HOLA: Human-like Orthogonal Network Layout

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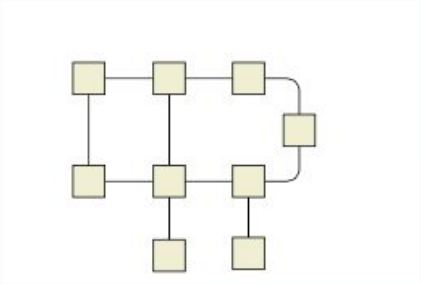
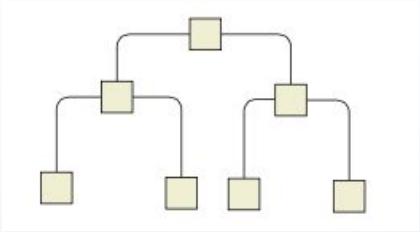
In a Nutshell...

Let's analyze human-drawn networks to improve automatic [orthogonal] network layout algorithms.

Orthogonal Networks

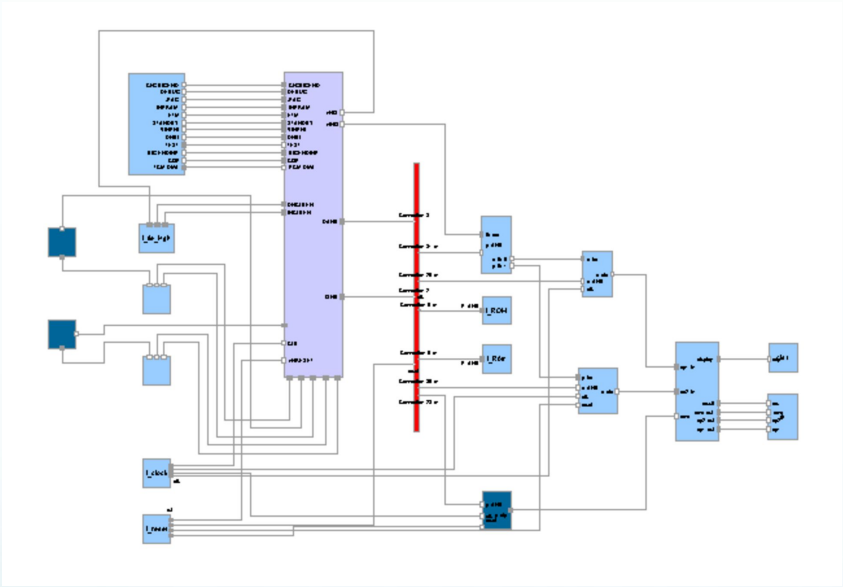
- An *orthogonal network* is a type of *node-link diagram*
- It is a visual encoding idiom
  - a *how?* in the *what-why-how* triad
- The *layout* is the arrangement of edges and nodes in a specific instance





Uses

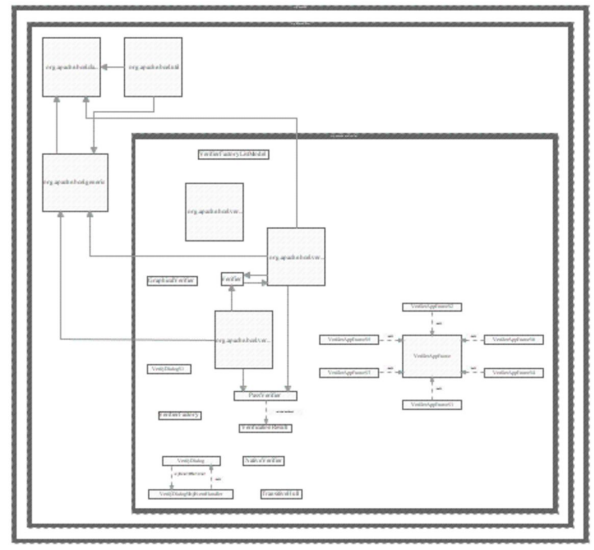
Electrical Engineering…



https://www.tomsawyer.com/gallery/

What: Circuit design network
Why: Locate paths/nodes, explore connectivity
How: orthogonal network

Software Engineering...



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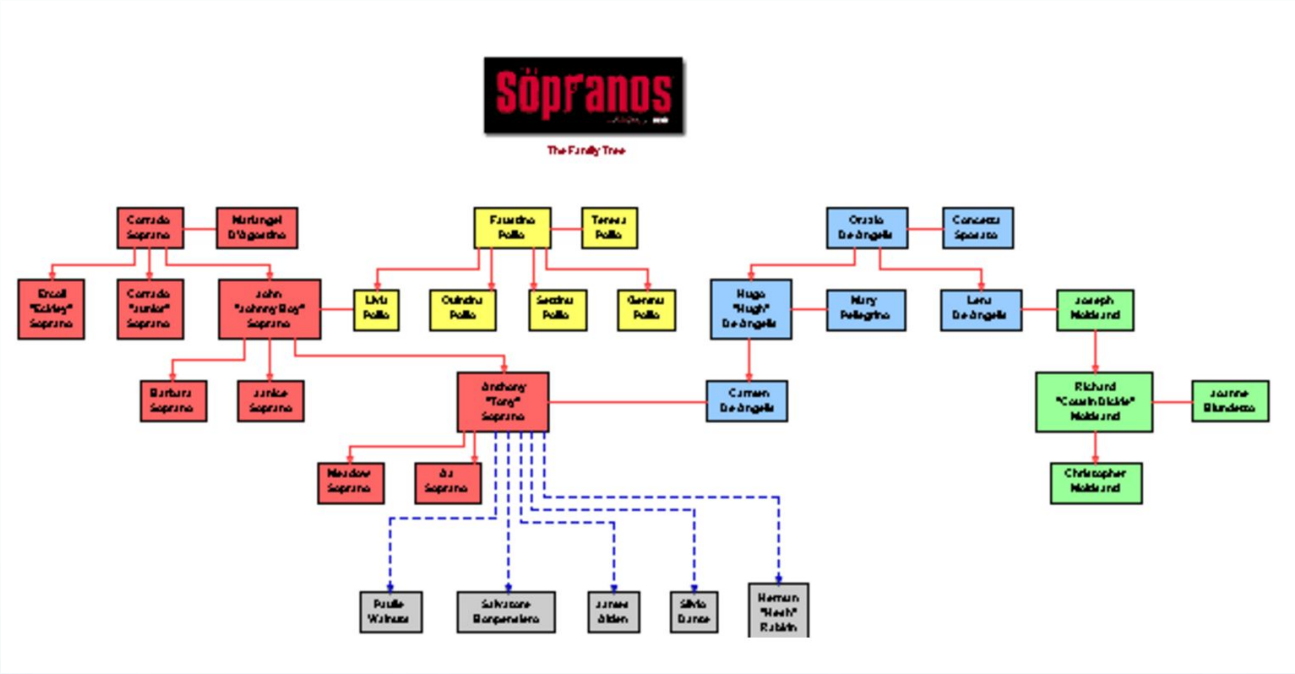
What: Software dependencies network (directed)
Why: Locate paths/nodes
How: orthogonal network

Uses



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What: Genealogical tree (directed, acyclic/hierarchical)
Why: Locate paths/nodes/clusters
How: orthogonal network

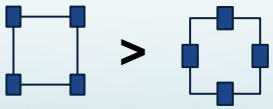
Automatic Network Layout Algorithms

- Have been an area of study since the 1960s
- Aesthetic principles historically determined based on
  - Designer intuition and perceptual principles
  - Algorithmic availability and convenience
- Several of these principles have been validated by user studies:

Edge Crossings:

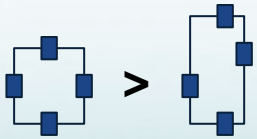
(task performance and preference)

Bend Points:



(task performance and preference)

Symmetry:



(preference)

Orthogonality:

(preference)

Automatic Network Layout Algorithms

- Nevertheless, automatic network layouts are still inferior to those carefully produced by humans

- Possible reasons:
  1. Studies to discover *new* aesthetic principles have not been conducted until very recently
     a. In these, users are asked to generate or alter networks manually
     b. Has not been done for orthogonal networks in particular
  2. No attempts to apply these discoveries to algorithm design

Contributions of Study

1. A new *methodology* for developing network layout algorithms based on user studies

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2. The first *user study* on aesthetic criteria for orthogonal network layouts

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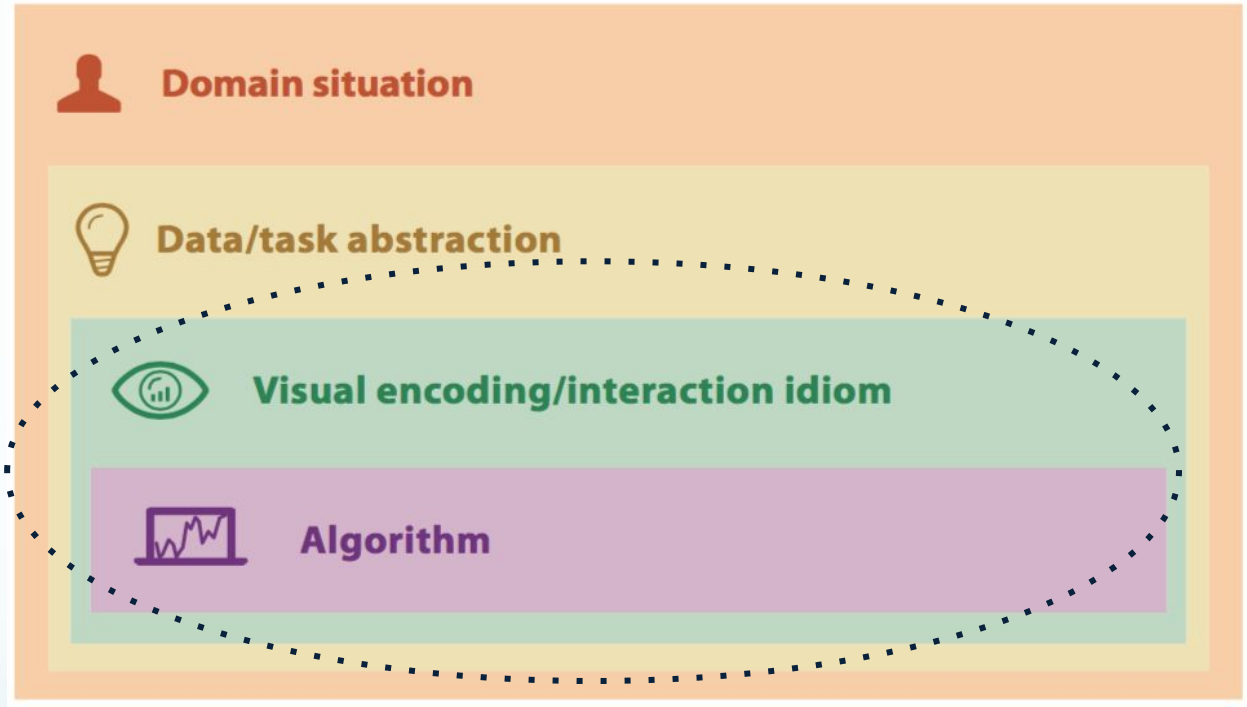
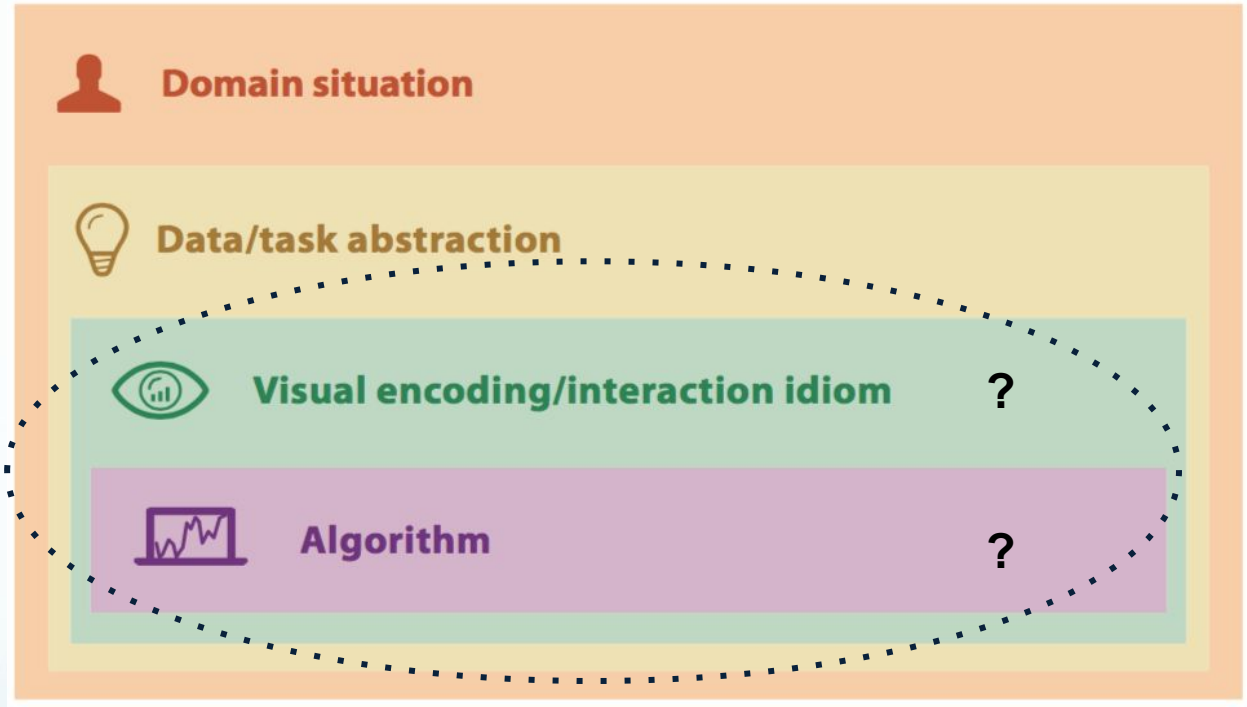
3. A new *algorithm* called HOLA developed using this methodology

Contributions of Study



Technique-driven work

Contributions of Study



Technique-driven work

Contributions of Study

1. **A new *methodology* for developing network layout algorithms based on user studies**

2. The first *user study* on aesthetic criteria for orthogonal network layouts

3. A new *algorithm* called HOLA developed using this methodology

“Human-centred” Methodology for Automatic Network Layout Algorithm Design

1. Conduct user studies to determine aesthetic criteria that people value
2. Develop an algorithm that encodes these aesthetics
3. Evaluate the layouts produced by this algorithm against manually-created layouts and the best automatic layouts

Contributions of Study

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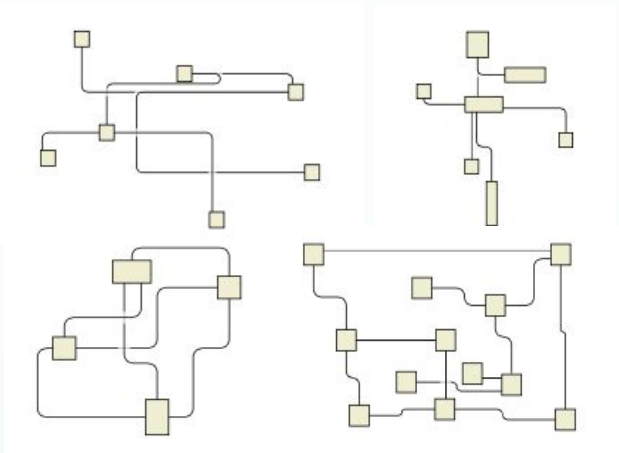
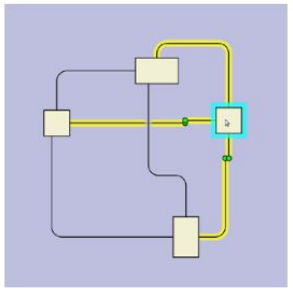
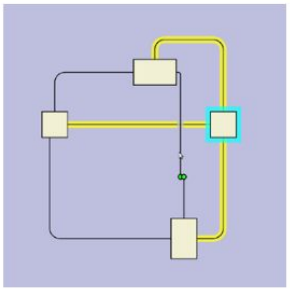
User Study - Stage A

- Seventeen participants were given eight orthogonal networks to manually edit using online tool





(a) Bend point "snap-to" when dragging a node



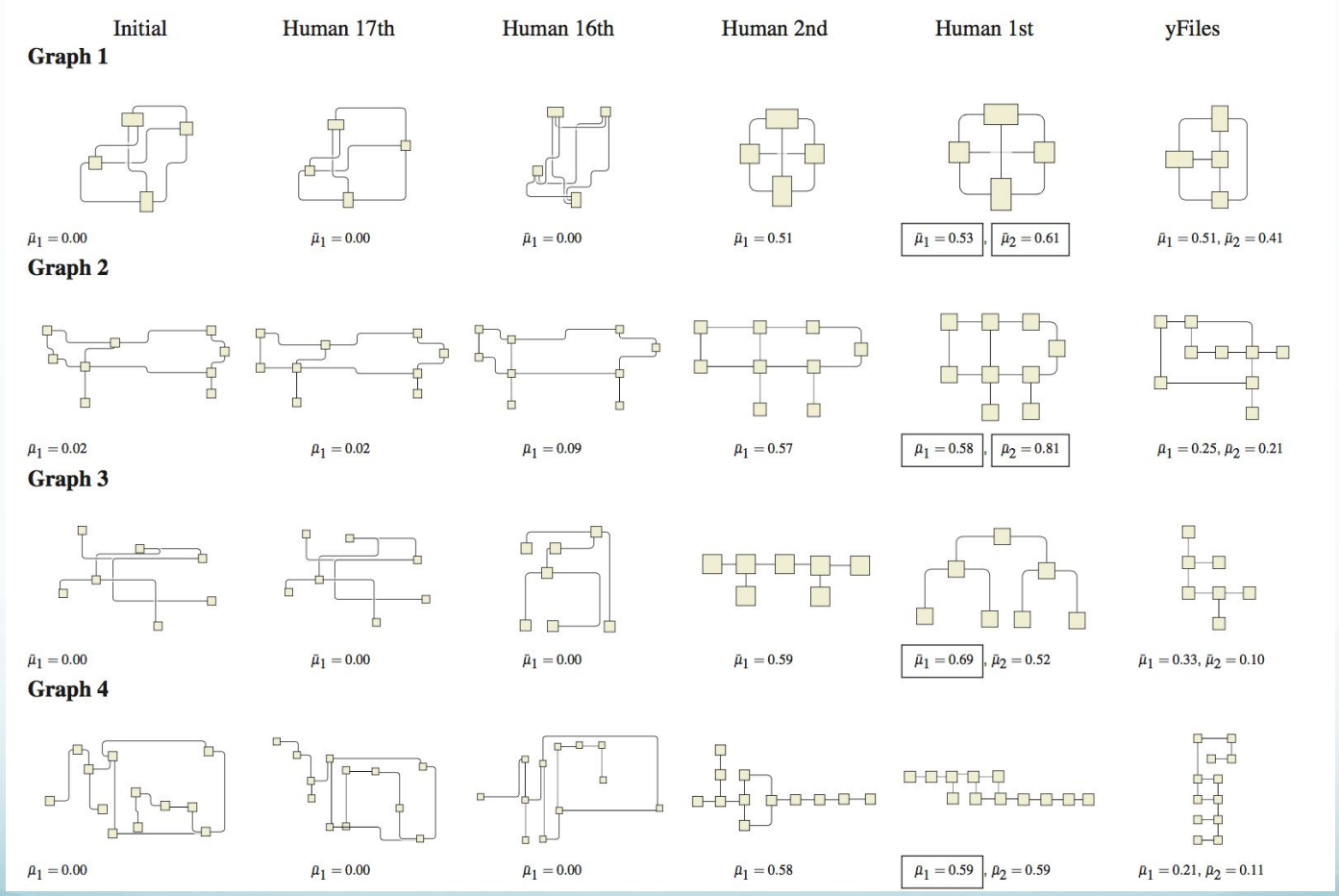
(b) Dragging an edge

- Instructed to edit each network until it "looked good" and the connections were clear

User Study - Stage B

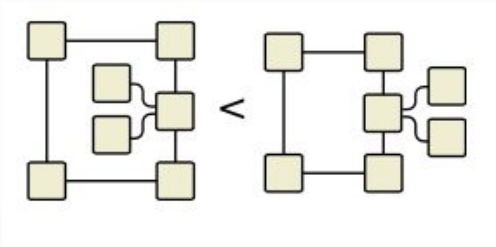
- 66 new participants ranked different representations of the eight original networks
- Included in each set were:
  - the 17 manually-created networks from Stage A
  - the original network
  - the network produced by yFiles (the best automatic layout tool)
- This was done tournament style - participants were shown three networks at a time and instructed to choose the best

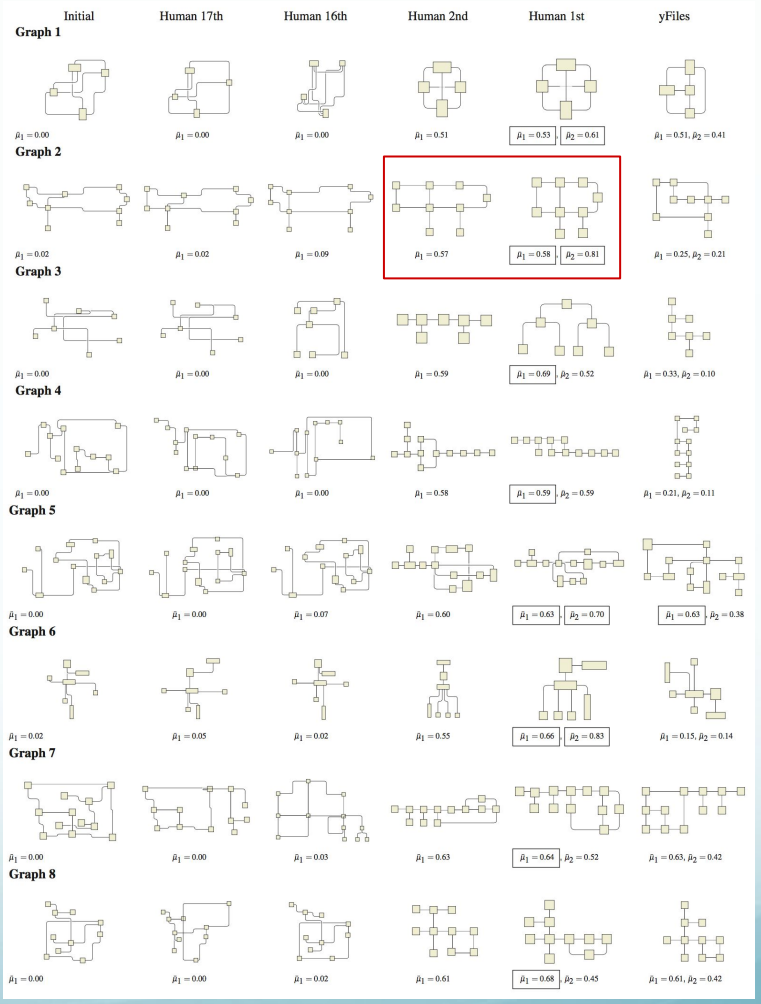
User Study - Results



User Study - Results

- **R1** (*new*) : users like trees placed on outside





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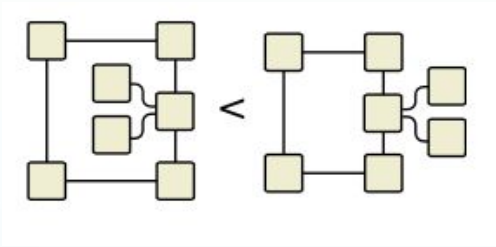
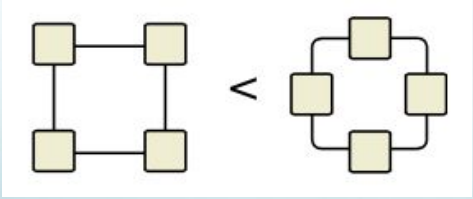
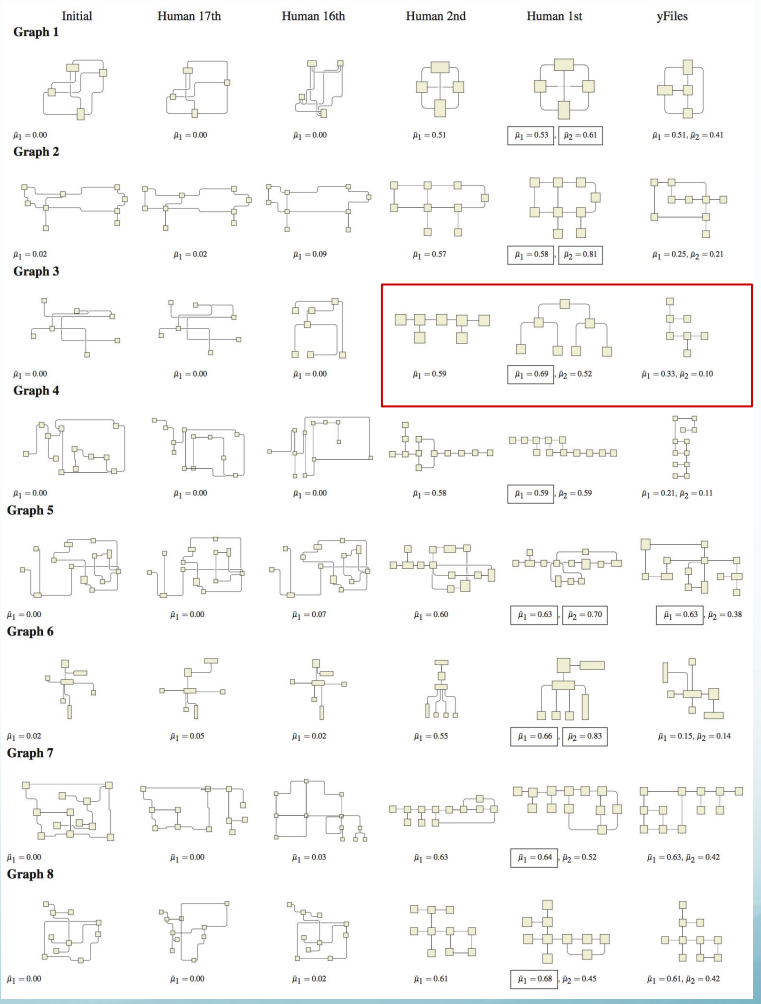


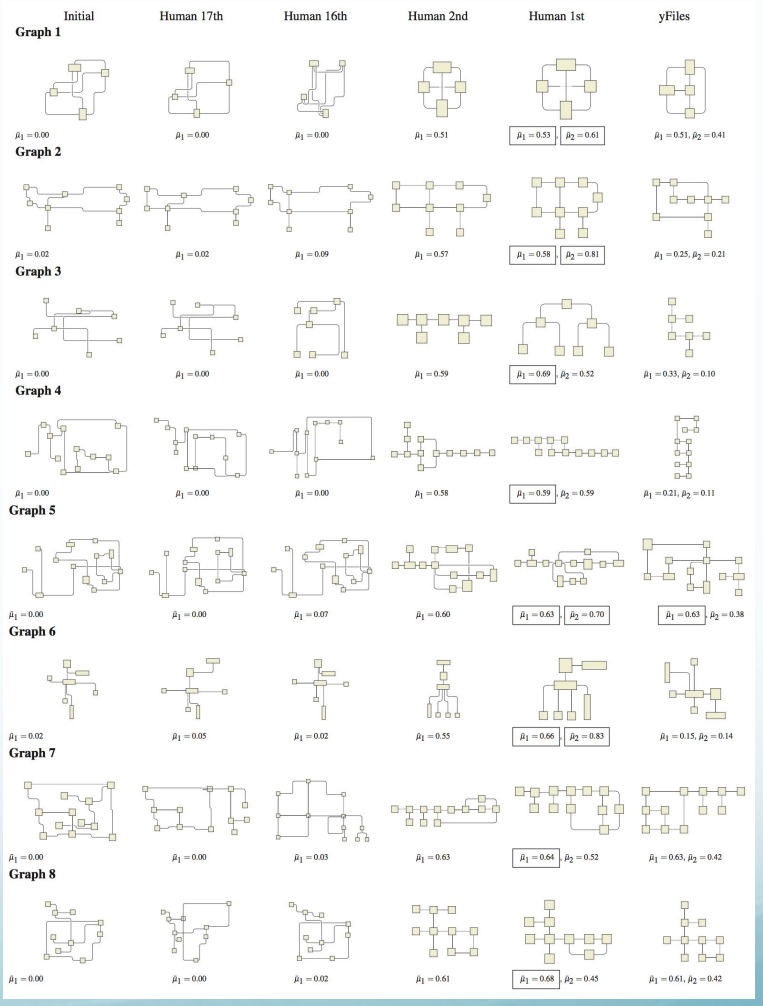
- **R2** (*new*) : users create “aesthetic bend points”





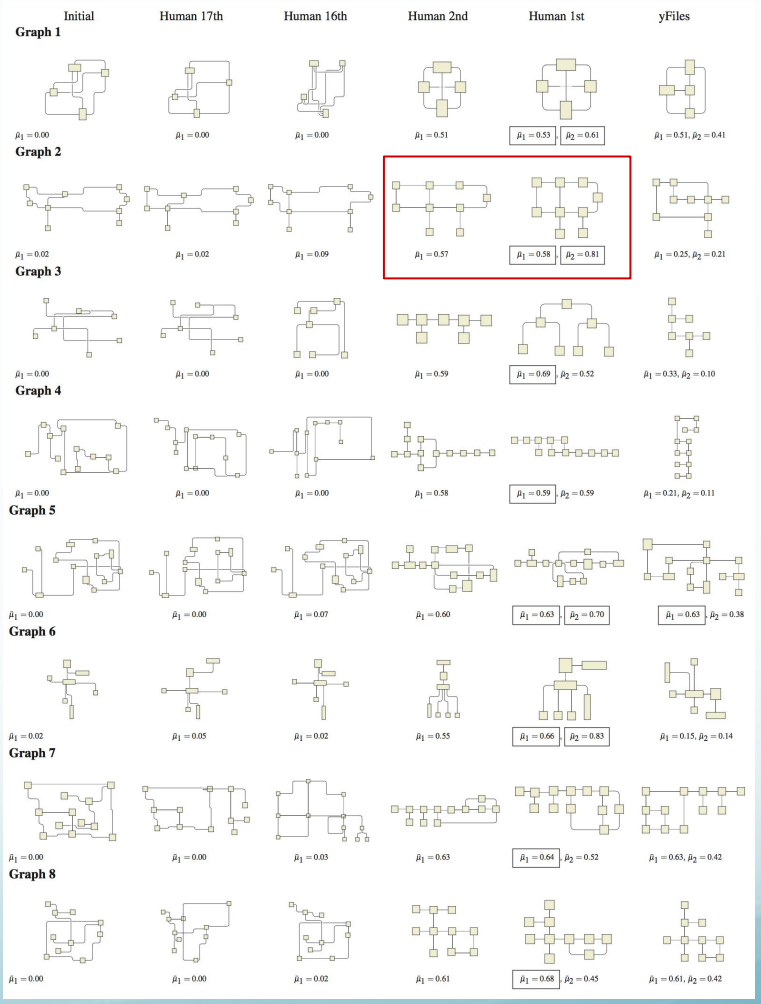
User Study - Results

- Users like...



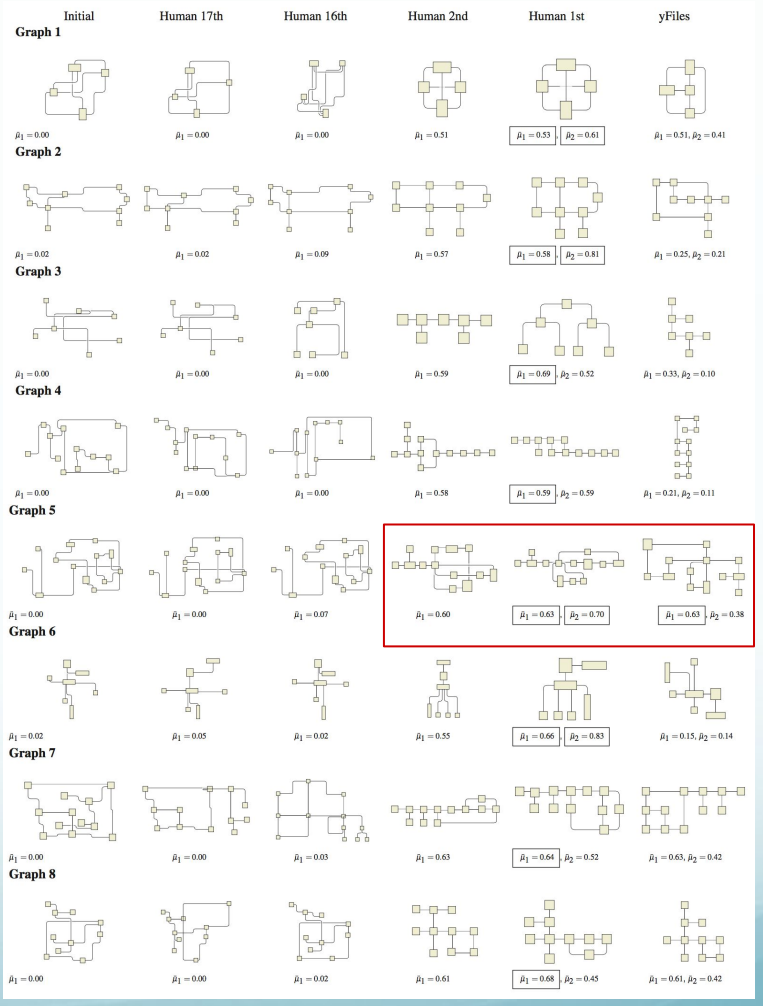
User Study - Results

- Users like...
- **R3** compactness



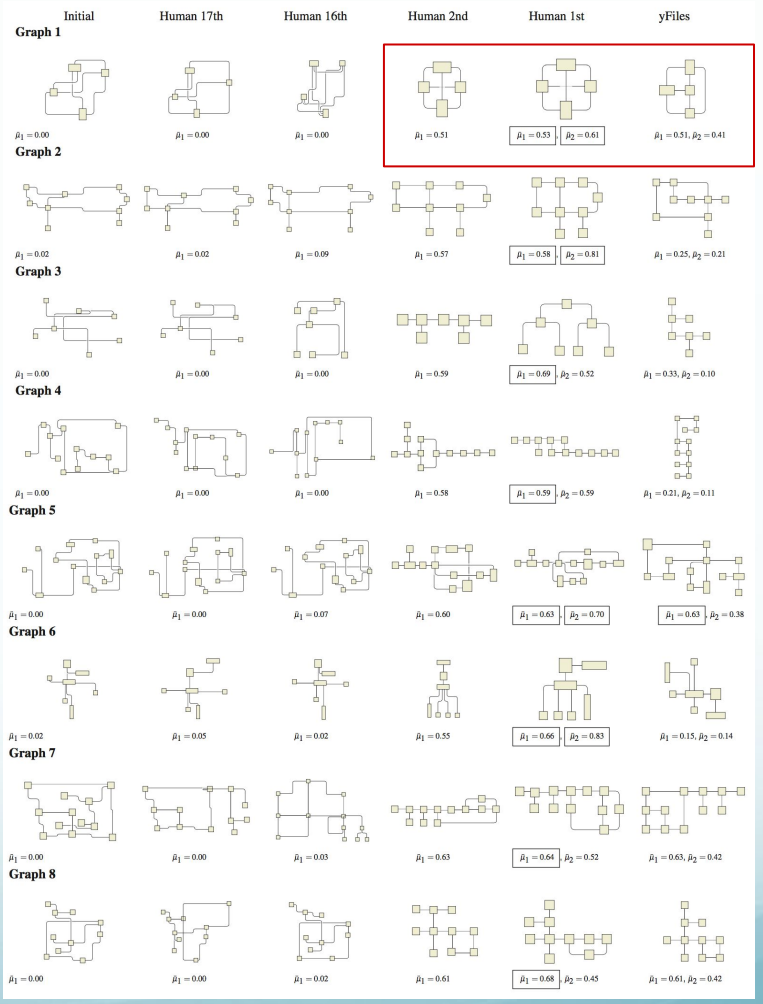
User Study - Results

- Users like...
- **R3** compactness
- **R4** “gridiness”



User Study - Results

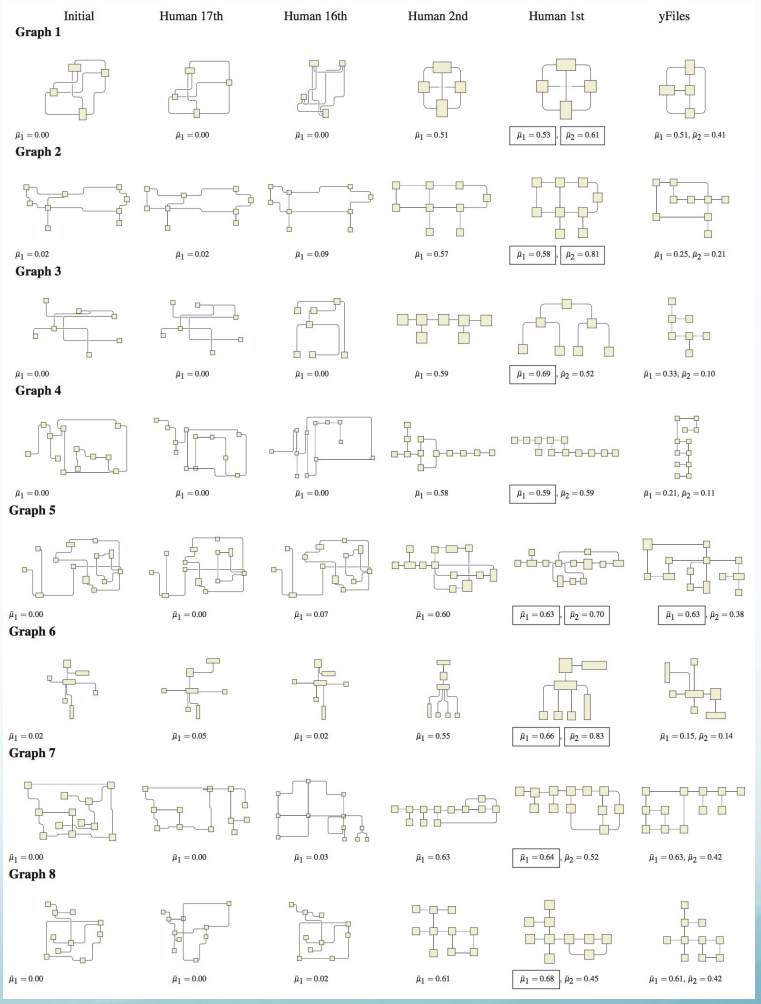
- Users like...
- **R3** compactness
- **R4** “gridiness”
- **R5** symmetry



User Study - Results

- Users like...
- **R3** compactness
- **R4** “gridiness”
- **R5** symmetry

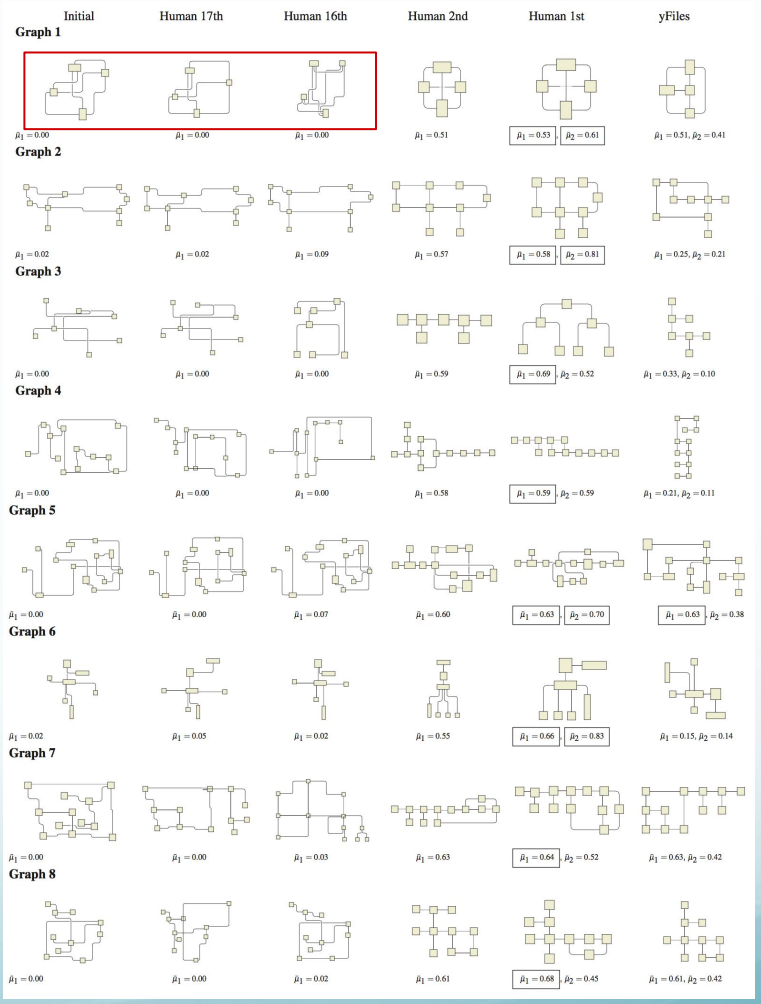
- Users don’t like…



User Study - Results

- Users like...
- **R3** compactness
- **R4** “gridiness”
- **R5** symmetry

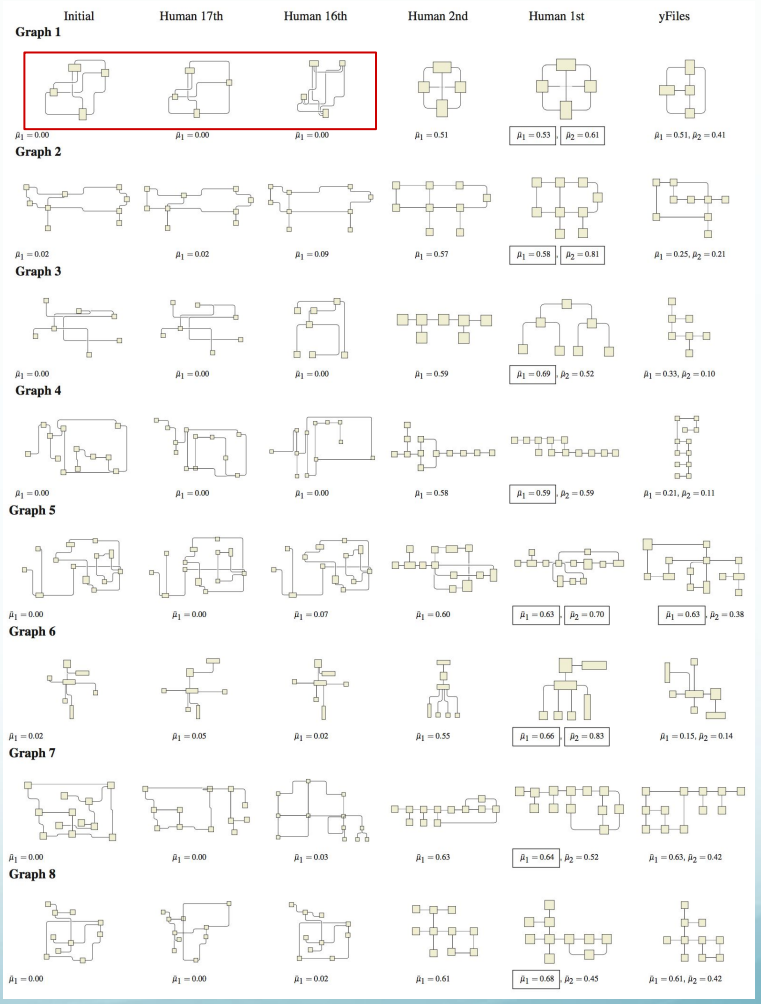
- Users don’t like…
- **R6** edge crossings



User Study - Results

- Users like...
- **R3** compactness
- **R4** “gridiness”
- **R5** symmetry

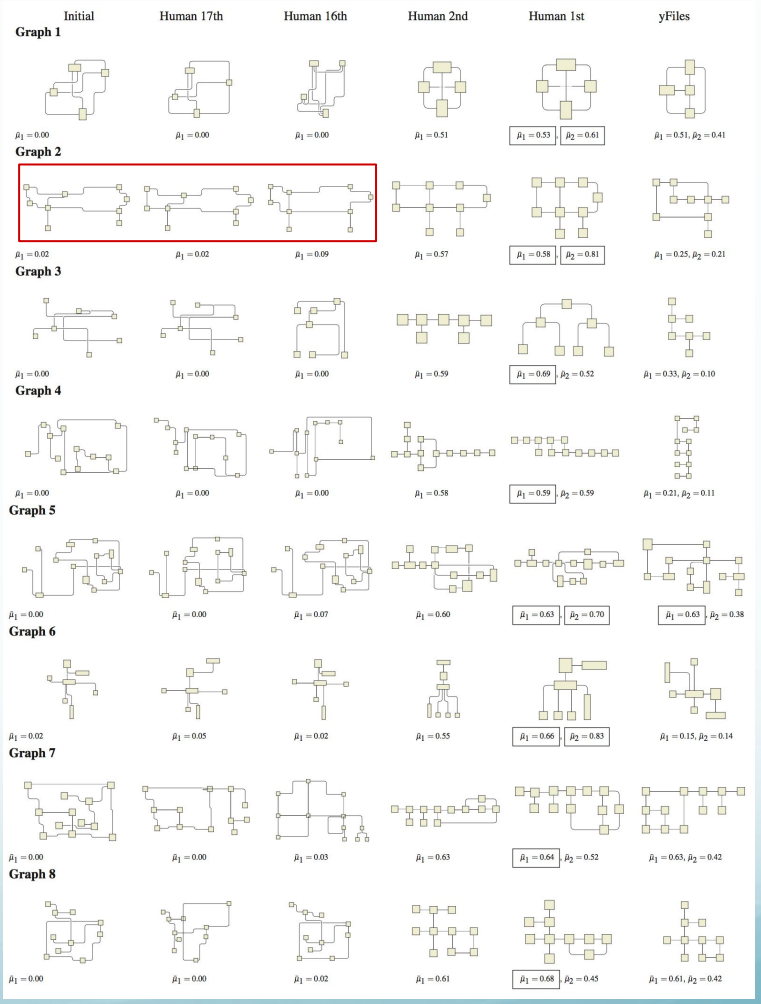
- Users don’t like…
- **R6** edge crossings
- **R7** bend points



User Study - Results

- Users like...
- **R3** compactness
- **R4** “gridiness”
- **R5** symmetry

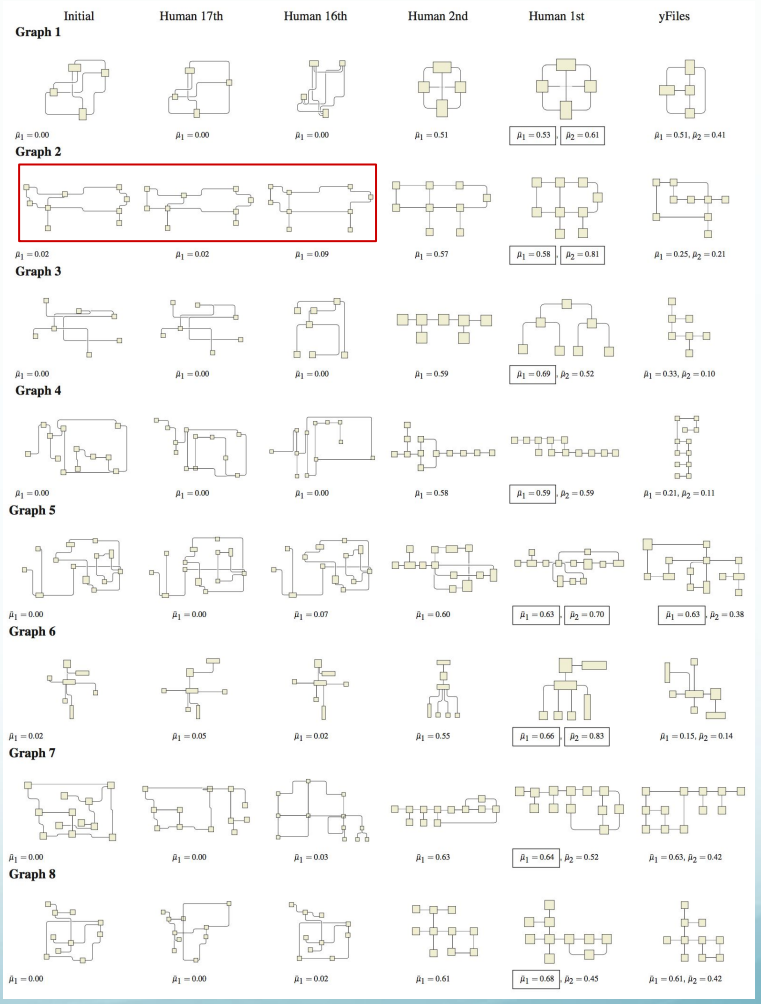
- Users don’t like…
- **R6** edge crossings
- **R7** bend points
- **R8** long edges



User Study - Results

- Users like...
- **R3** compactness
- **R4** “gridiness”
- **R5** symmetry

- Users don’t like…
- **R6** edge crossings
- **R7** bend points
- **R8** long edges
- **R9** “stress”



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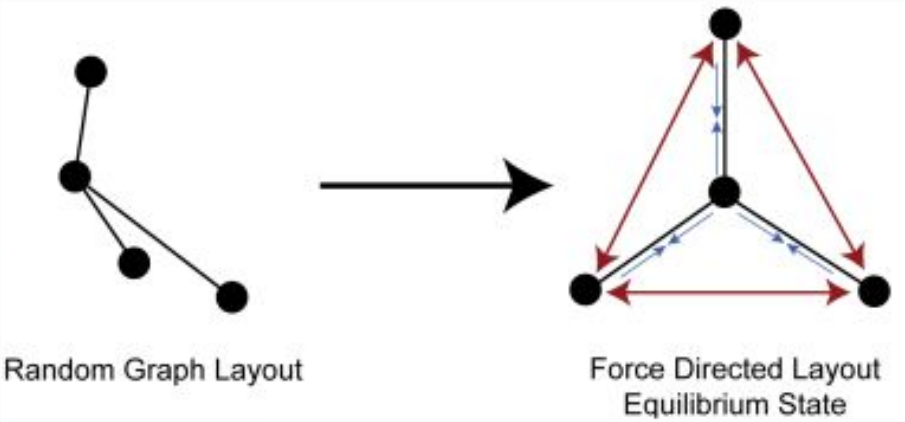
State-of-the-Art

- yFiles uses an approach called Topology-Shape-Metrics
- Strategy:
  1. Minimize edge crossings
  2. Minimize bend points
  3. Maximize compactness
- Does not care about symmetry or edge-length regularity

Alternative

- *Force-directed layout algorithms* minimize stress



http://www.eulerdiagrams.com/tutorial/AutomatedDiagramDrawing.html

- Good balance between minimizing edge crossings, compactness, symmetry, and edge-length regularity

HOLA Design Principles

P1 : Use force-directed approach *first* to untangle network

- Compactness (R3)
- Symmetry (R5)
- Minimize edge crossing (R6)
- Edge length regularity (R8,R9)

P2 : Apply incremental improvements like a human would

- Tune bend points (R2)
- Enforce gridiness (R4)

P3 : Treat acyclic subcomponents (trees) independently

- Enforce placement of trees outside of cycles (R1)
- Encourages symmetry of subcomponents (R5)

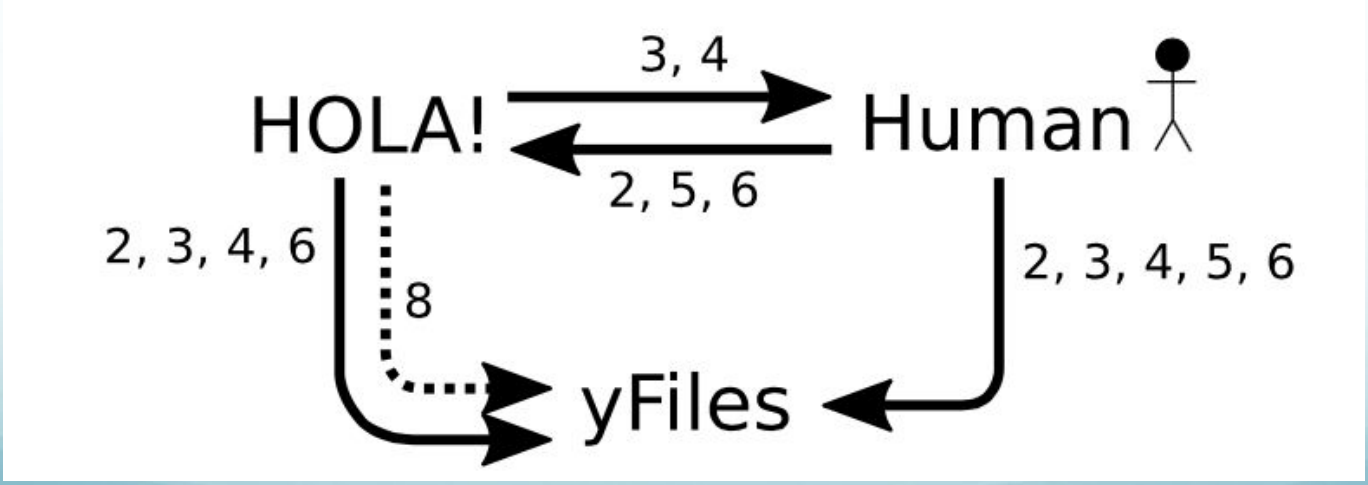
HOLA Steps

1. Decompose layout into “core” and subtrees
2. Layout the core
3. Layout and place the subtrees
4. Fine tune

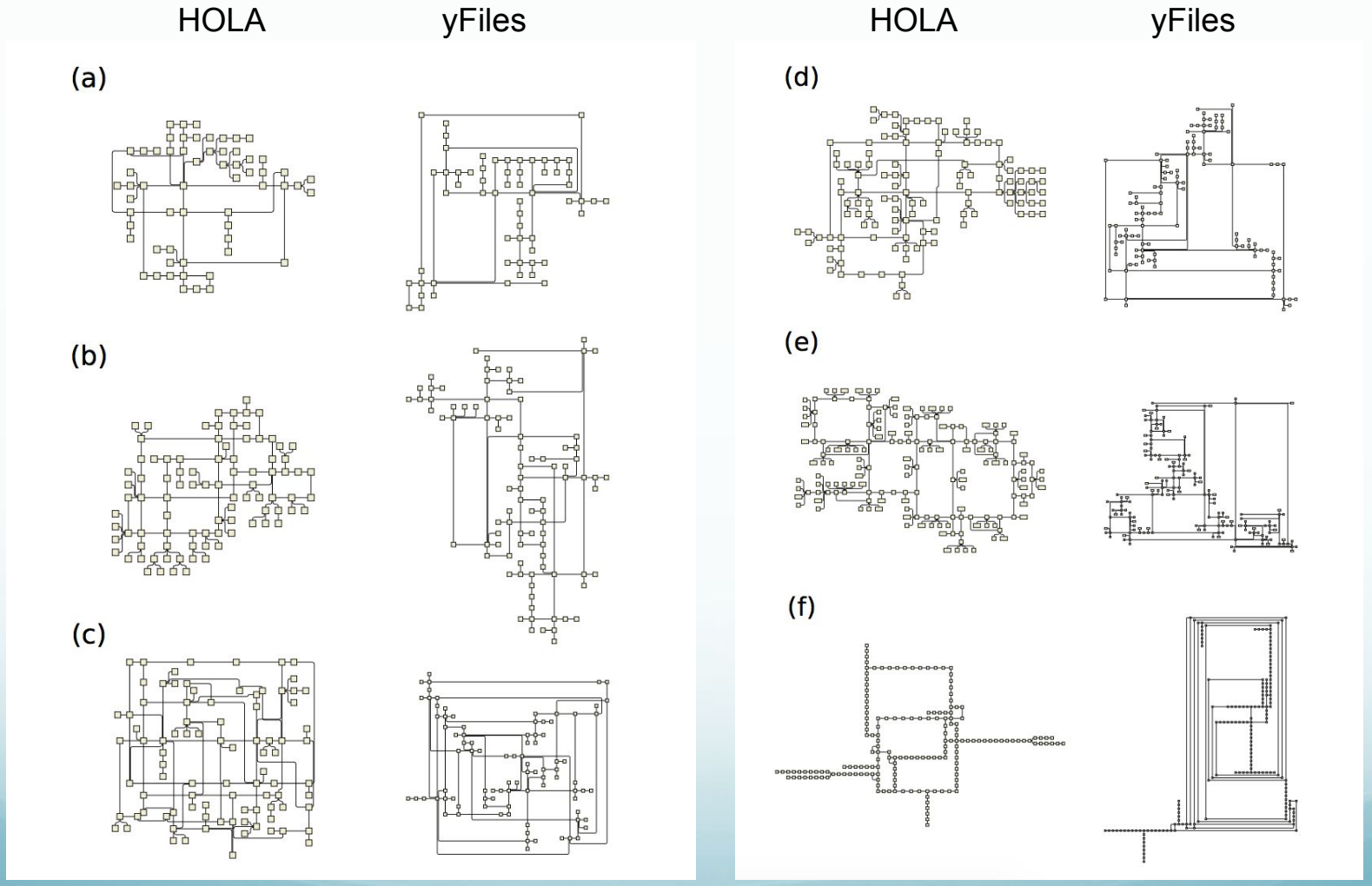
Evaluation of Algorithm - Small Networks

- Participants ranked the following for each of the eight networks from the original user study:
  - HOLA output
  - yFiles output
  - The best human-made network from the user study

- Result:



Evaluation of Algorithm - Large Networks



Evaluation of Algorithm - Large Networks

- ***Preference-based evaluation:***
  - Users preferred HOLA result for all pairs except (c), for which there was no significant difference

- ***Performance-based evaluation:*** participants were asked to complete two tasks:
  1. Find the path between two nodes
  2. Find the neighbors of a node

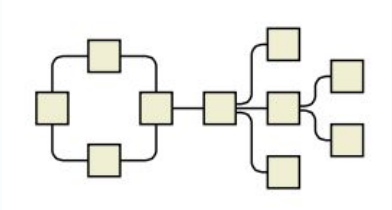
	Mean Error HOLA	Mean Error yFiles	Mean Speed HOLA	Mean Speed yFiles
Shortest Path	0.162	0.548	12.27s	29.15s
Neighbours	0.159	0.349	10.10s	12.98s

Synthesis

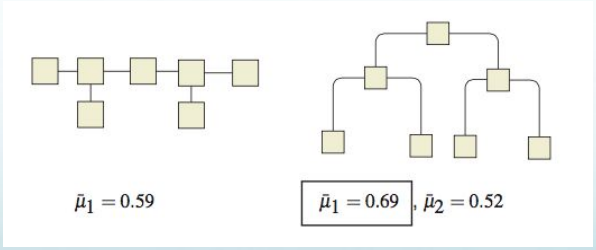
- What it a success? All in all, Yes!
- They made a couple new discoveries about what people like in network layouts and validated old discoveries
- They developed an automatic orthogonal layout algorithm that is competitive with human-made layouts
  - More nuanced that TSM or force-directed approaches alone
  - Nicely balances characteristics people value in networks
- They established a framework for others to follow
- They did an excellent job relating the various sections to each other (e.g. the Rs and Ps)

Criticisms

- User Study:
  - "Select the layout others would like" → stick to conventions?
  - Pretty elbow links not possible in editing tool… could give HOLA an unfair advantage



  - Fail to discuss another potential value: *convey hierarchy*



Criticisms

- Algorithm:
  - No empirical support provided for relationships between design principles (the Ps) and aesthetic values (the Rs)
- Evaluation:
  - No comparison of outputs by metric (compactness, etc.)
  - Would be nice to see metrics for outputs at each stage of the algorithm - can we change the order of tasks and get better results?
  - No pairwise comparisons of task performance on large networks
- What about networks with non-uniform distance between nodes?

Reference

S. Kieffer, T. Dwyer, K. Marriot, and M. Wybrow. HOLA: Human-like Orthogonal Network Layout. *IEEE Transactions on Visualization and Computer Graphics*, 22(1):349-58, 2015.