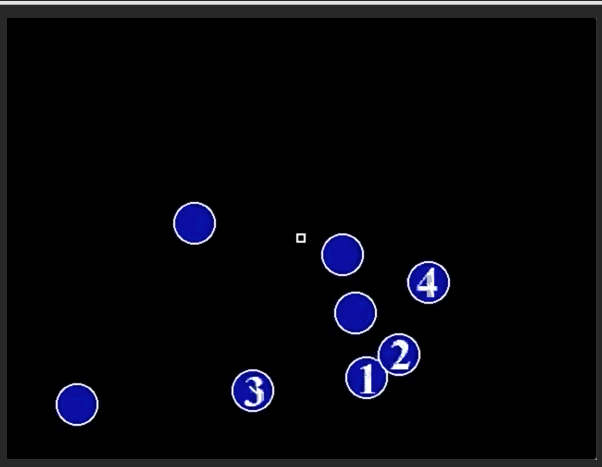
Tracking multiple targets



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[Yantis 92, Pylyshn 88, Cavanagh 05]

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Motions directly show transitions

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (mostly translations)

start

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Motions directly show transitions

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (mostly translations)

end

30

Motions directly show transitions

Can see change from one state to next

- States are spatial layouts
- Changes are simple transitions (translation, rotation, 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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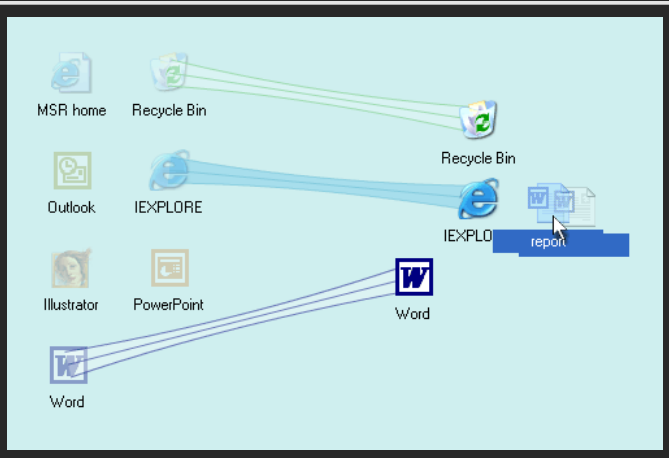
Drag-n-pop [Baudisch 03]



Relevant applications jump to file you are dragging with paths drawn as stretched bands (meant for large screen displays)

What about other transformations (rotation / scale)?

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Constructing narratives

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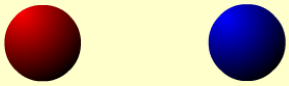
Attribution of causality [Michotte 46]

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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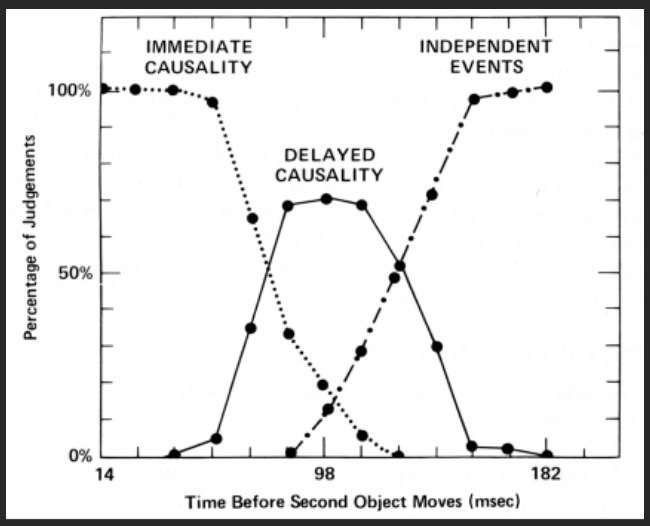
Attribution of causality [Michotte 46]



[Reprint from Ware 04]

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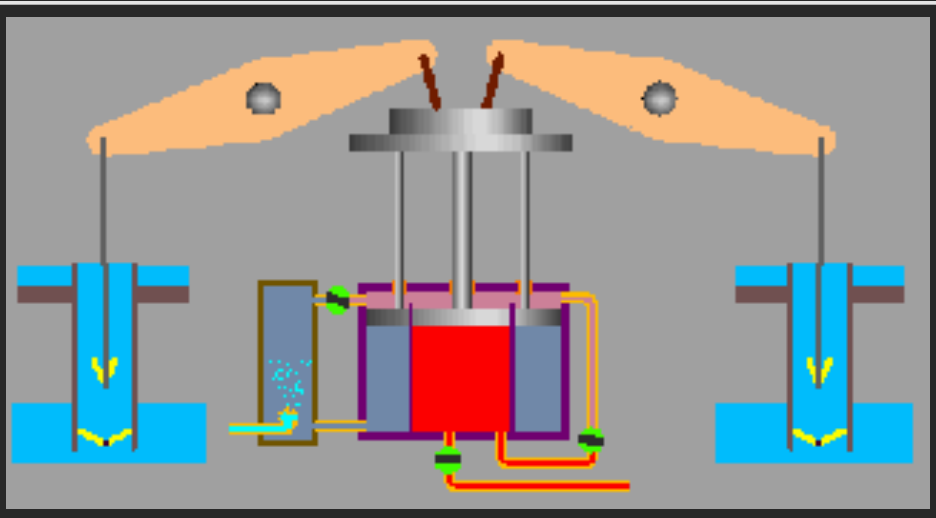
How does it work?



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Problems [Tversky 02]

Difficulties in understanding animation

- Difficult to estimate paths and trajectories
- Motion is fleeting and transient
- Cannot simultaneously attend to multiple motions
- Trying to parse motion into events, actions and behaviors
- Misunderstanding and wrongly inferring causality
- Anthropomorphizing physical motion may cause confusion or lead to incorrect conclusions

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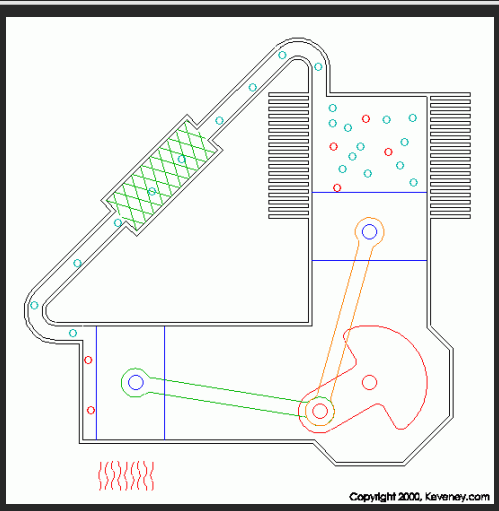
Solution I: Break into static steps



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

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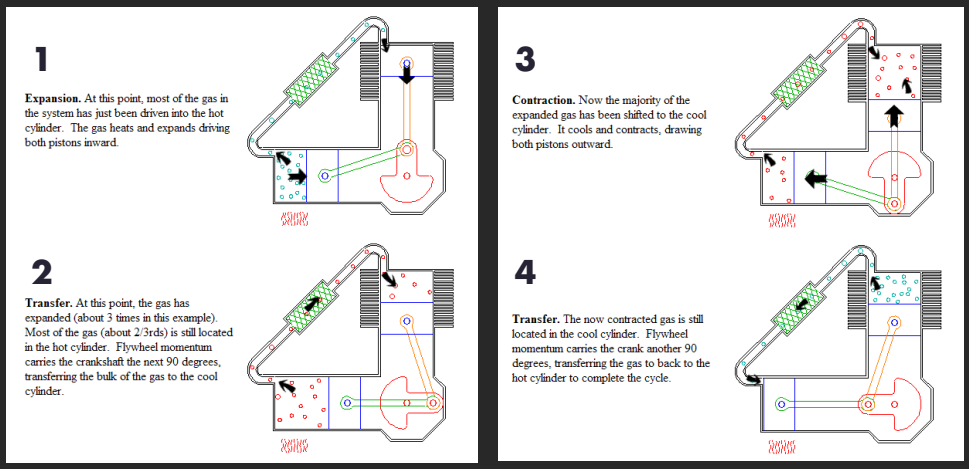
Solution I: Break into static steps



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?
- Note: Steps often shown sequentially for clarity, rather than showing everything simultaneously

Tversky suggests

- Coarse level – segment based on objects
- Finer level – segment based on actions
  - Static depictions often do not show finer level segmentation

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Animated Transitions in Statistical Graphics

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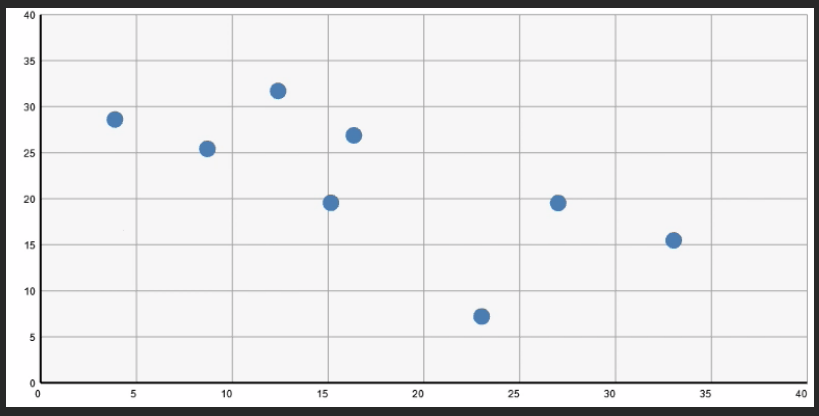

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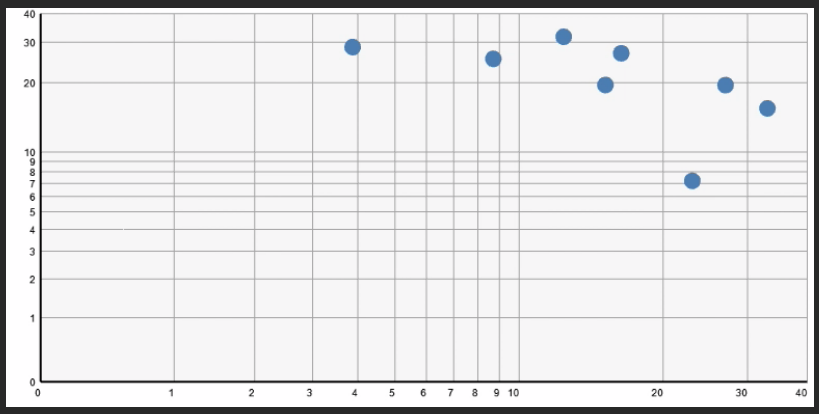
Log Transform



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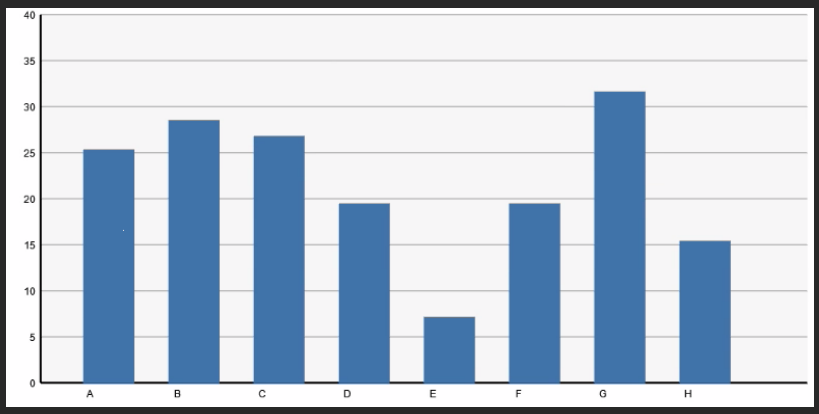

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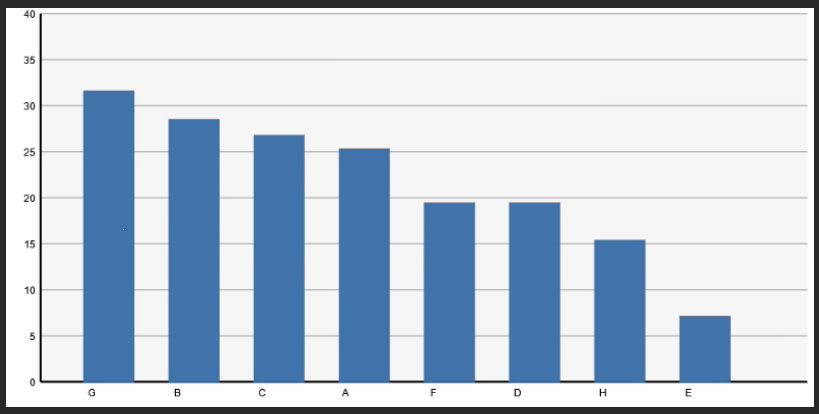
Sorting



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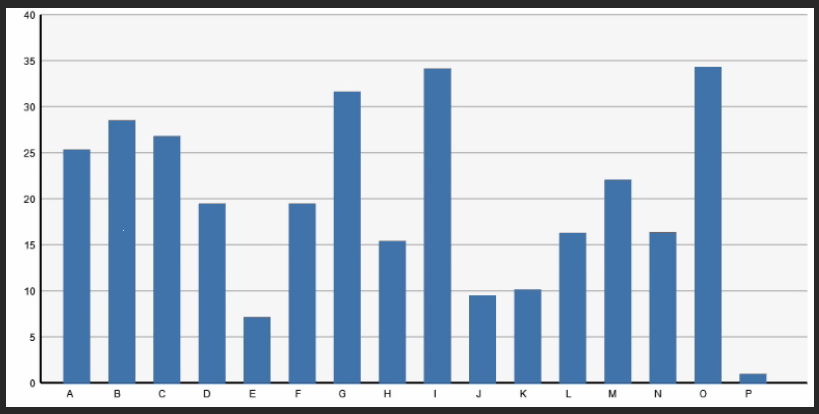

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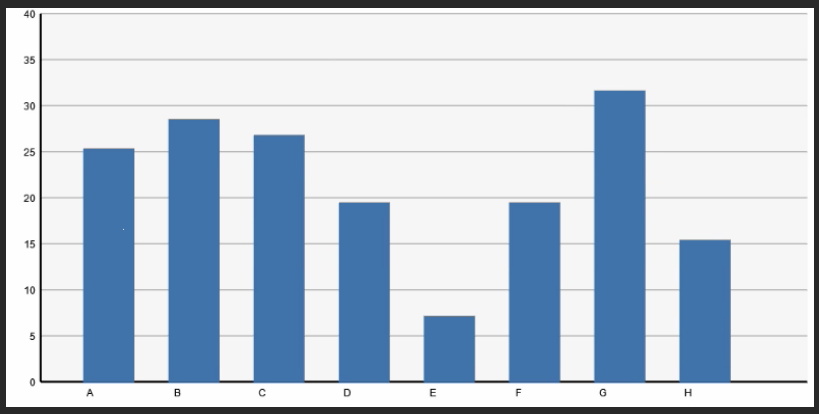
Filtering



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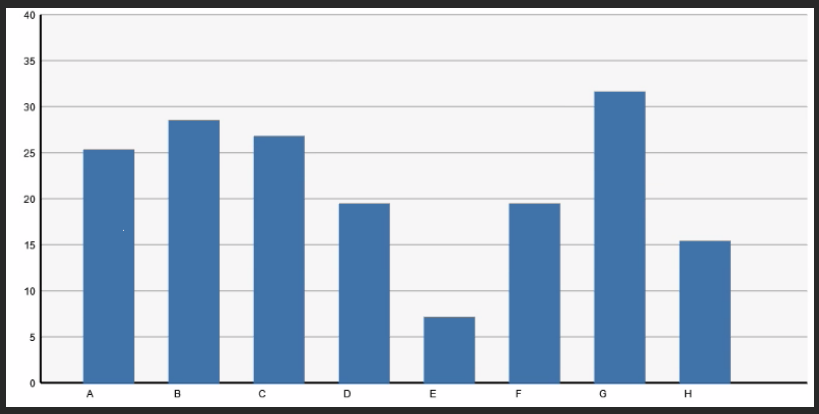

Month 1

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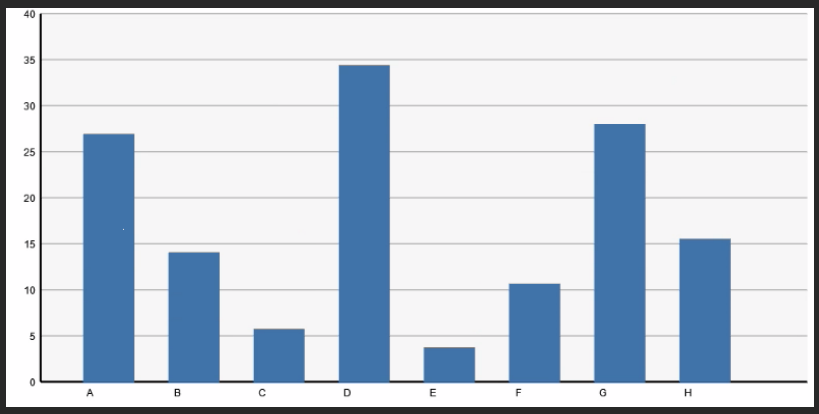
Timestep



Month 2

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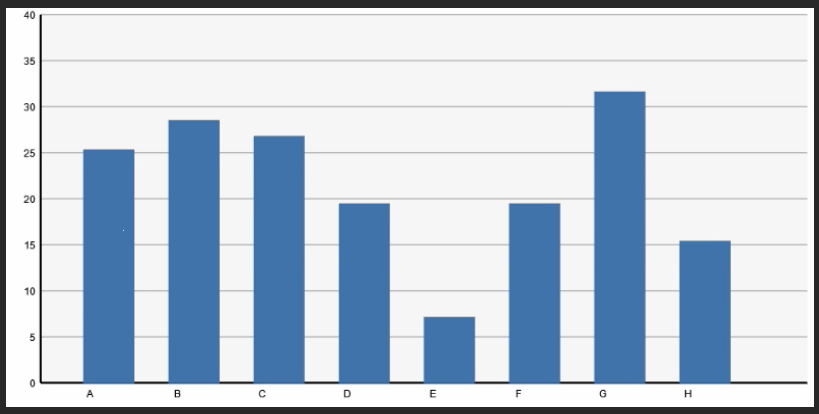

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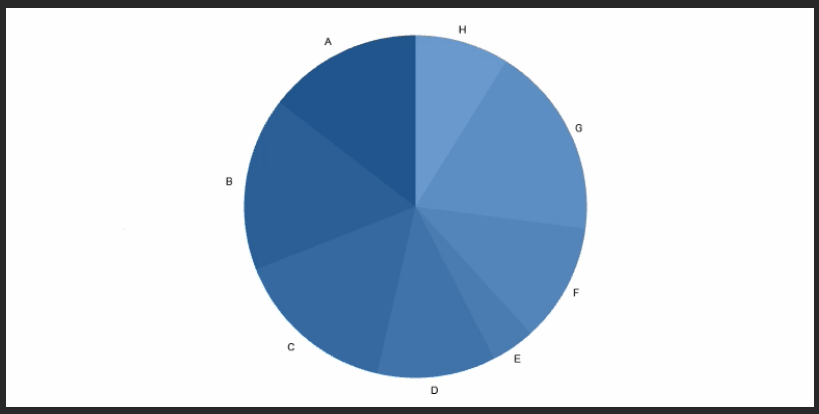
Change Encodings



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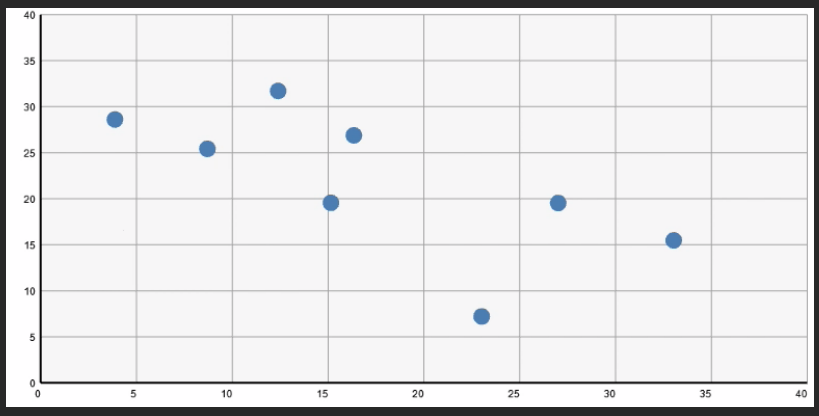

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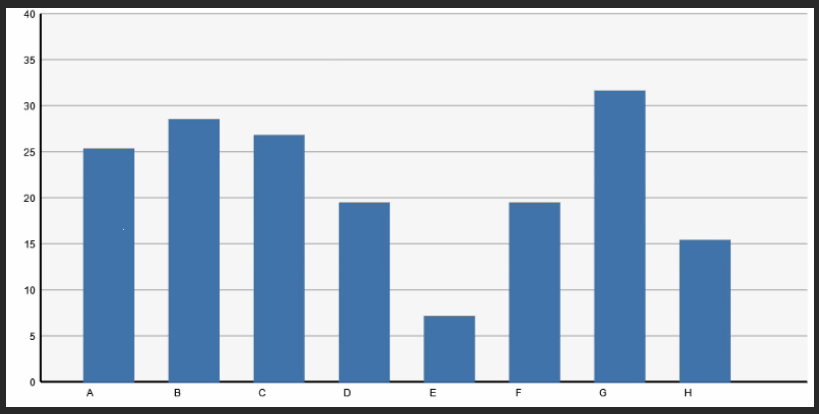
Change Data Dimensions



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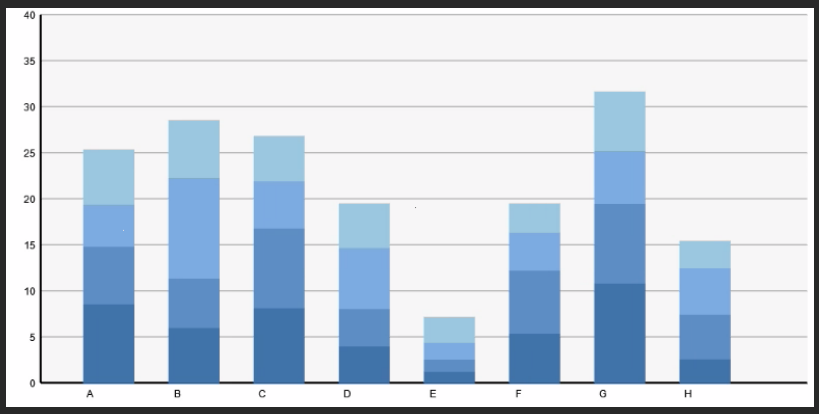
Change Data Dimensions



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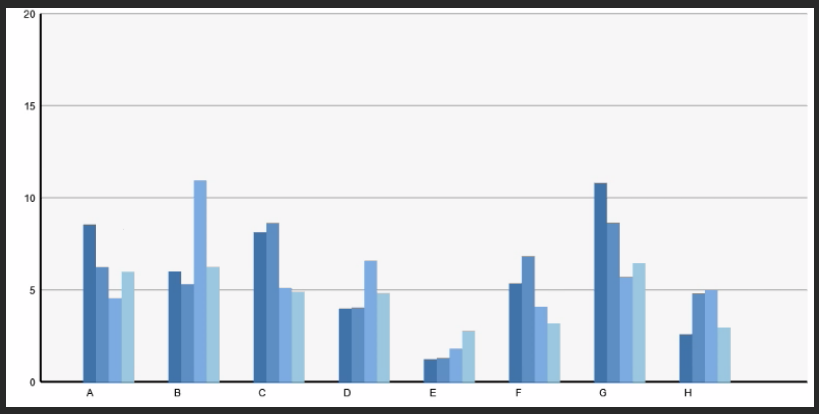
Change Encodings + Axis Scales



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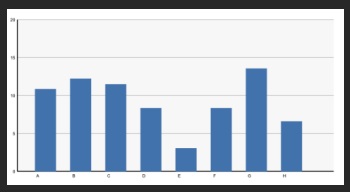
Data Graphics & Transitions

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

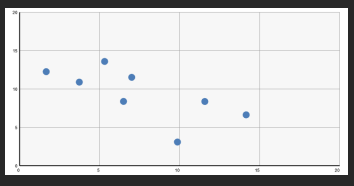
Visual Encoding



Change selected data dimensions or encodings

Animation to communicate changes?

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



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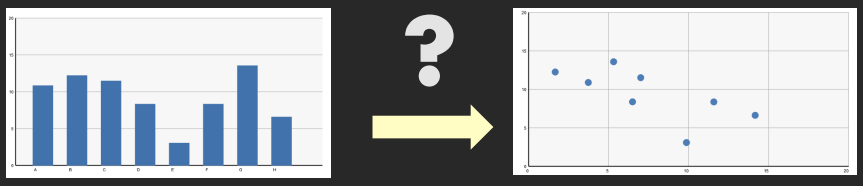
Transitions between charts



It is common to transition between *related* charts
Can animation help?
How does this impact perception?

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Principles for conveying information

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.

[from Tversky 02]

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Principles for Animation

Congruence

- Maintain valid data graphics during transitions
- Use consistent syntactic/semantic mappings
- 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

Congruence

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Different operators should have distinct animations.

Apprehension

- Group similar transitions
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Principles for Animation

Congruence

- Maintain valid data graphics during transitions
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- 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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Apprehension

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- 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

Appropriate animation improves graphical perception

Simple transitions beat "*do one thing at a time*"

Simple staging was 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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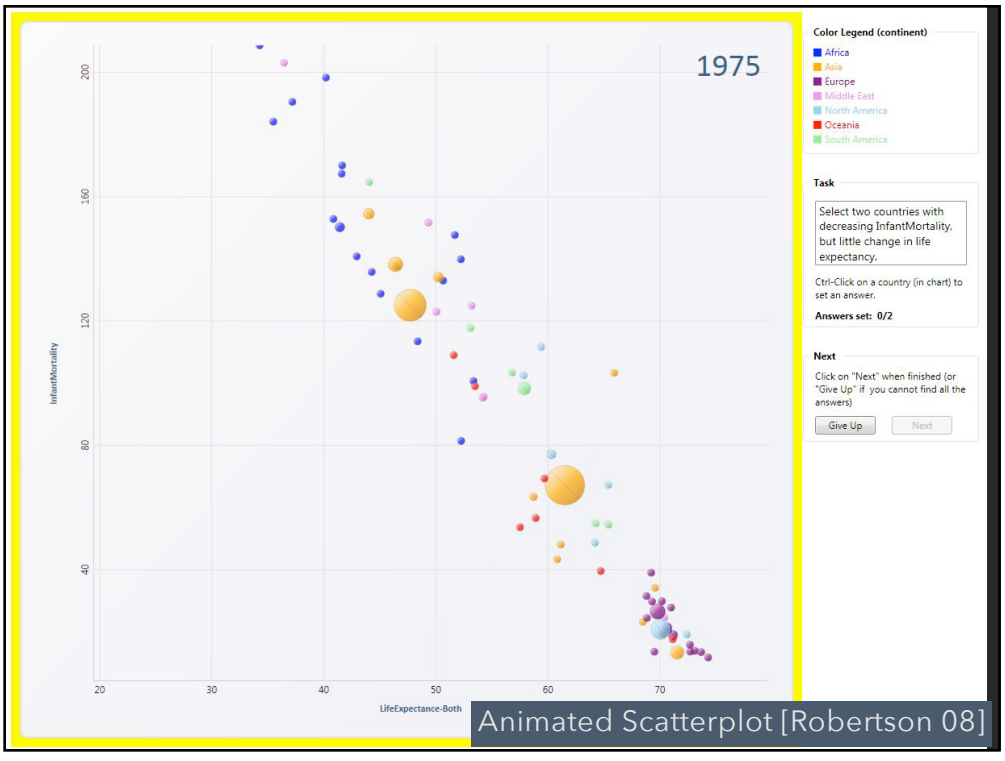
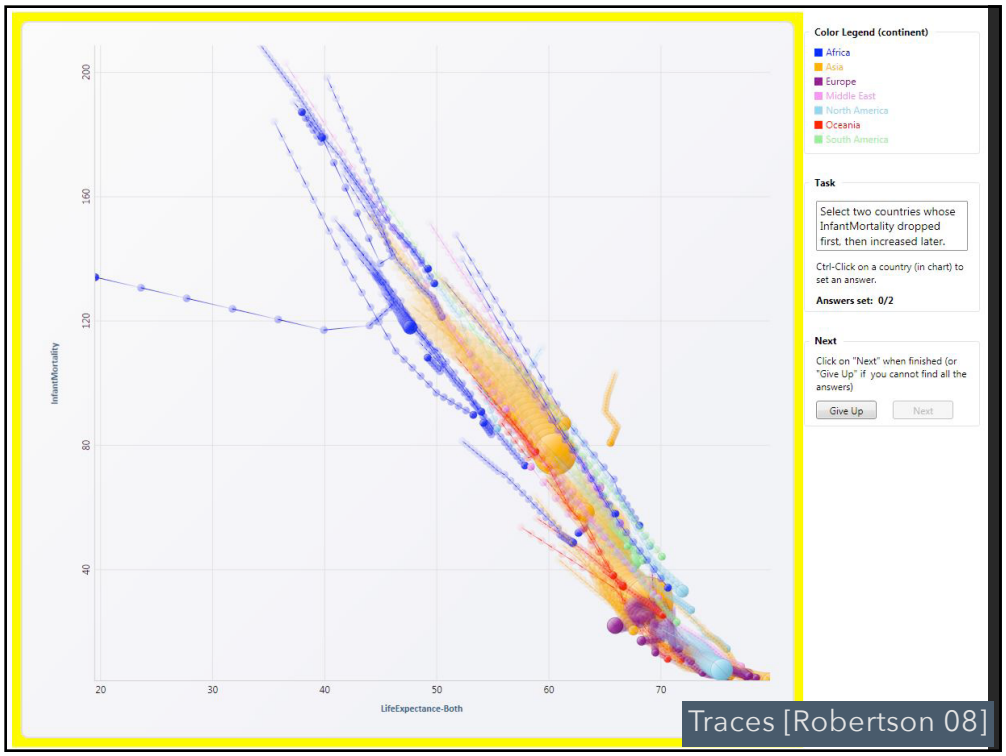


Animated Scatterplot [Robertson 08]

78


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
InfantMortality
LifeExpectance-Both
Traces [Robertson 08]

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Color Legend (continent)
Africa
Asia
Europe
Middle East
North America
Oceania
South America
Task
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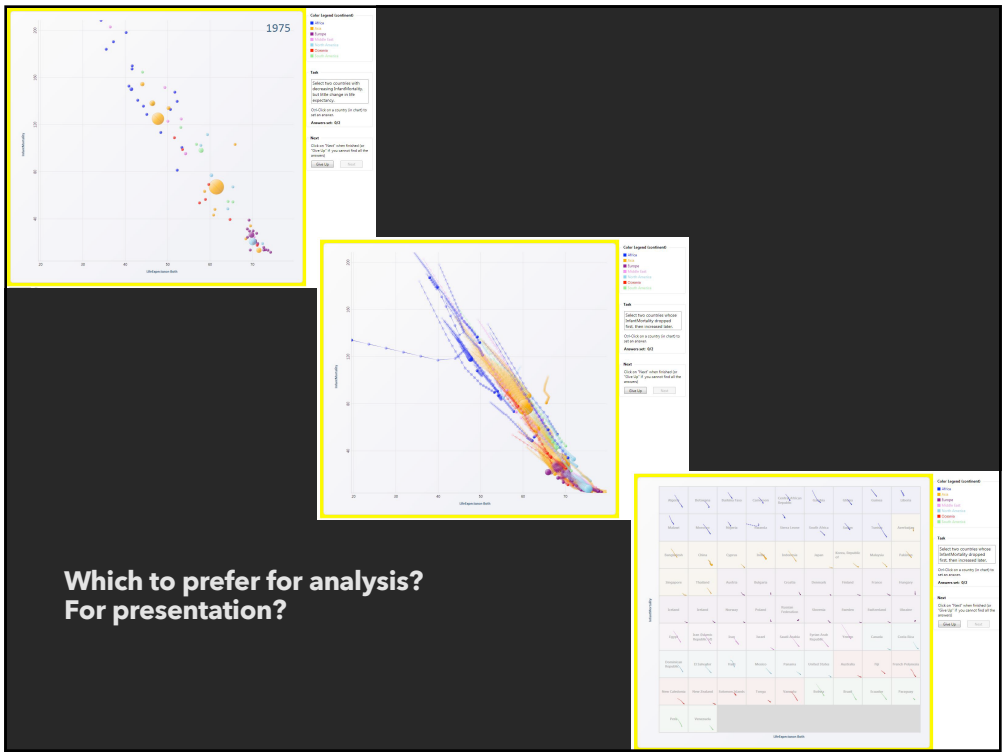
Click on "Next" when finished (or "Give Up" if you cannot find all the answers)
Give Up
Next
InfantMortality
LifeExpectance-Both
Small Multiples [Robertson 08]

80



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Study: Analysis & Presentation

Subjects asked comprehension questions.

Presentation **condition** included narration.

Multiples 10% *more accurate* than animation
Presentation: Anim. 60% *faster* than multiples

Analysis: Animation 82% *slower* than multiples
User preferences favor 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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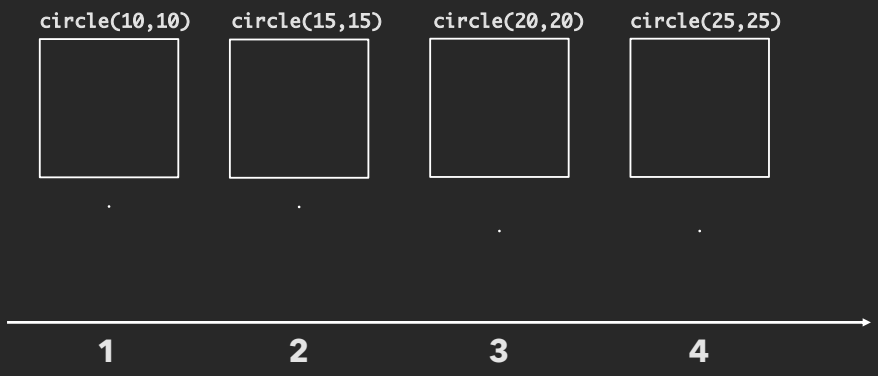
Frame-based Animation



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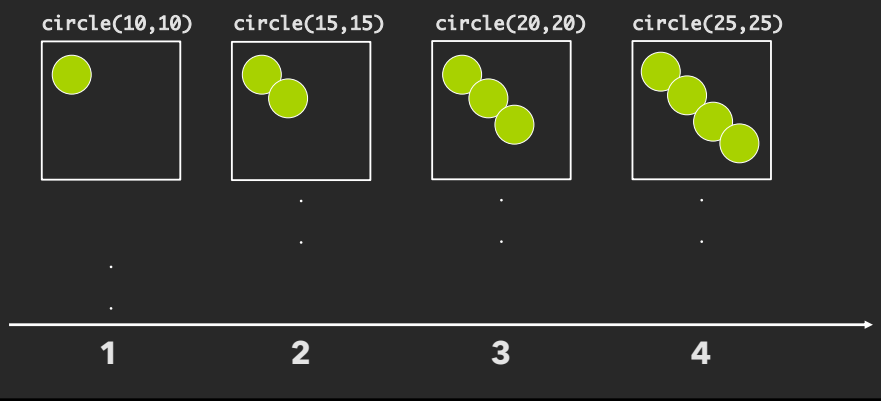
Frame-based Animation



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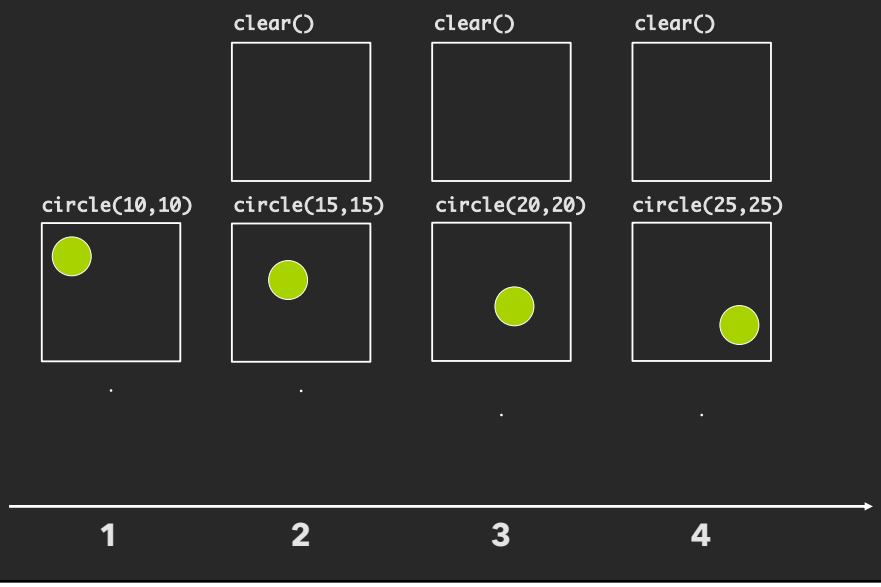
Frame-based Animation



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Animation Approaches

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

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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 '93)

Specify property value, duration & easing (tweening)
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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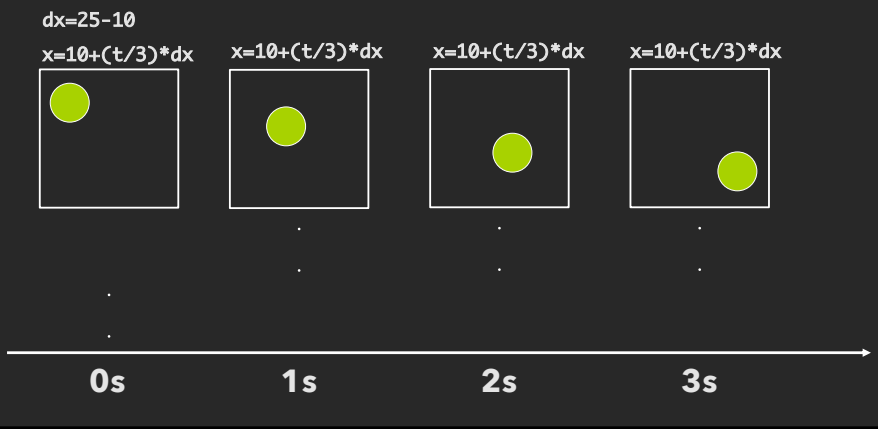
Transition-based Animation

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



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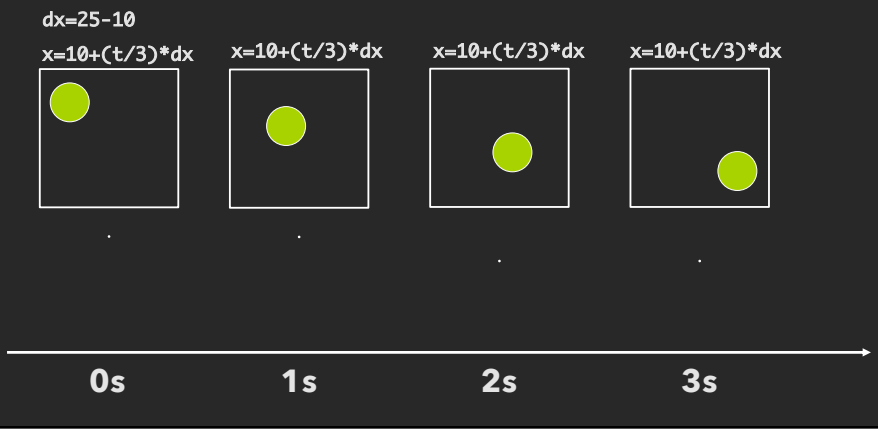
Transition-based Animation

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



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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);
```

94

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));
```

96

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

```
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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.**

Basic idea is to warp time: as *duration* goes from start (0%) to end (100%), dynamically adjust the *interpolation fraction* using an easing function**.**

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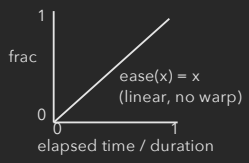

101

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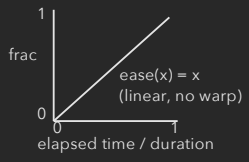

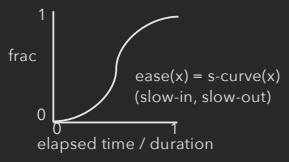

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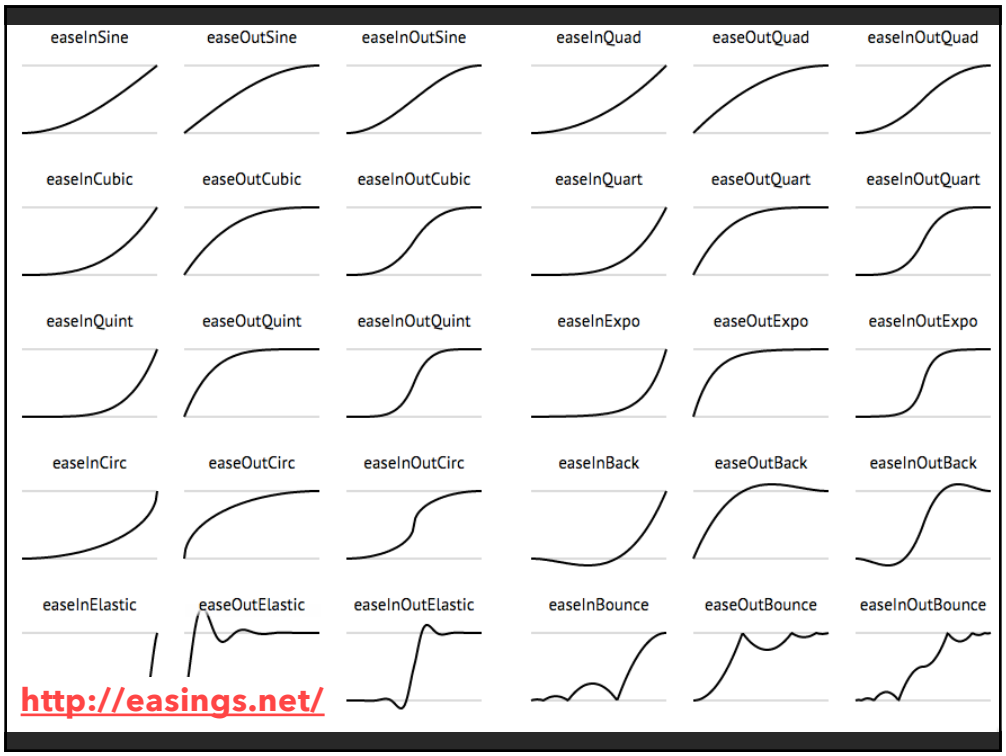

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CSS Transitions

Extends CSS with Animated Transitions

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



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

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CSS Transitions

Extends CSS with Animated Transitions

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

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

Duration

Property

Easing

105

CSS Transitions

Extends CSS with Animated Transitions

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

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

Duration

Property

Easing

Animate color transition upon mouse in / out.

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Summary

Animation is a salient visual phenomenon
Attention, object constancy, causality, timing

Design with care: congruence & apprehension

For processes, static images may be preferable
For transitions, animation has some benefits, but consider task and timing

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