Why use motion?
Visual variable to encode data
Direct attention
Understand system dynamics (?)
Understand state transition
Increase engagement

Cone Trees [Robertson 91]

Volume rendering [Lacroute 95]
**Motion Perception**

Under what conditions does a sequence of static images give rise to motion perception?

Smooth motion perceived at ~10 frames/second (100 ms).

http://www1.psych.purdue.edu/Magniphi/PhilsNotBeta/phiz2.html

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**Name Voyager** [Wattenberg 04]

http://www.babynamewizard.com/namevoyager/nv0105.html

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**Topics**

- Motion perception
- Principles for animation
- Animation to convey process/dynamics
- Animated transitions

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**Perceiving Animation**

Under what conditions does a sequence of static images give rise to motion perception?

Smooth motion perceived at ~10 frames/second (100 ms).
**Motion as a visual cue**

- Pre-attentive, stronger than color, shape, ...
- More sensitive to motion at periphery
- Similar motions perceived as a group
- Motion parallax provide 3D cue (like stereopsis)

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**Tracking Multiple Targets**

- How many dots can we simultaneously track?
- ~4-6. Difficulty increases sig. at 6.  
  [Yantis 92, Pylyshen 88, Cavanagh 05]

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**Segment by Common Fate**

- [http://dragon.uml.edu/psych/commfate.html](http://dragon.uml.edu/psych/commfate.html)

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**Grouped dots count as 1 object**

- Dots moving together are grouped
  
  [http://coe.sdsu.edu/set/articles/visualperct/start.htm](http://coe.sdsu.edu/set/articles/visualperct/start.htm)
Grouping based on biological motion

Motions show transitions
See change from one state to next

Motions show transitions
See change from one state to next

Motions show transitions
See change from one state to next

Motions show transitions
See change from one state to next

[Johansson 73]

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

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

start end
**Velocity Perception**

What is perceived as smooth, uniform motion?

Velocity perception can be affected by:

- Path curvature
- Size / depth perception
- Luminance contrast

(DEMO)

**Constructing Narratives**

 Attribution of causality [Michotte 46]

[Michotte demonstration 1](http://cogweb.ucla.edu/Discourse/Narrative/michotte-demo.swf) 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.

[Reprint from Ware 04]
### Animation

<table>
<thead>
<tr>
<th>Helps?</th>
<th>Hurts?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention</td>
<td>distraction</td>
</tr>
<tr>
<td>Object Constancy</td>
<td>false relations</td>
</tr>
<tr>
<td>Causality</td>
<td>false agency</td>
</tr>
<tr>
<td>Engagement</td>
<td>increase interest “chart junk”</td>
</tr>
<tr>
<td>Calibration</td>
<td>too slow: boring</td>
</tr>
<tr>
<td></td>
<td>too fast: errors</td>
</tr>
</tbody>
</table>

### Principles for Animation

**Character Animation**

(Johnston & Thomas '81, Lasseter '87)

- Squash and stretch
- Exaggeration
- Anticipation, Follow-through
- Staging, Overlapping Action
- Slow-in / Slow-out

**Squash and stretch**

Defines rigidity of material

Should maintain constant volume

Smoothes fast motion, similar to motion blur
**Staging**

Clear presentation of one idea at a time

Highlight important actions
- Lead viewers’ eyes to the action
- Motion in still scene, stillness in busy scene
- Motion clearest at silhouette

**Anticipation**

Show preparation for an action

**Follow-through**

Emphasize termination of action

**Slow-in, slow-out**

Space in-betweens to provide slow-in and out

Linear interpolation is less pleasing
**Principles for Animation**

**Animated Presentations**
(Zongker & Salesin ’03)

- Make all movement meaningful
- Avoid squash-and-stretch, exaggeration
- Use anticipation and staging
- Do one thing at a time

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**Principles for conveying information**

**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.

[from Tversky 02]

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**How does it work?**

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Convey Process and Dynamics
Animation: Can It Facilitate?

Tversky et al reviewed studies in animation for conveying dynamic processes.

- Where benefits were found, the comparison was often unfair: the information was not equivalent
- In other cases, no difference in learning

Implications:

- Comparisons of static and animated displays should use displays with equivalent information
- Static sequence may be as good or better

Problems understanding animation [Tversky]

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

Break into static steps

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

Break into static steps

1. Expansion. When the gas is heated, the piston moves the gas to the expansion chamber.
2. Compression. When the gas is cooled, the piston moves the gas to the compression chamber.
3. Contraction. When the gas is cooled, the piston moves the gas back to the expansion chamber.
4. Transfer. The valve is opened, and the gas enters the next chamber.

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

Choosing the set of steps
- How to segment process into steps?
- 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 omit finer level segmentation

Resource: Understanding Comics by Scott McCloud

Assign 3: Interactive Visualization

Create an interactive visualization application. Choose a data domain and select an appropriate visualization technique.

1. Choose a data set and storyboard your interface
2. Implement the interface using tools of your choice
3. Submit your application and produce a final write-up

You should work in groups of 2.
Due by 5:00pm on Friday, November 2 (← extension!)

Animated Transitions
**Cone Trees** [Robertson 91]

Animate pivots across intersecting hierarchies.
Tested a number of animation parameters.
Best duration: ~1 sec
Rotational movement degraded performance, translation preferred.

**Polyarchy Visualization** [Robertson 02]

**Degree-of-Interest Trees** [Heer 04]
Animation of expanding/collapsing branches

**SpaceTree** [Grosjean 04]
Break animated transitions into discrete stages
Radial Graph Layout

Optimize animation to aid comprehension

Animation in Radial Graph Layout

Help maintain context of nodes and general orientation of user during refocus

Transition Paths
- Linear interpolation of polar coordinates
- Node moves in an arc, not straight lines
- Moves along circle if not changing levels
- When changing levels, spirals to next ring

Animation in Radial Graph Layout

Transition constraints
- Minimize rotational travel (move former parent away from new focus in same orientation)
- Avoid cross-over of edges

Constraint: Retain Edge Orientation
Constraint: Retain Neighbor Order

Animated Transitions in Statistical Data Graphics

NameVoyager [Wattenberg 04]

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

Change Encodings
Change Data Dimensions

Change Encodings + Axis Scaling

Data Graphics and Transitions
Transitions between Data Graphics

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

Can animation help?
How does this impact perception?

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]

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

Visual marks should always represent the same data tuple.
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

Different operators should have distinct animations.

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

Objects are harder to track when occluded.
How does animation affect perception?

Conducted 2 controlled experiments
24 subjects (10 female), aged 26-62 ($M = 49.6$)
Business owners, educators, analysts, administrators

Exp 1: Object Tracking (Syntactic Analysis)
Measure object correspondence across transitions

Exp 2: Value Change Estimation (Semantic Analysis)
Measure graphical perception of changing values

Experiment 1: Object Tracking

Experimental Task
Track 2 targets across a transition (then mask display)
Click final positions of targets

Dependent Variable
Distance between clicks and targets

Experiment 1 Results: Animation

Animated conditions outperform static
Limited benefits for staging (except scatterplot)
Duration constant; should stages be longer?

Experiment 2: Change Estimation

Experimental Task
Follow 1 target across a transition (then mask display)
Estimate percentage change in value (or Unknown)

Dependent Variable
Estimation error
Experiment 2 Results: Animation

Animation more accurate (except Stacked Bars)
Staged animation sig. worse in Donut
Axis rescaling increases errors and “?” estimates
Subjective Preferences

Significant preference for animation. Staged animation was the most preferred, but not sig. for multi-stage timesteps in Stacked Bars and Donut Chart

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 lines)
Subjects preferred animated transitions

Animation in Trend Visualization

Heer & Robertson 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, InfoVis 2008
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

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 demonstrated benefits, but consider task and timing