Network Layout

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CS 448B: Visualization
Fall 2021

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Reading Response Questions/Thoughts

For the final project, do you have a recommendation of a place to go to view other data visualization research papers that conducted user studies?

As animations contain more and more data, is it possible that we can overload or overstimulate the user? Can animations be harmful by being too distracting? If so, how can we safeguard our designs to make sure they don't cause this overstimulation?

Is there a more formal or mathematical rule set governing which colors to use to highlight information, and which to contrast? Or is it mostly a combination of multiple factors that you need to see to know? In a similar vein, do colors need to be different in shade as well as color for black and white printing? How do we know to vary transparency with color or just color?

How seriously should we take self-reported stated preferences when evaluating the strength of a visualization? How much should we weight user's expressed preference relative to usability, learning, and recall data when evaluating the efficacy of a visualization?

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Last Time: Animation
Understanding Motion

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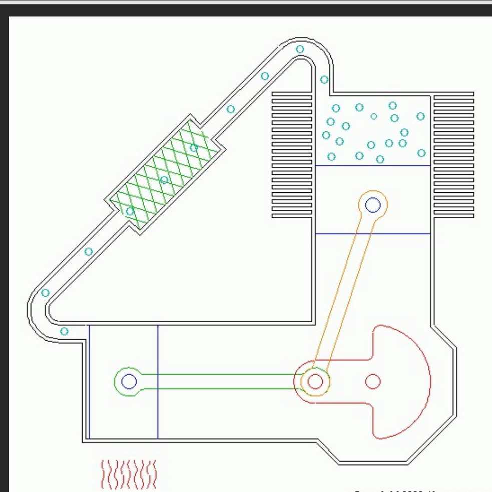
How does it work?



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

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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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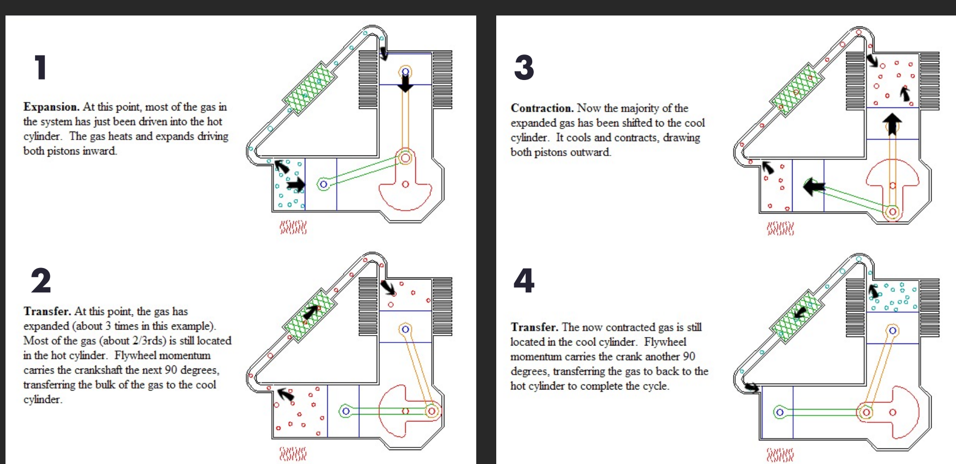
Solution I: Break into static steps



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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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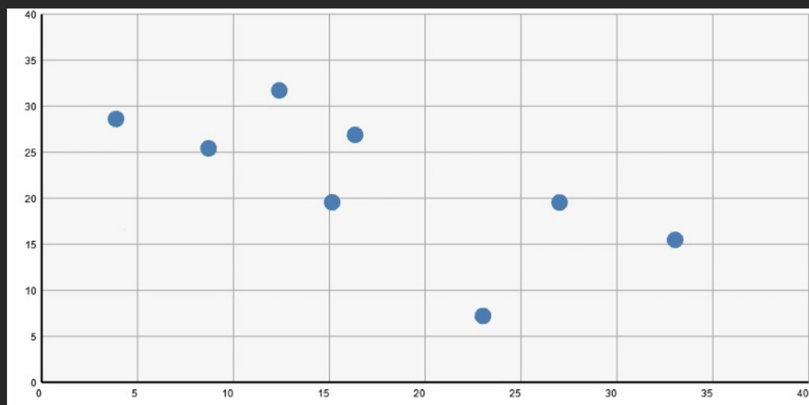

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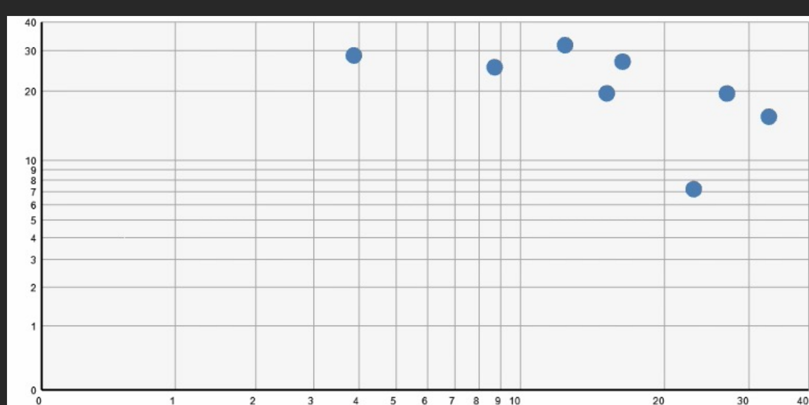
Log Transform



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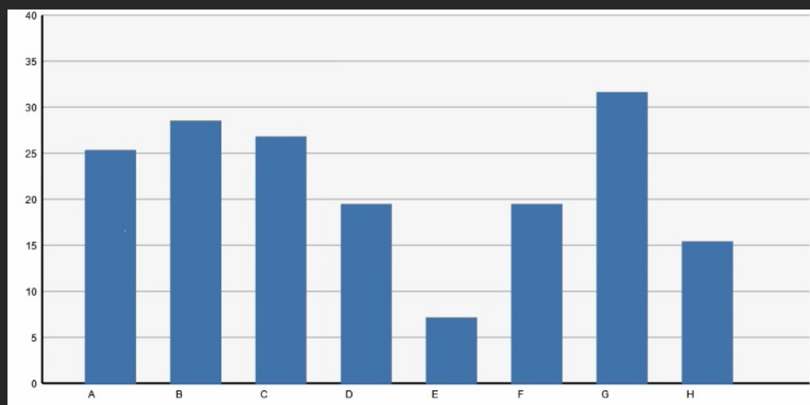

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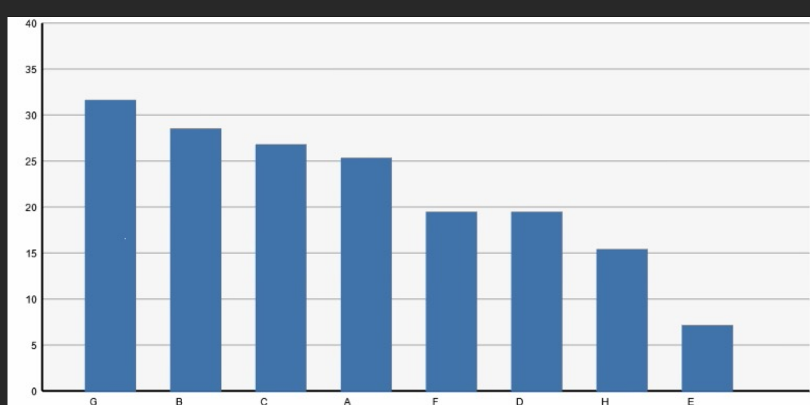
Sorting



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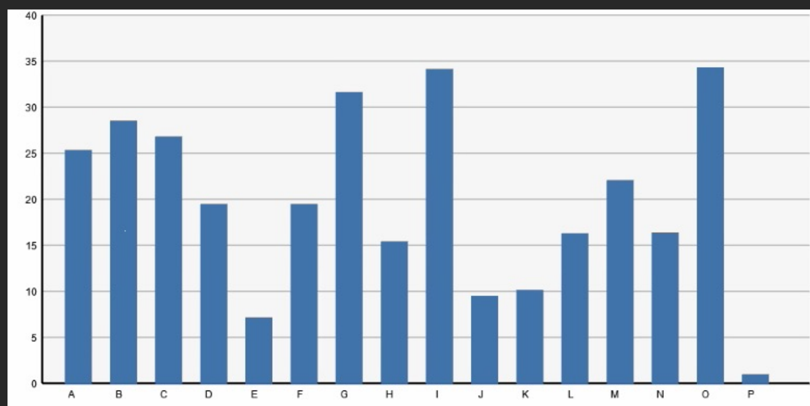

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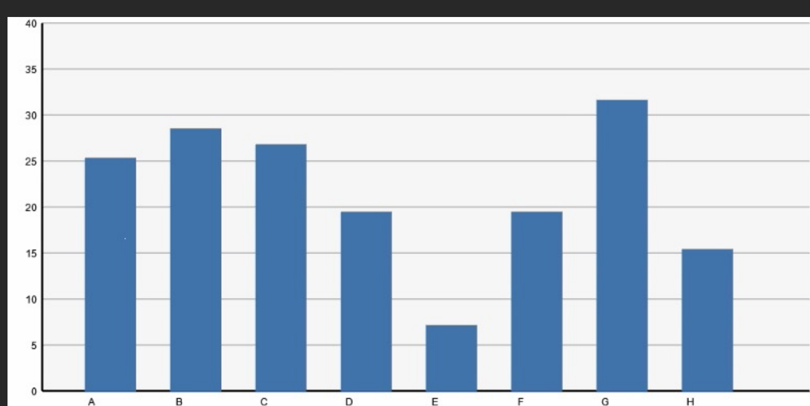
Filtering



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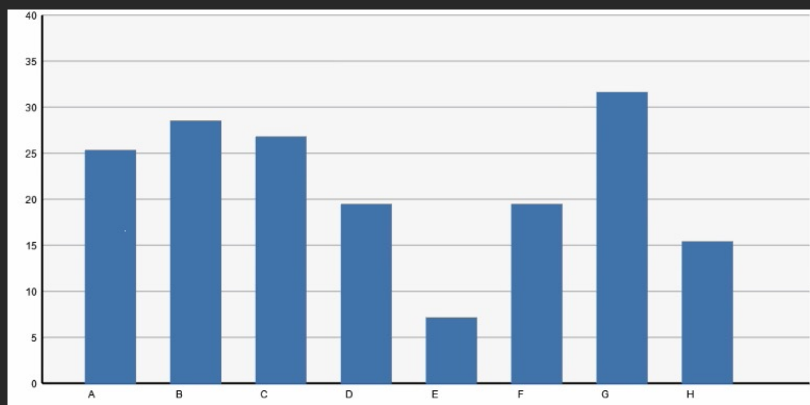

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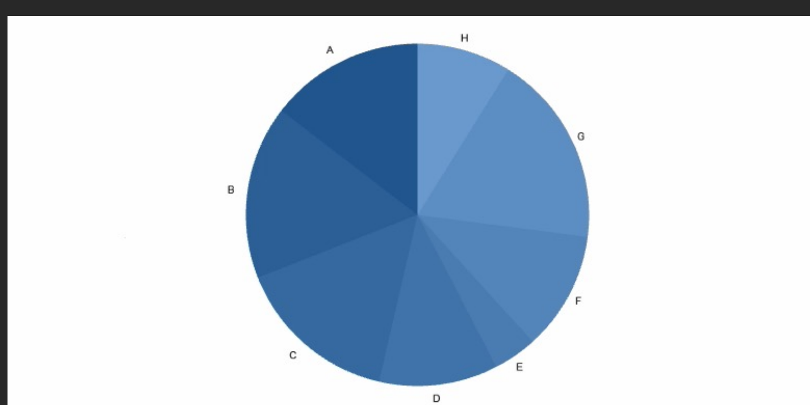
Change Encodings



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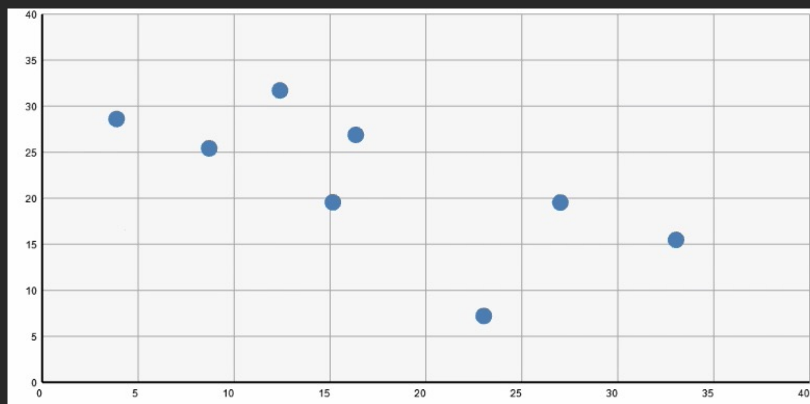

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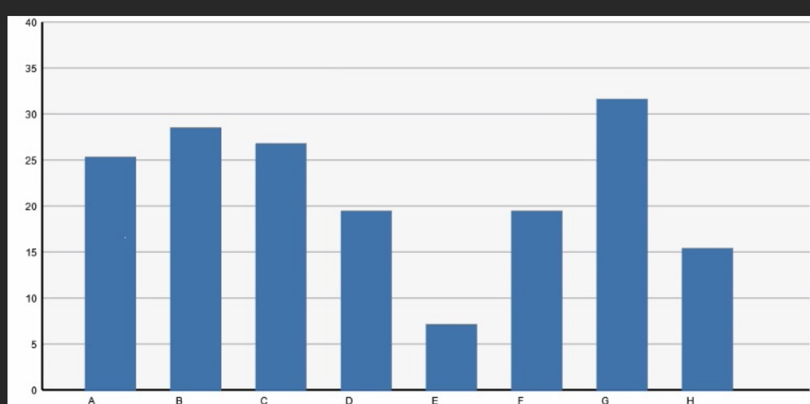
Change Data Dimensions



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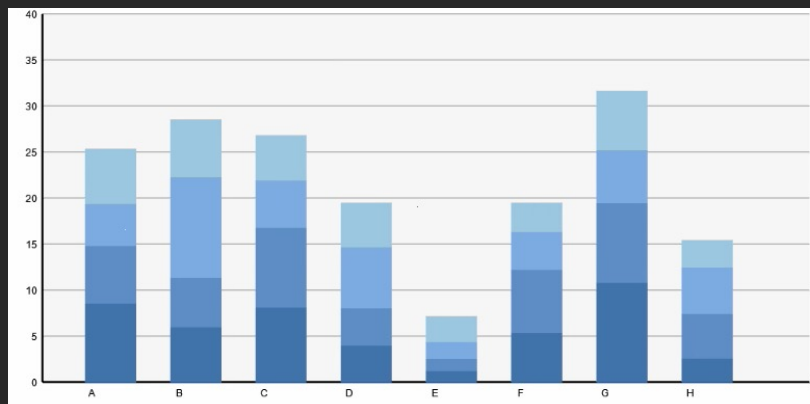
Change Data + Encodings



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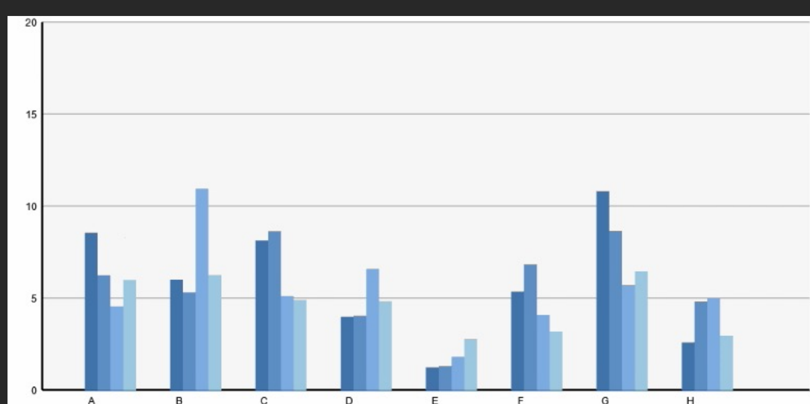
Change Encodings + Axis Scales



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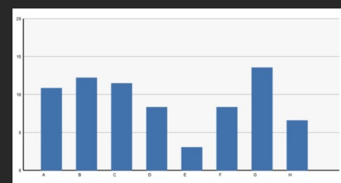
Data Graphics & Transitions

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

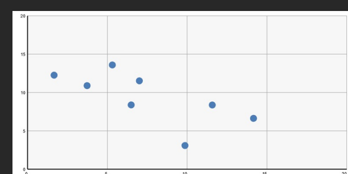
Visual Encoding



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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Animated Transitions in Statistical Data Graphics

Jeffrey Heer
George G. Robertson

Microsoft Research

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Study Conclusions

Appropriate animation improves graphical perception

Use simple staged transitions, *but* doing one thing at a time not always best

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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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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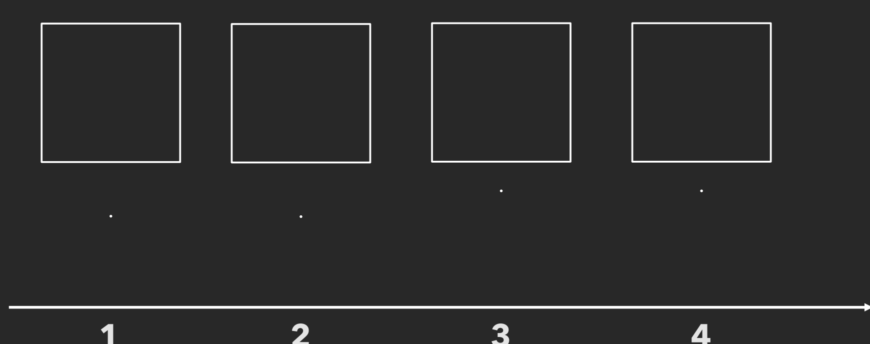
Frame-based Animation



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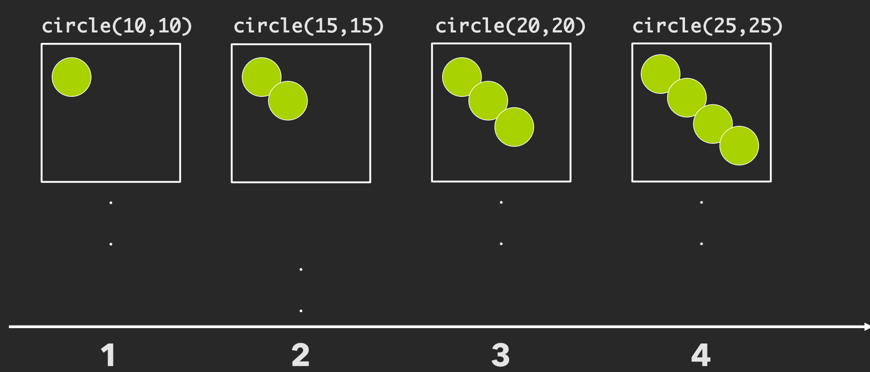

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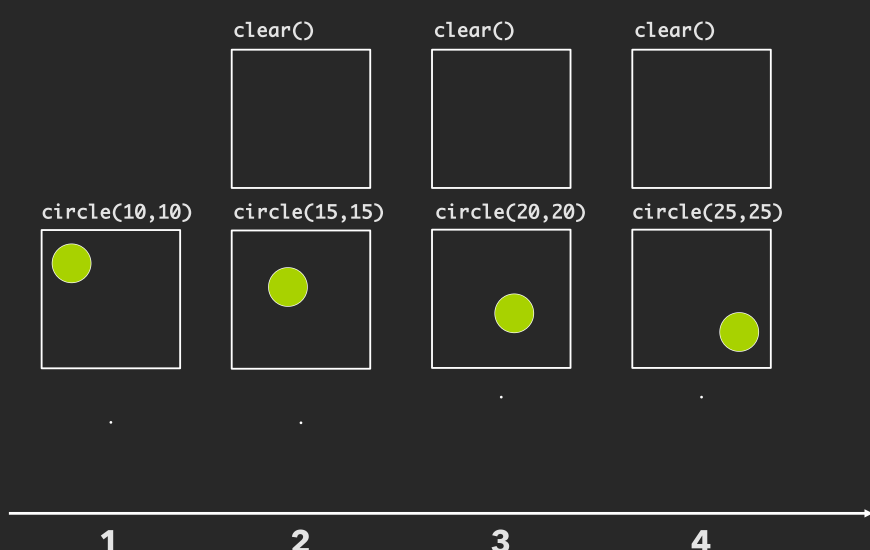
Frame-based Animation



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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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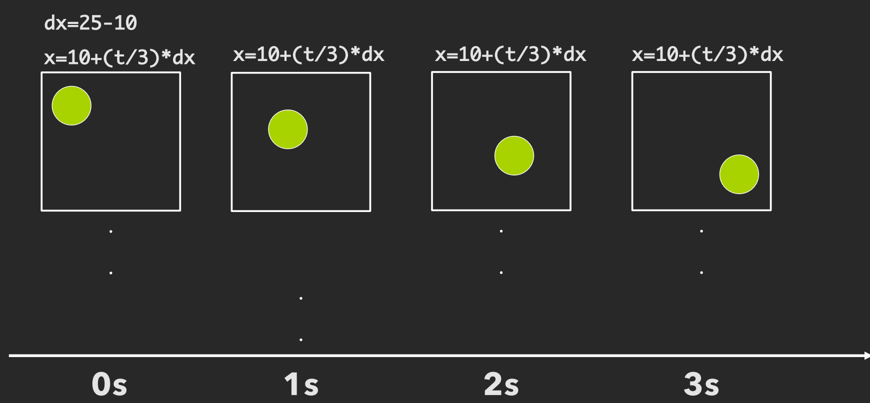
Transition-based Animation

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



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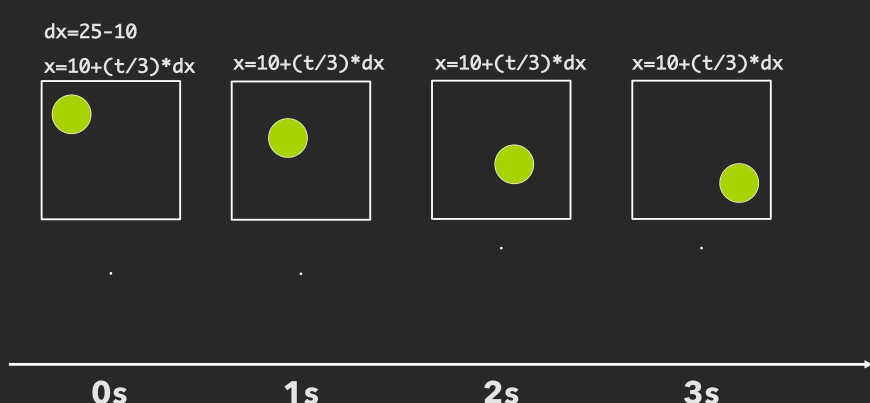
Transition-based Animation

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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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);
```

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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.

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// 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.**

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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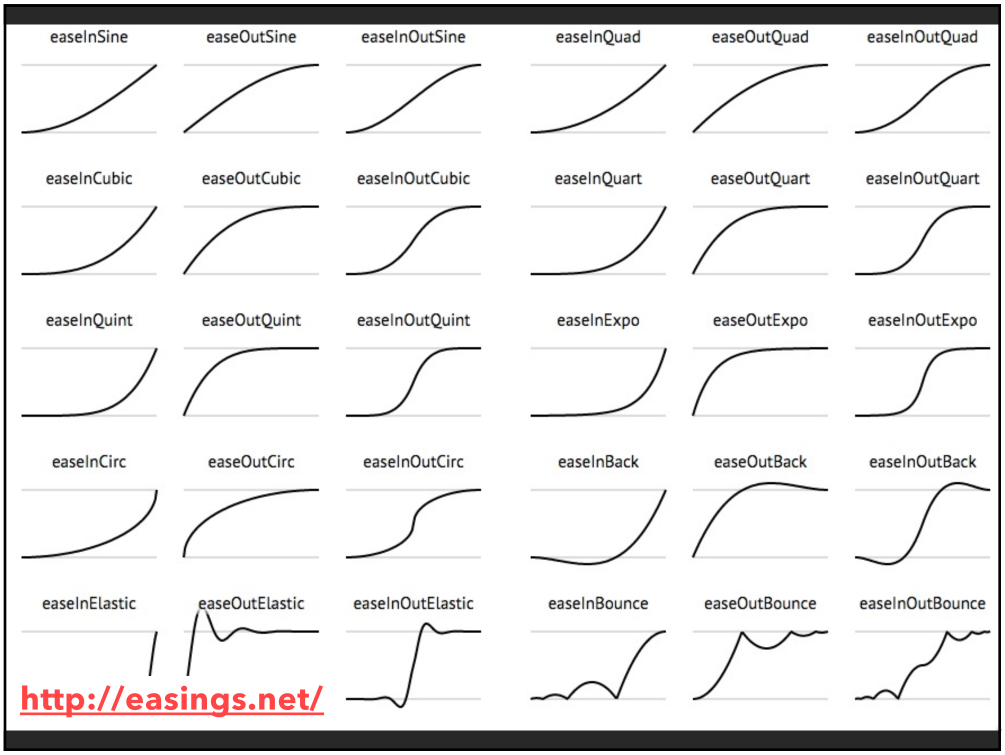

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Summary

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

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

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Announcements

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Final project

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

Deliverables
- **Data analysis/explainer**: Article with multiple different interactive visualizations
- **Research**: Implementation of solution and web-based demo if possible
- **Short video (2 min)** demoing and explaining the project

Schedule
- Project proposal: Wed 11/3
- Design Review and Feedback: 10th week of quarter
- Final code and video: Fri 12/10 11:59pm

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

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Network Layout

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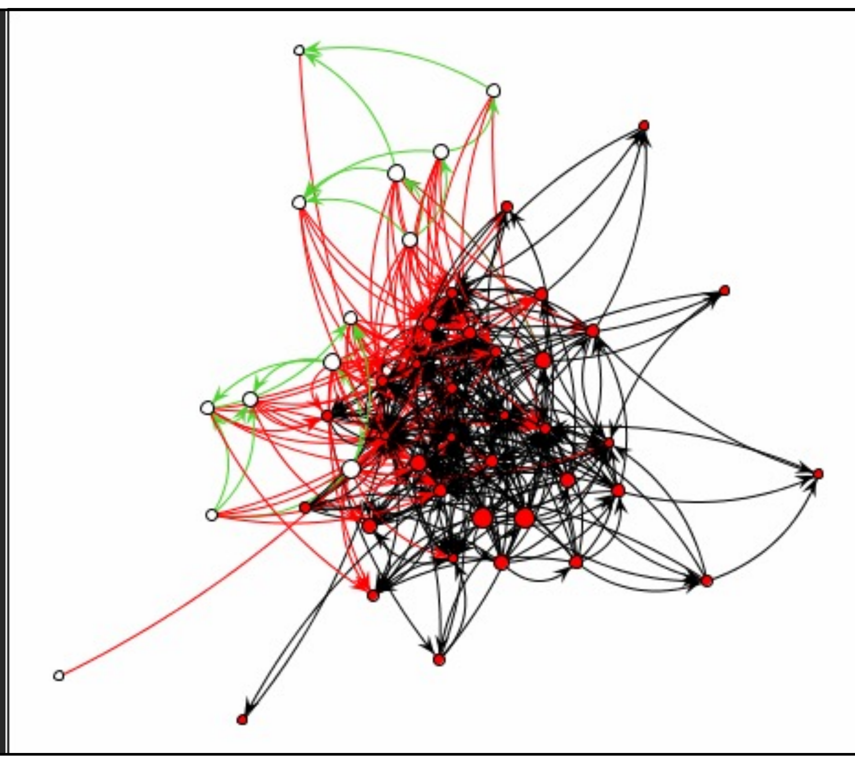

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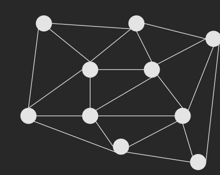
Graphs and Trees

Graphs

Model relations among data

Nodes and *edges*

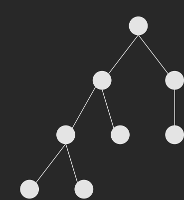


Trees

Graphs with hierarchical structure

Connected graph with N-1 edges

Nodes as *parents* and *children*



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Tree Layout

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Tree Visualization

Indentation

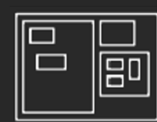
- Linear list, indentation encodes depth

Node-Link diagrams

- Nodes connected by lines/curves

Enclosure diagrams

- Represent hierarchy by enclosure



Layering

- Layering and alignment

Tree layout is fast: O(n) or O(n log n), enabling real-time layout for interaction

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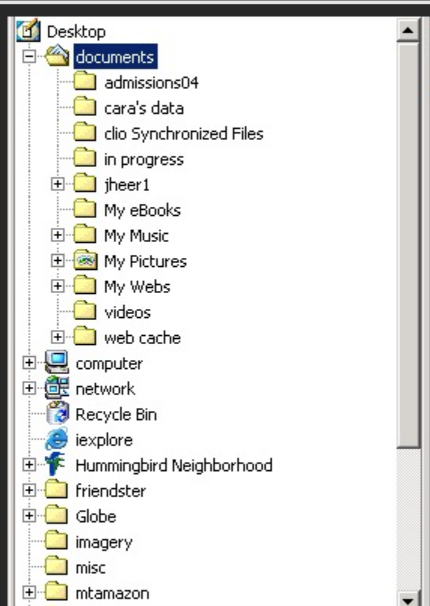
Indentation



Items along vertically spaced rows

Indentation shows parent/child relationships

Often used in interfaces

Breadth/depth contend for space

Often requires scrolling

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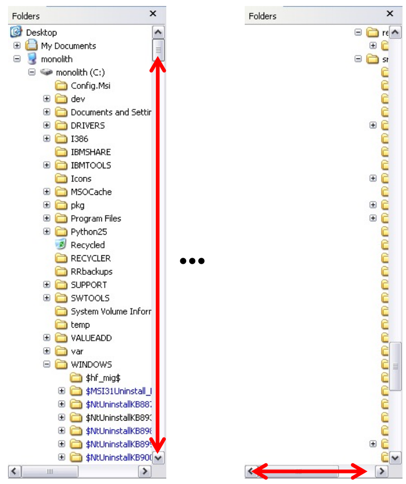
Visualizing Large Hierarchies



Indented Layout

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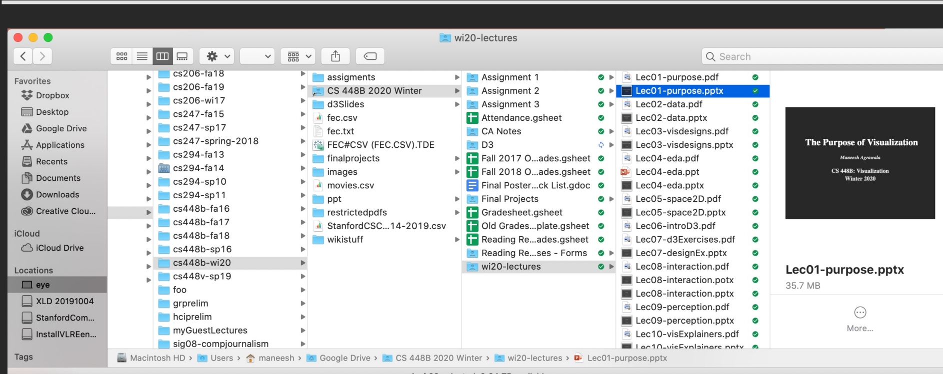
Single-Focus (Accordion) List



Separate breadth & depth in 2D
Focus on single path at a time

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Node-Link Diagrams

Nodes distributed in space, connected by lines
Use 2D space to break apart breadth and depth
Space used to communicate hierarchical orientation
    Typically towards authority or generality

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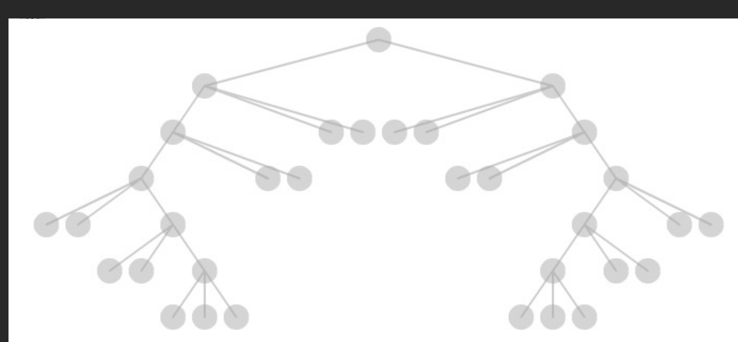
Basic Recursive Approach

Repeatedly divide space for subtrees by leaf count

- Breadth of tree along one dimension
- Depth along the other dimension



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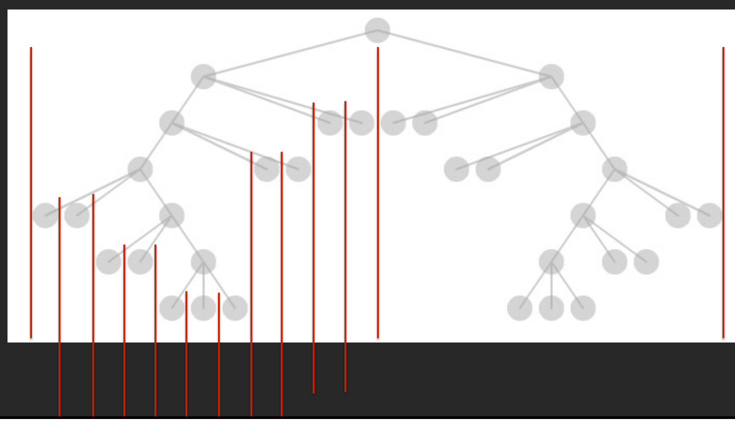

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Basic Recursive Approach

Repeatedly divide space for subtrees by leaf count

- Breadth of tree along one dimension
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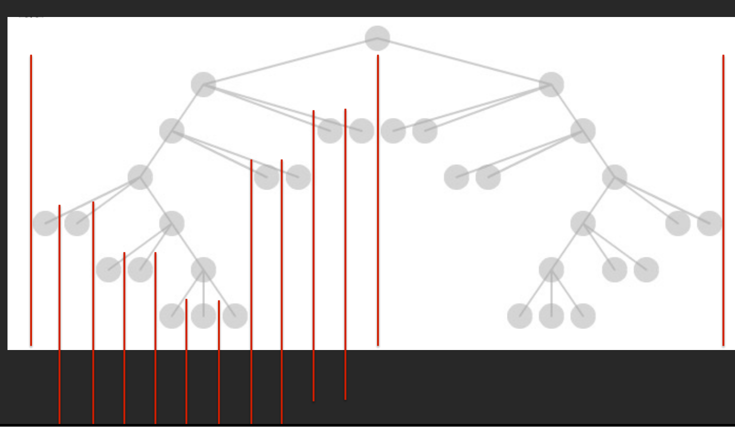
Problem: Exponential growth of breadth



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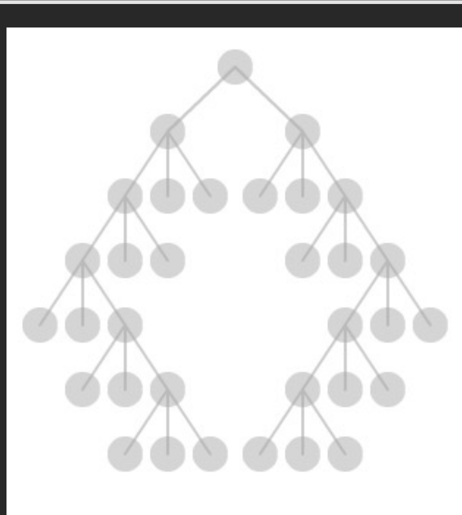
Reingold & Tilford's Tidier Layout



Goal: maximize density and symmetry.

Originally for binary trees, extended by Walker to cover general case.

This extension was corrected by Buchheim et al. to achieve a linear time algorithm

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Reingold-Tilford Layout

Design concerns

- Clearly encode depth level
- No edge crossings
- Isomorphic subtrees drawn identically
- Ordering and symmetry preserved
- *Compact layout (don't waste space)*

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Reingold-Tilford Algorithm

Initial bottom-up (postorder) tree traversal
- Set y-coordinate based on depth
- Initialize x-coordinate to zero

At each parent node, merge left and right subtrees
- Shift right subtree as close as possible to left
  - Computed efficiently by maintaining subtree contours
- Center parent nodes above children
- Record "Shift" in position offset for right subtree

Final top-down (preorder) traversal to set x-coordinates
- Sum aggregated shift

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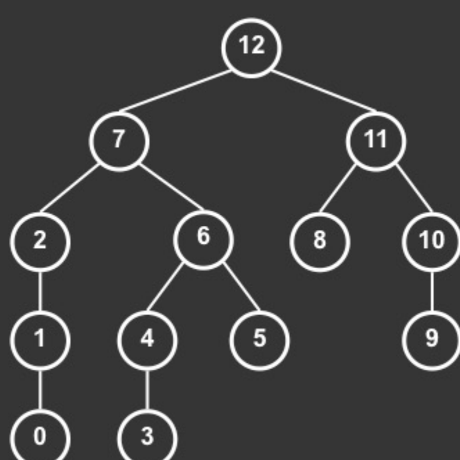
Reingold-Tilford Algorithm



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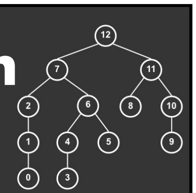

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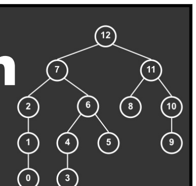

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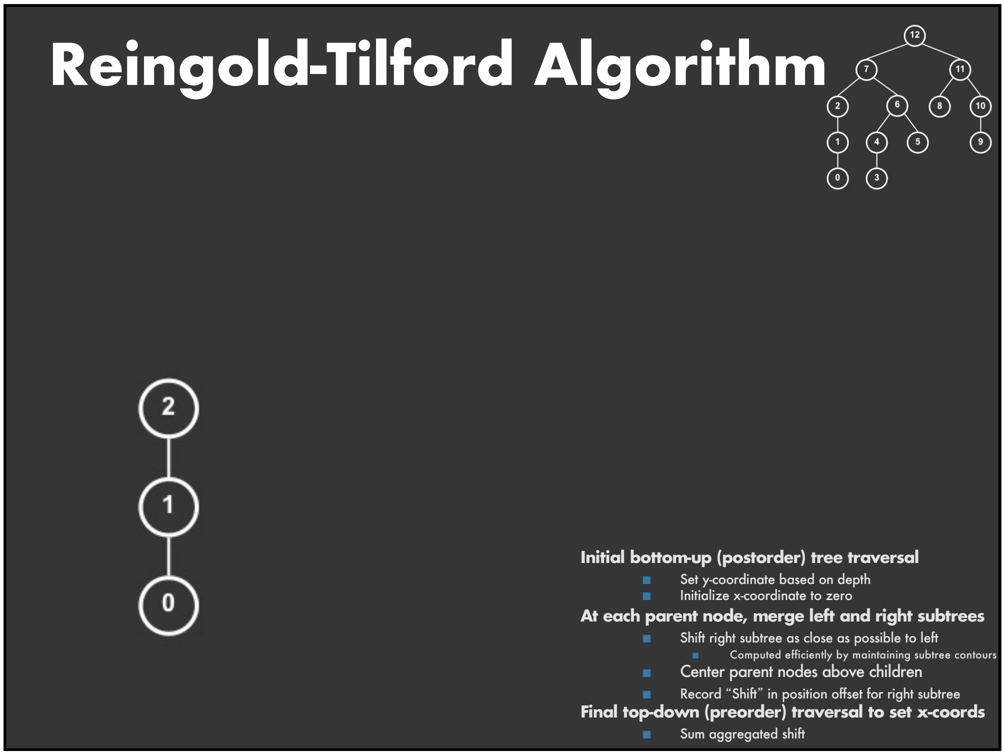
Reingold-Tilford Algorithm
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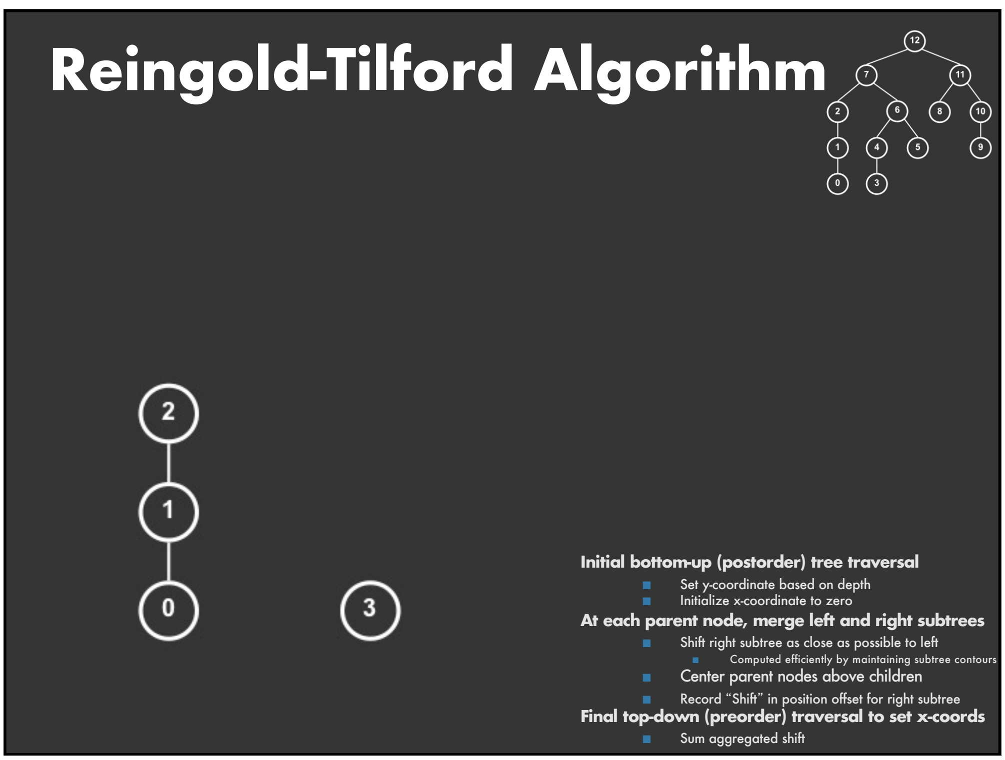
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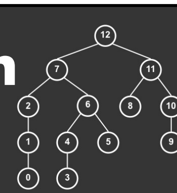

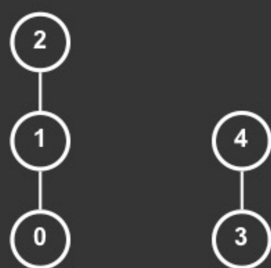

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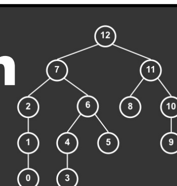

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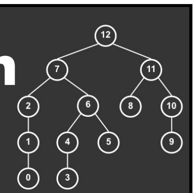

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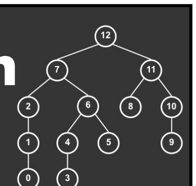
94

Reingold-Tilford Algorithm



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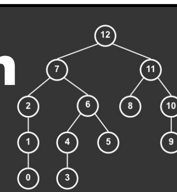

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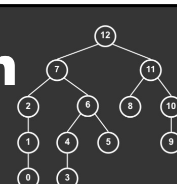

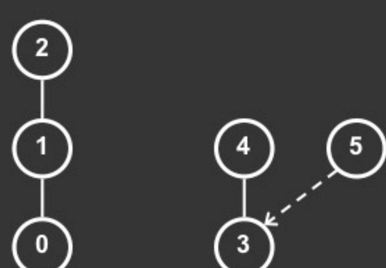

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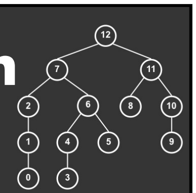

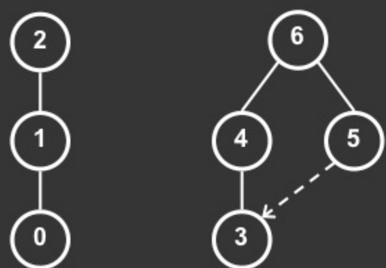

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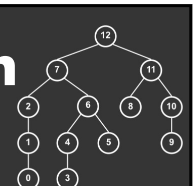

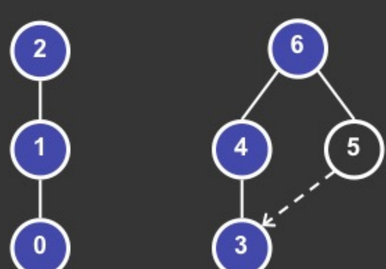

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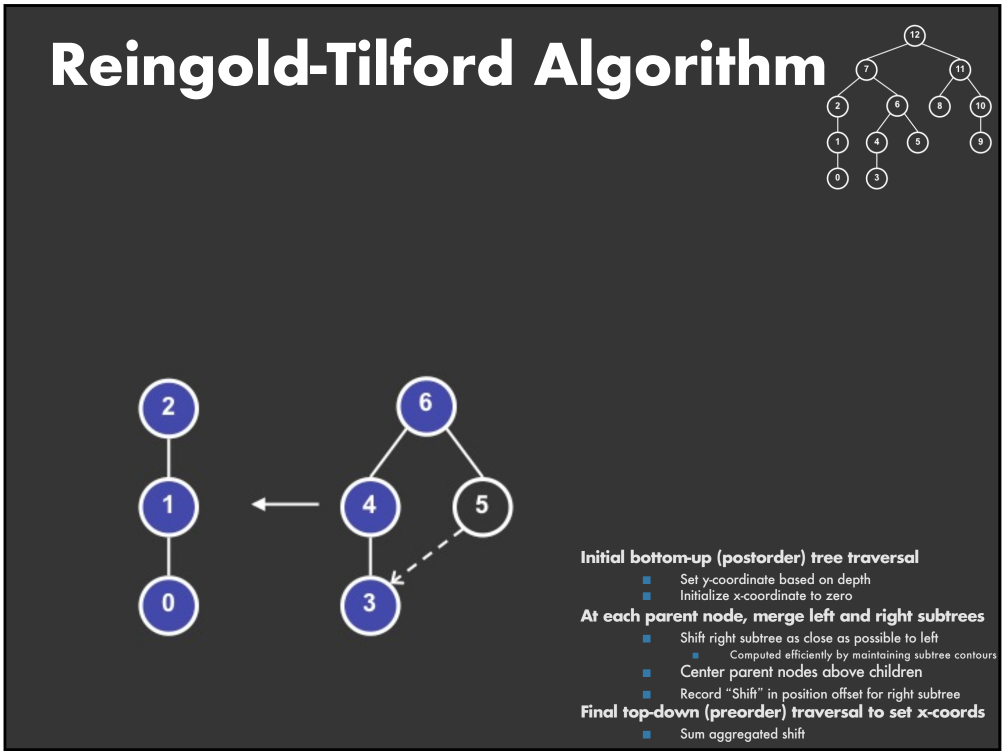
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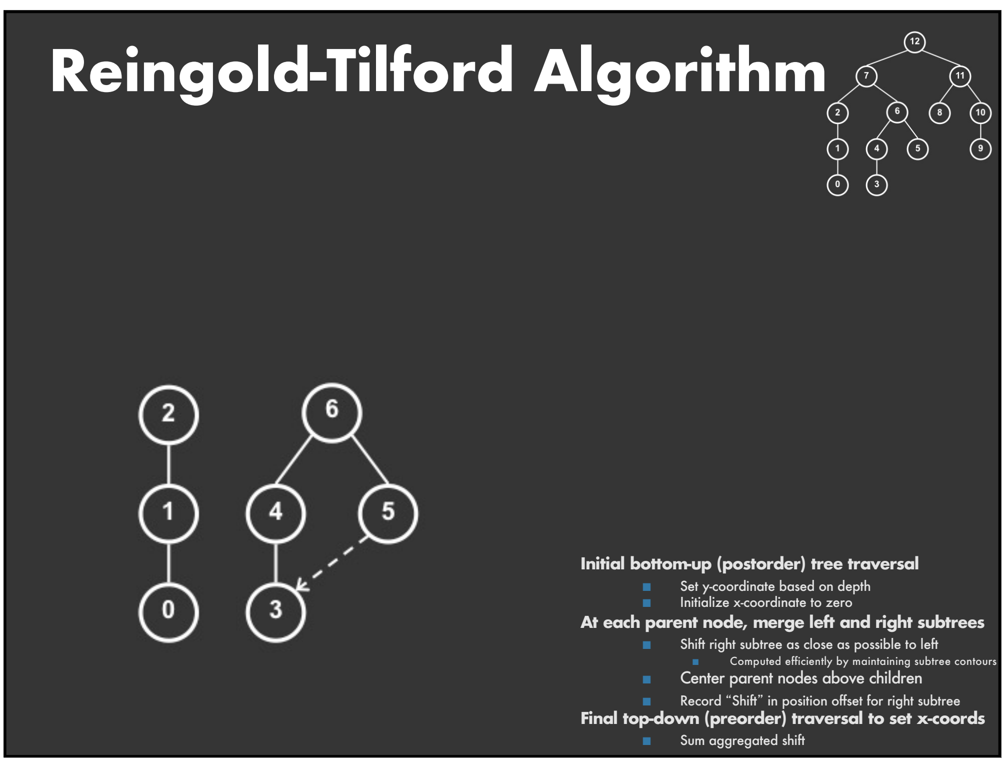
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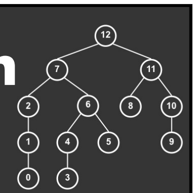

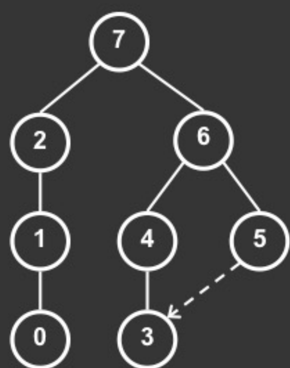

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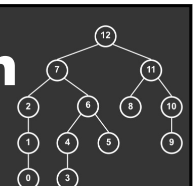

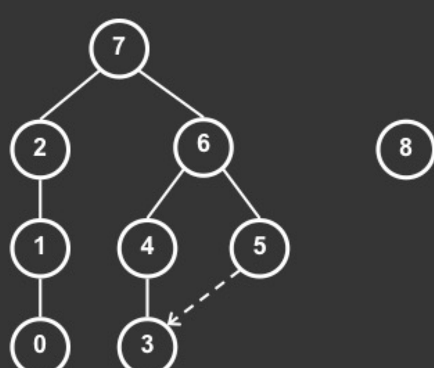

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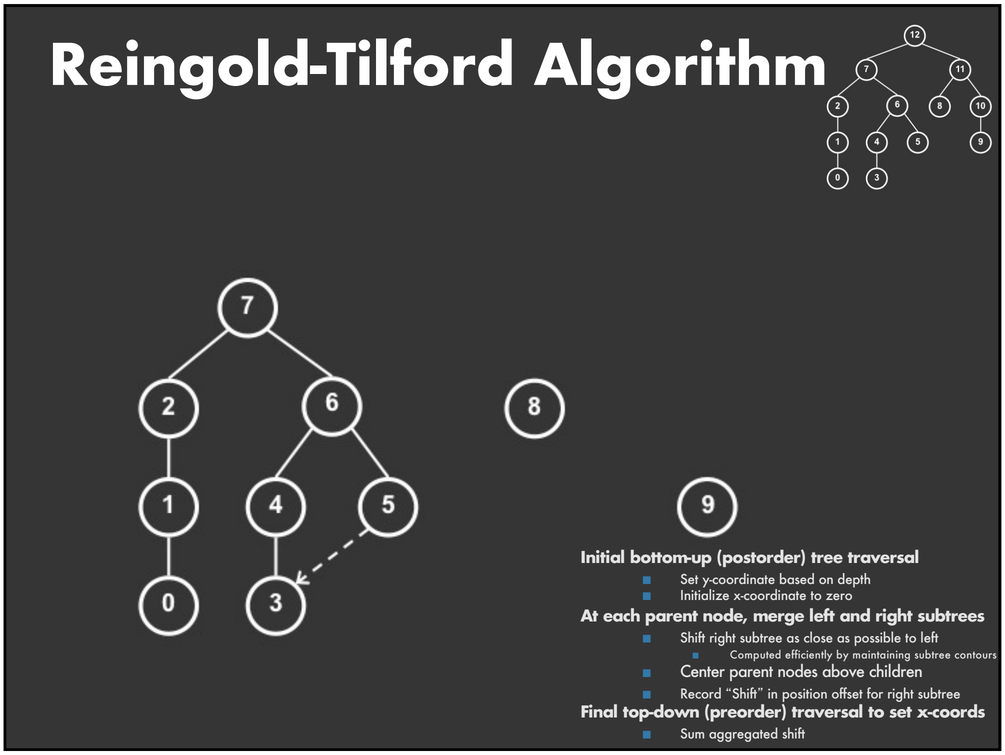
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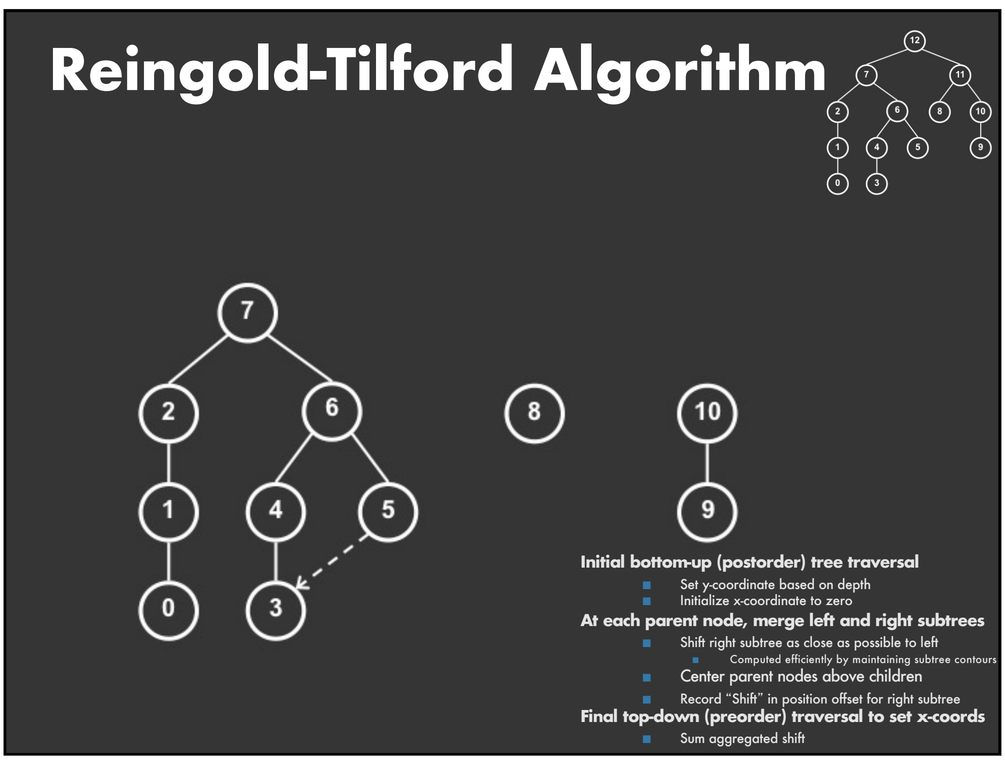
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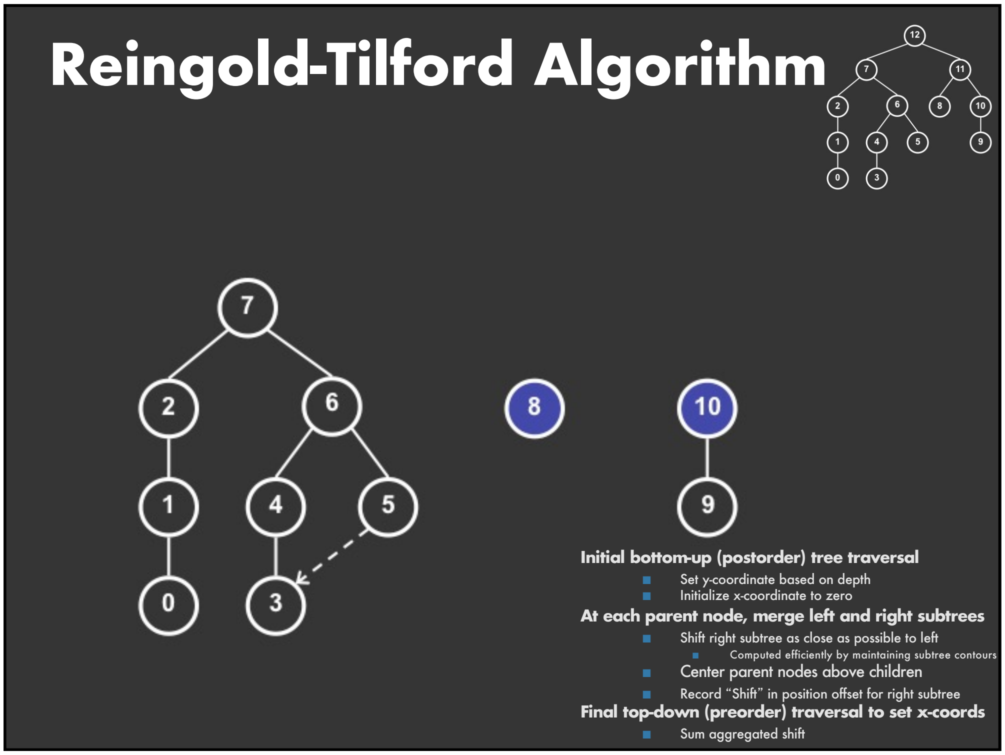
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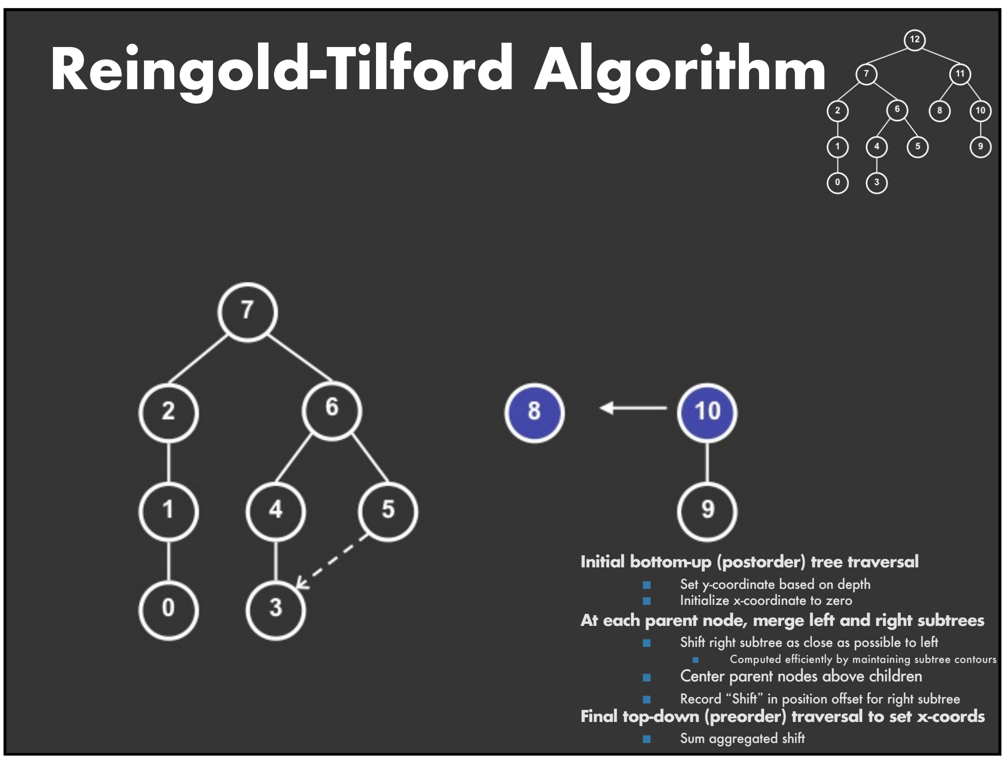
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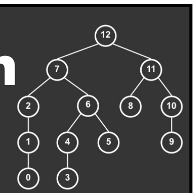

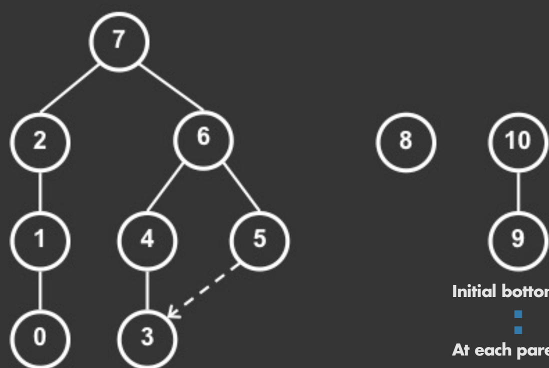

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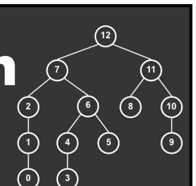

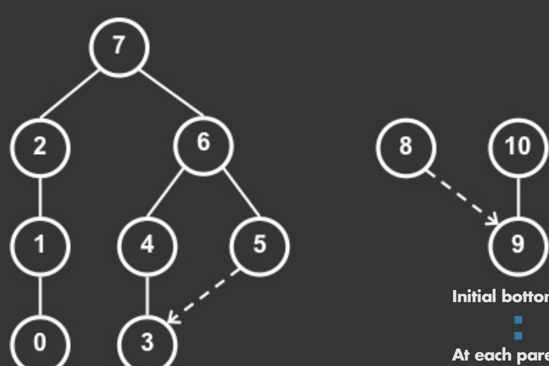

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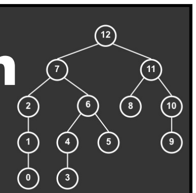

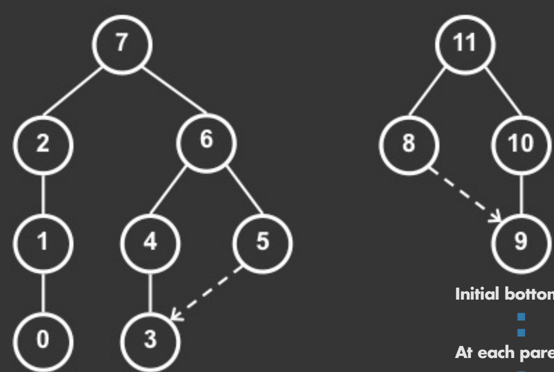

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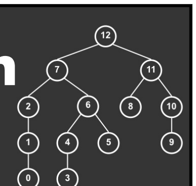

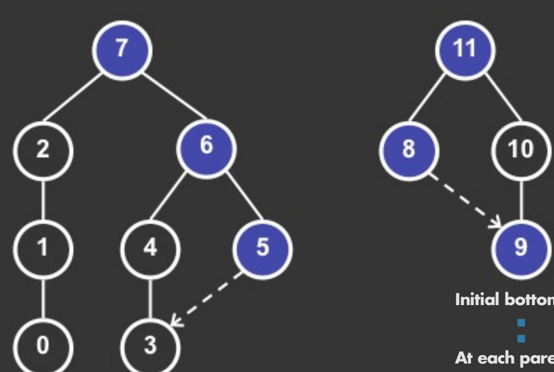

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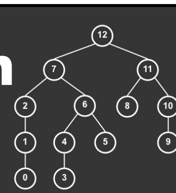

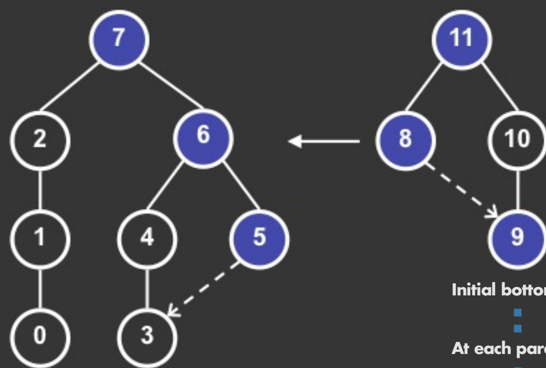

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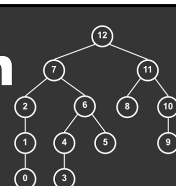

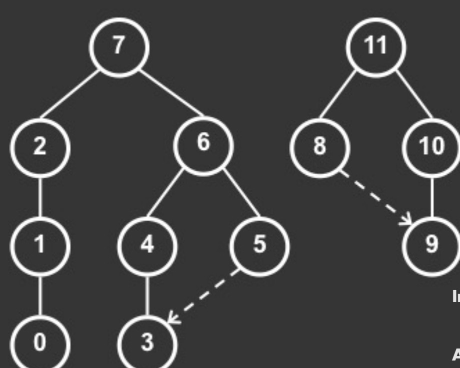

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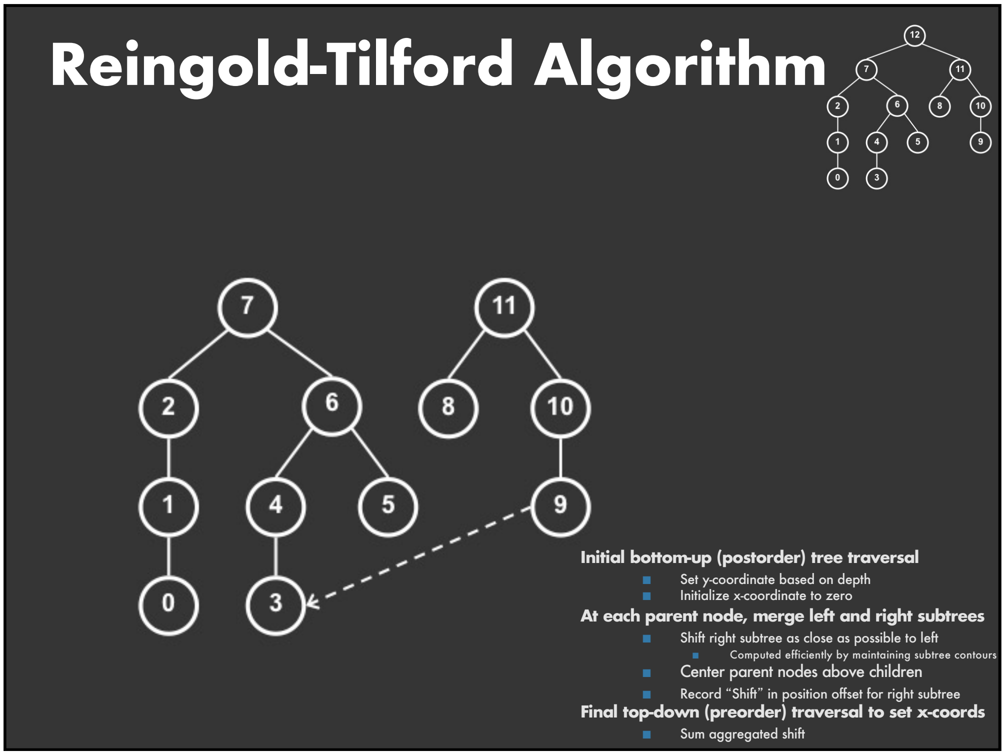
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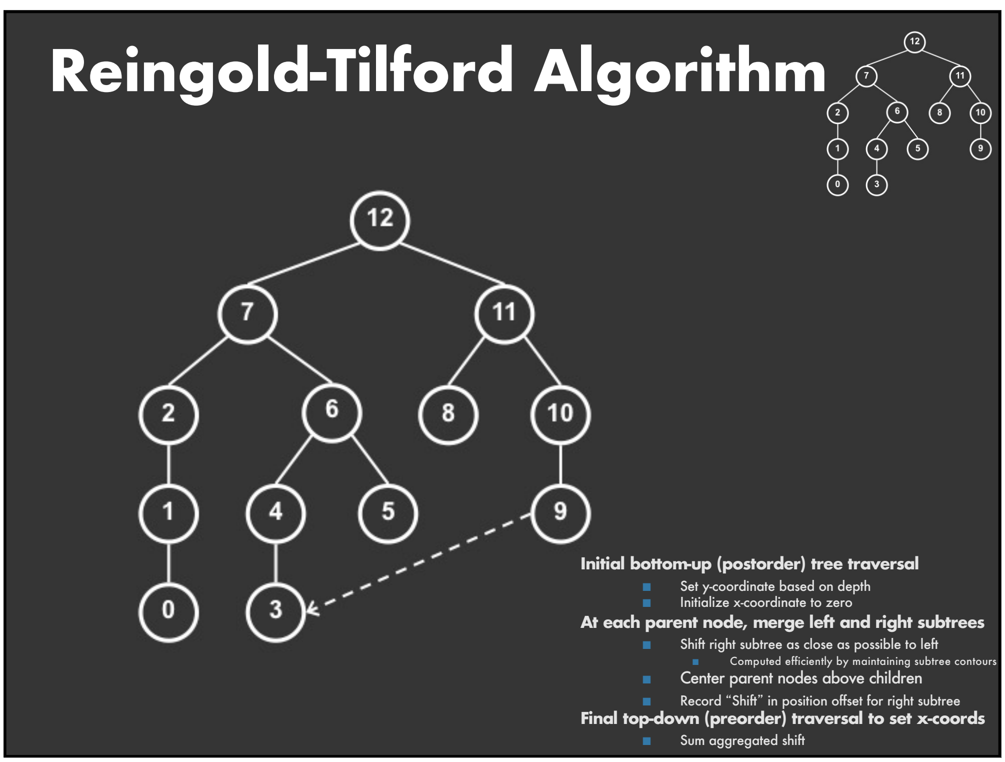
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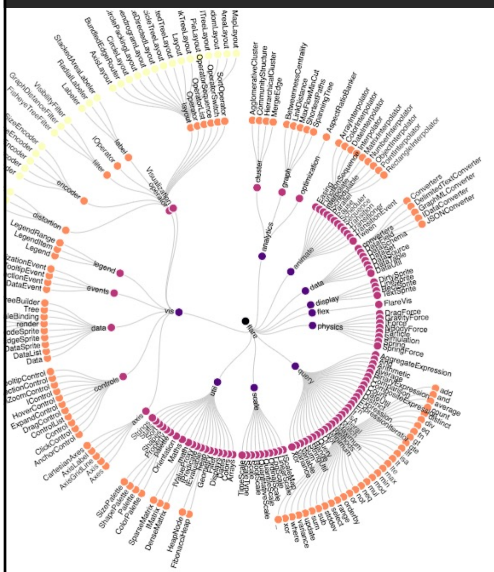
Radial Layout



Node-link diagram in polar coords

Radius encodes depth root at center

Angular sectors assigned to subtrees (recursive approach)

Reingold-Tilford approach can also be applied here

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Problems with Node-Link Diagrams

Scale

- Tree breadth often grows exponentially
- Even with tidier layout, quickly run out of space

Possible solutions

- Filtering
- Focus+Context
- Scrolling or Panning
- Zooming
- Aggregation

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Visualizing Large Hierarchies

Indented Layout

Reingold-Tilford Layout

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MC Escher, *Circle Limit IV*

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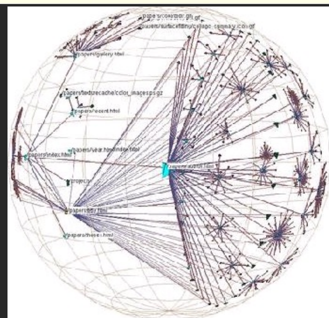
Hyperbolic Layout

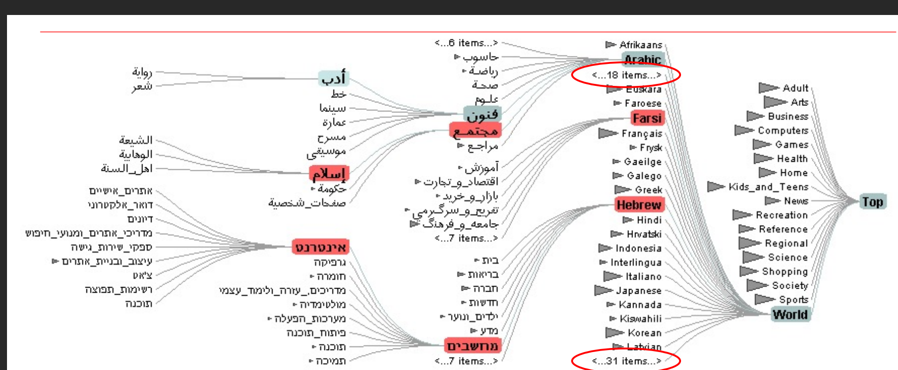


Layout in hyperbolic space, then project on to Euclidean plane

Why? Like tree breadth, the hyperbolic plane expands exponentially

Also computable in 3D, projected into a sphere

Degree-of-Interest Trees [AVI 04]

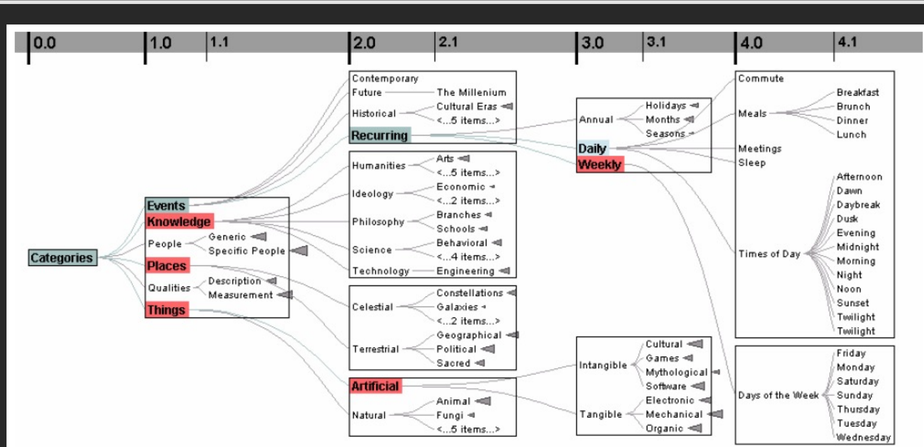


Space-constrained, multi-focal tree layout

https://www.youtube.com/watch?v=RTQ0N4QY0vc

https://observablehq.com/@d3/collapsible-tree

Degree-of-Interest Trees



Cull "un-interesting" nodes on a per block basis until all blocks on a level fit within bounds

Center child blocks under parents

https://www.youtube.com/watch?v=RTQ0N4QY0yc

https://observablehq.com/@d3/collapsible-tree

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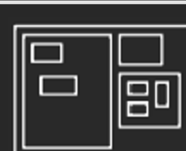
Enclosure Diagrams



Encode structure using spatial enclosure

Popularly known as TreeMaps

Benefits

- Provides a single view of an entire tree
- Easier to spot large/small nodes

Problems

- Difficult to accurately read depth

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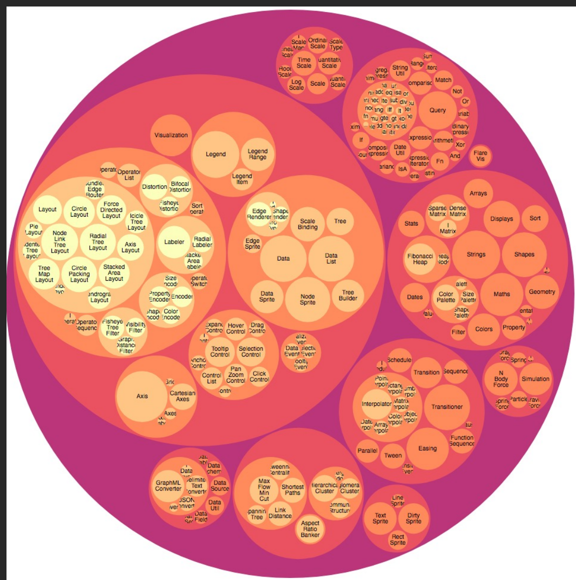
Circle Packing Layout



Nodes represented as sized circles

Nesting to show parent-child relationships

Problems:

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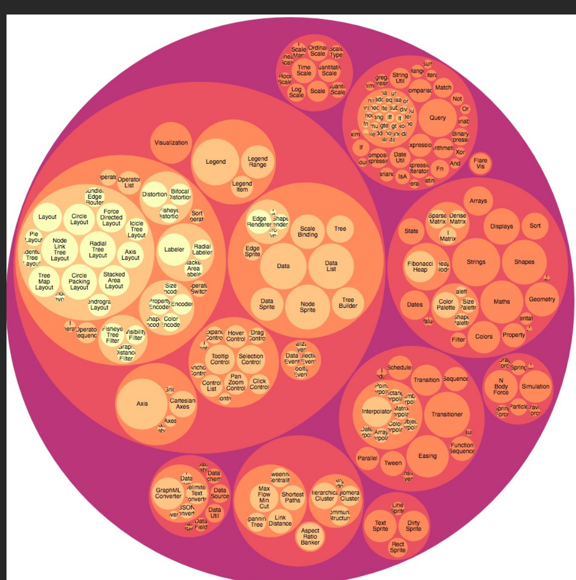
Circle Packing Layout



Nodes represented as sized circles

Nesting to show parent-child relationships

Problems:

- Inefficient use of space
- Parent size misleading

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Treemaps

Hierarchy visualization that emphasizes values of nodes via area encoding

Partition 2D space such that leaf nodes have sizes proportional to data values

First layout algorithms proposed by Shneiderman et al. in 1990, with focus on showing file sizes on a hard drive

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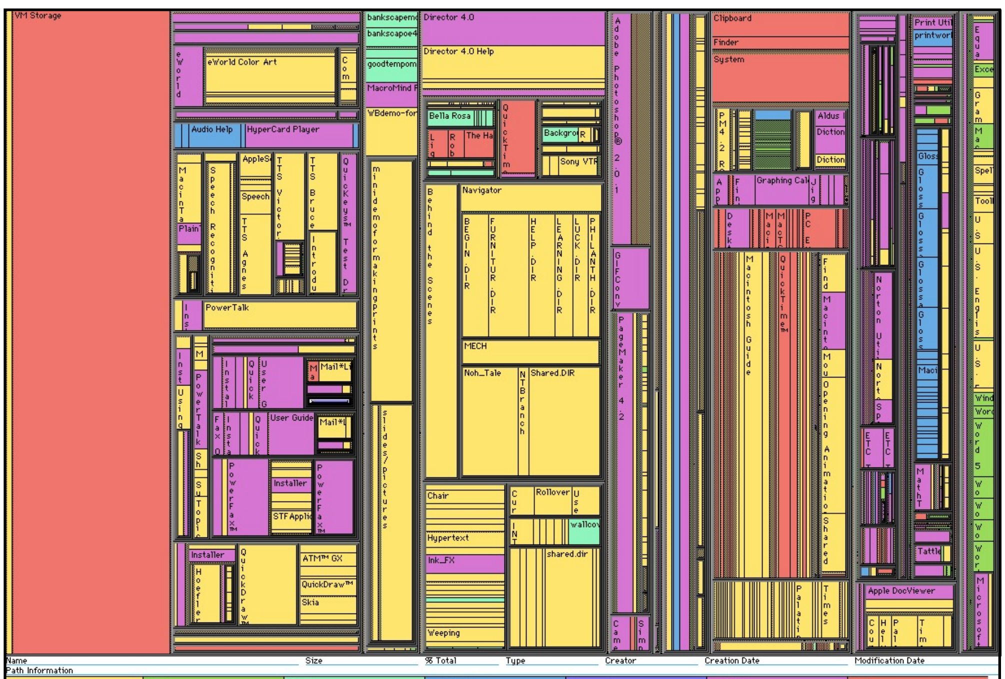

Slice & Dice **layout: Alternate horizontal / vertical partitions.**

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Squarifed **layout: Try to produce square (1:1) aspect ratios**

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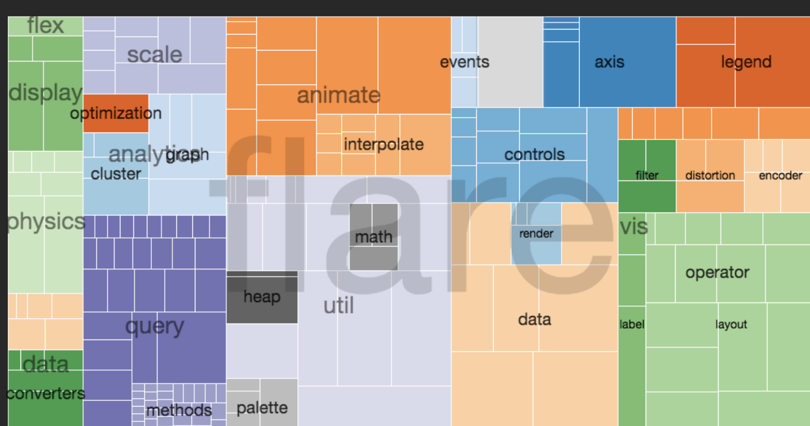
Squarified Treemaps [Bruls 00]

Greedy optimization for objective of square rectangles
Slice/dice within siblings; alternate whenever ratio worsens



https://vega.github.io/vega/examples/treemap/

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Why Squares

Posited Benefits of 1:1 Aspect Ratios

1. Minimize perimeter, reducing border ink.
2. Easier to select with a mouse cursor.
   Validated by empirical research & Fitt's Law!
3. Similar aspect ratios are easier to compare.
   Seems intuitive, but is this true?

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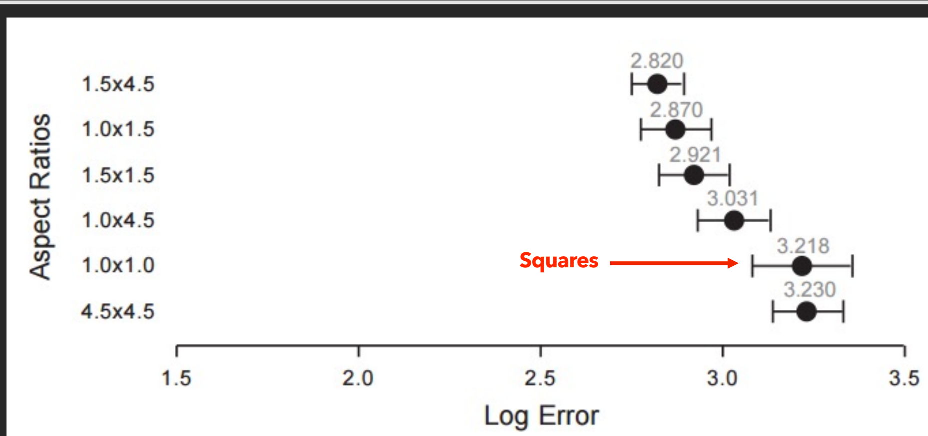
Error vs. Aspect Ratio [Kong 10]



1. Comparison of squares has higher error!
2. Squarify works because it fails to meet its objective?

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Why Squares

Posited Benefits of 1:1 Aspect Ratios

1. Minimize perimeter, reducing border ink.
2. Easier to select with a mouse cursor.
   Validated by empirical research & Fitt's Law!
3. Similar aspect ratios are easier to compare.
   ~~*Seems intuitive, but is this true?*~~
   Extreme ratios & squares-only more inaccurate.
   Balanced ratios better? Target golden ratio?

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