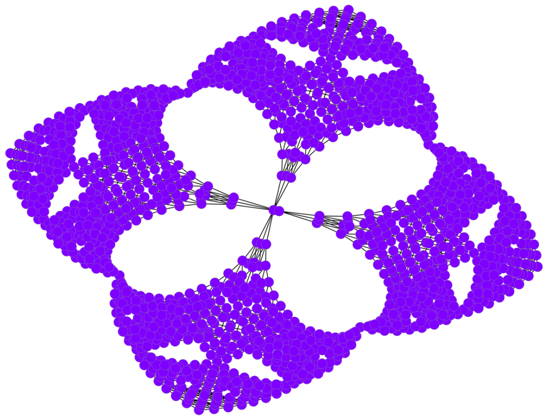
Simon van Wageningen, Tamara Mchedlidze & Alexandru C. Telea

Same Quality Metrics, Different Graph Drawings

Utrecht University

33rd International Symposium on Graph Drawing and Network Visualization, GD 2025 Norrköping

- Graph drawings come in all shapes and sizes
- Different drawing algorithms → visually distinct drawings



Stress Majorization

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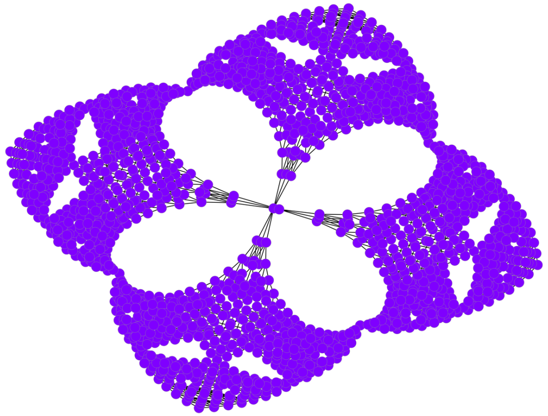
- Different drawing algorithms → visually distinct drawings



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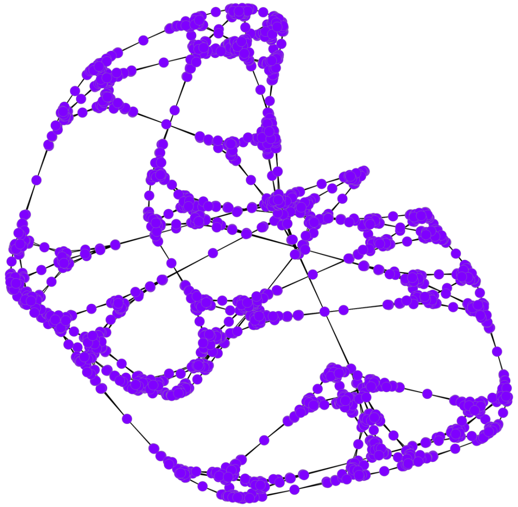
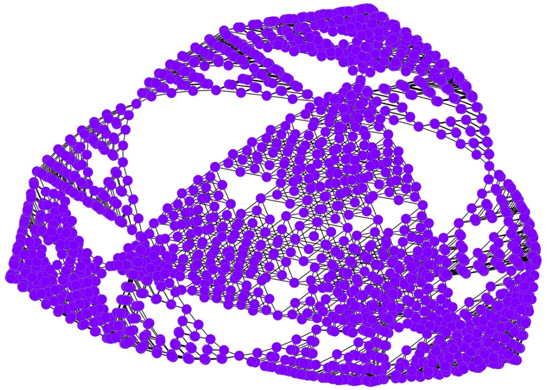
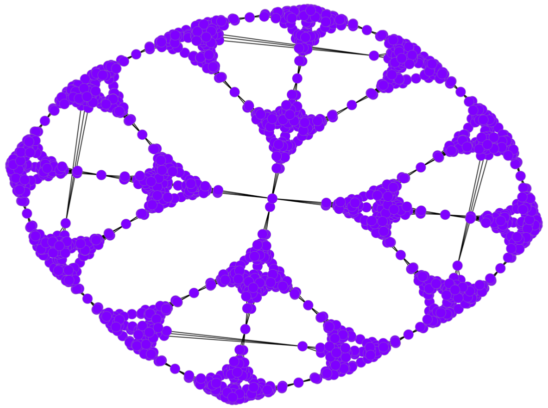


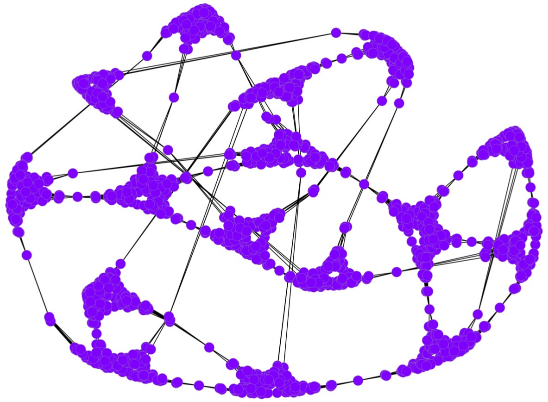
ForceAtlas2



PivotMDS



tsNET



tsNET*

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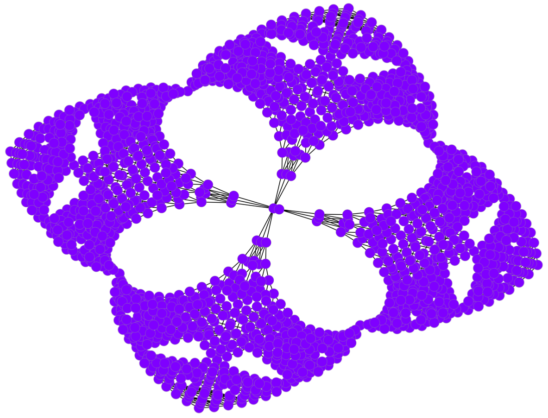
How to **compare**?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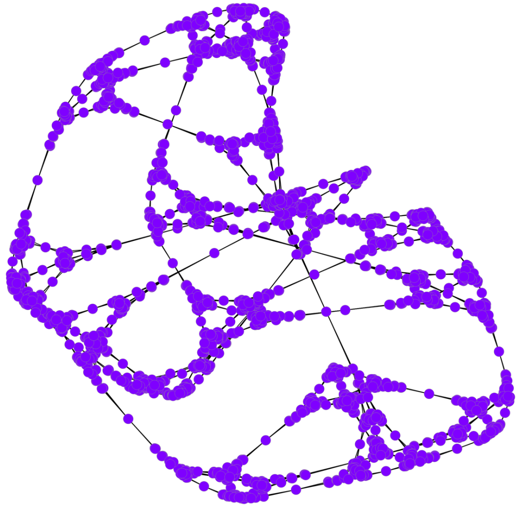
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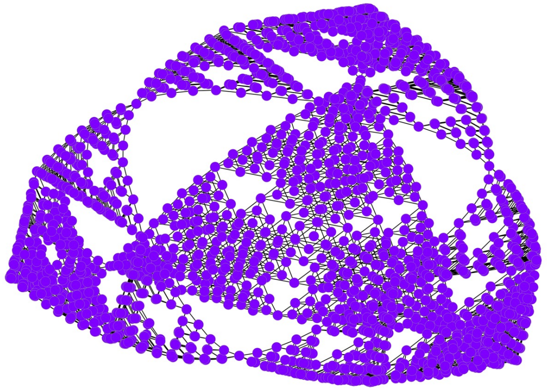
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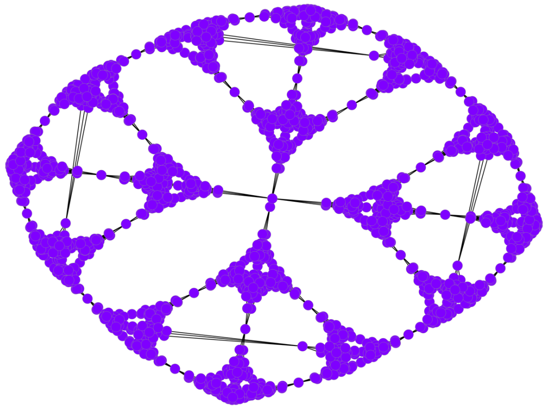
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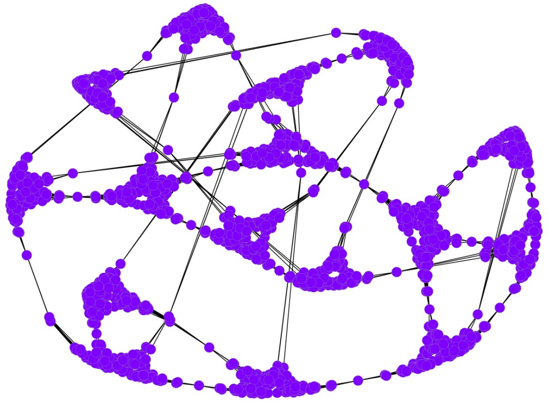
tsNET*

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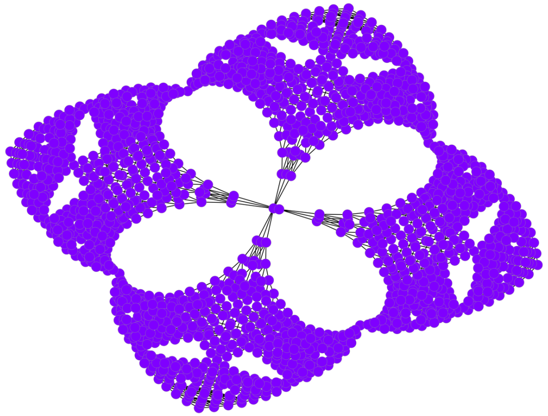
How to **compare**?

Quality metrics[1]! E.g.

- edge length uniformity
- Number of edge crossings
- Stress
- Angles of adjacent edges or crossing edges



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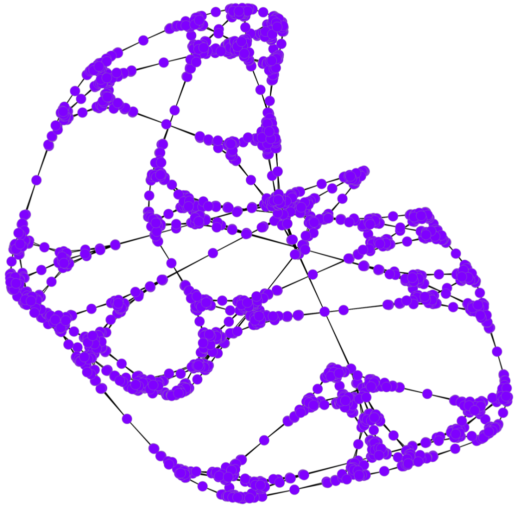

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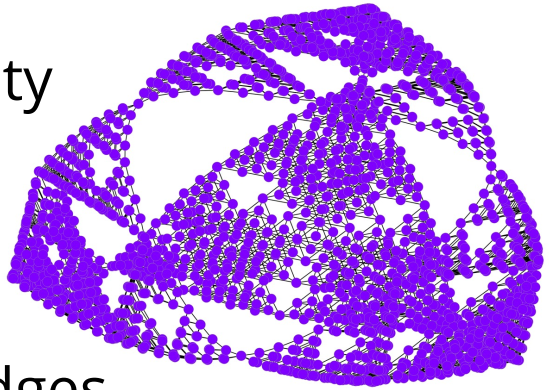

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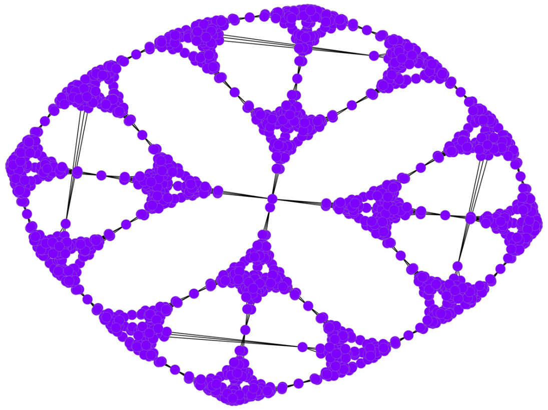

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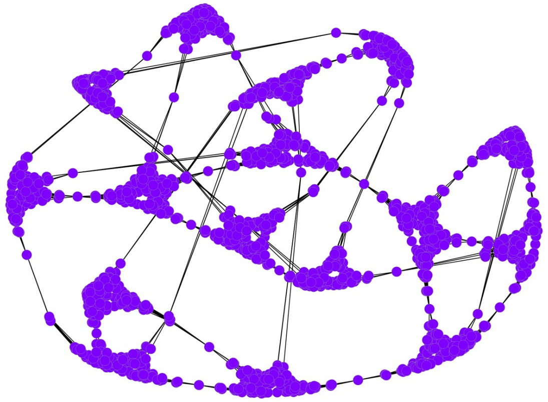
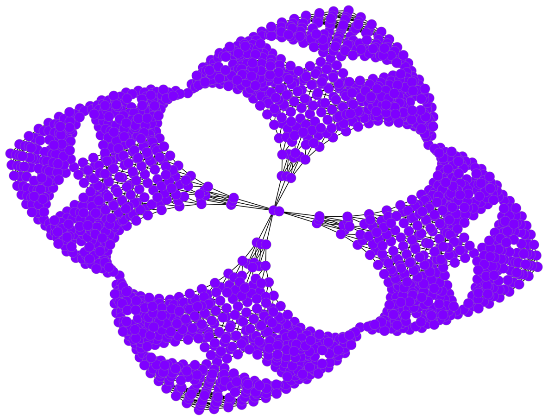


tsNET*

Easy **assumptions** to make:

1. 'Good' quality metric **value(s) → 'good'** drawing

2. **Similar** quality metric **value(s) → similar** visual quality



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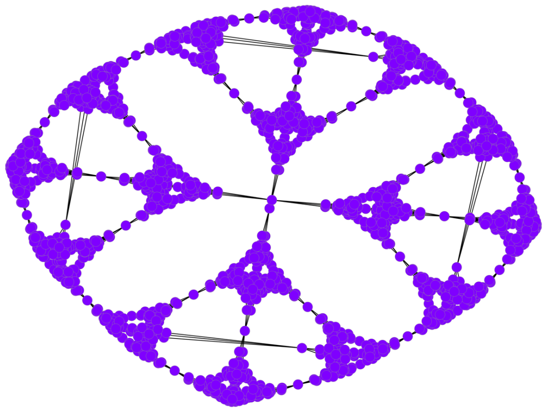

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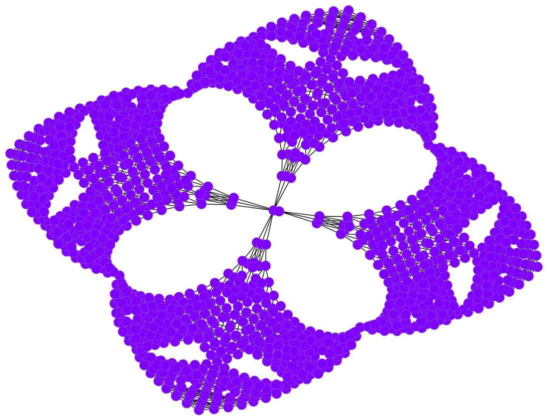
We know these assumptions are **wrong**!

E.g. graph drawing live challenge[2]:

2020, minimize number of crossings in a directed upward straight-line drawing



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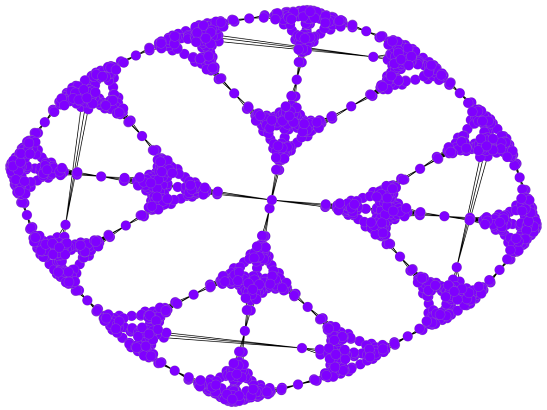

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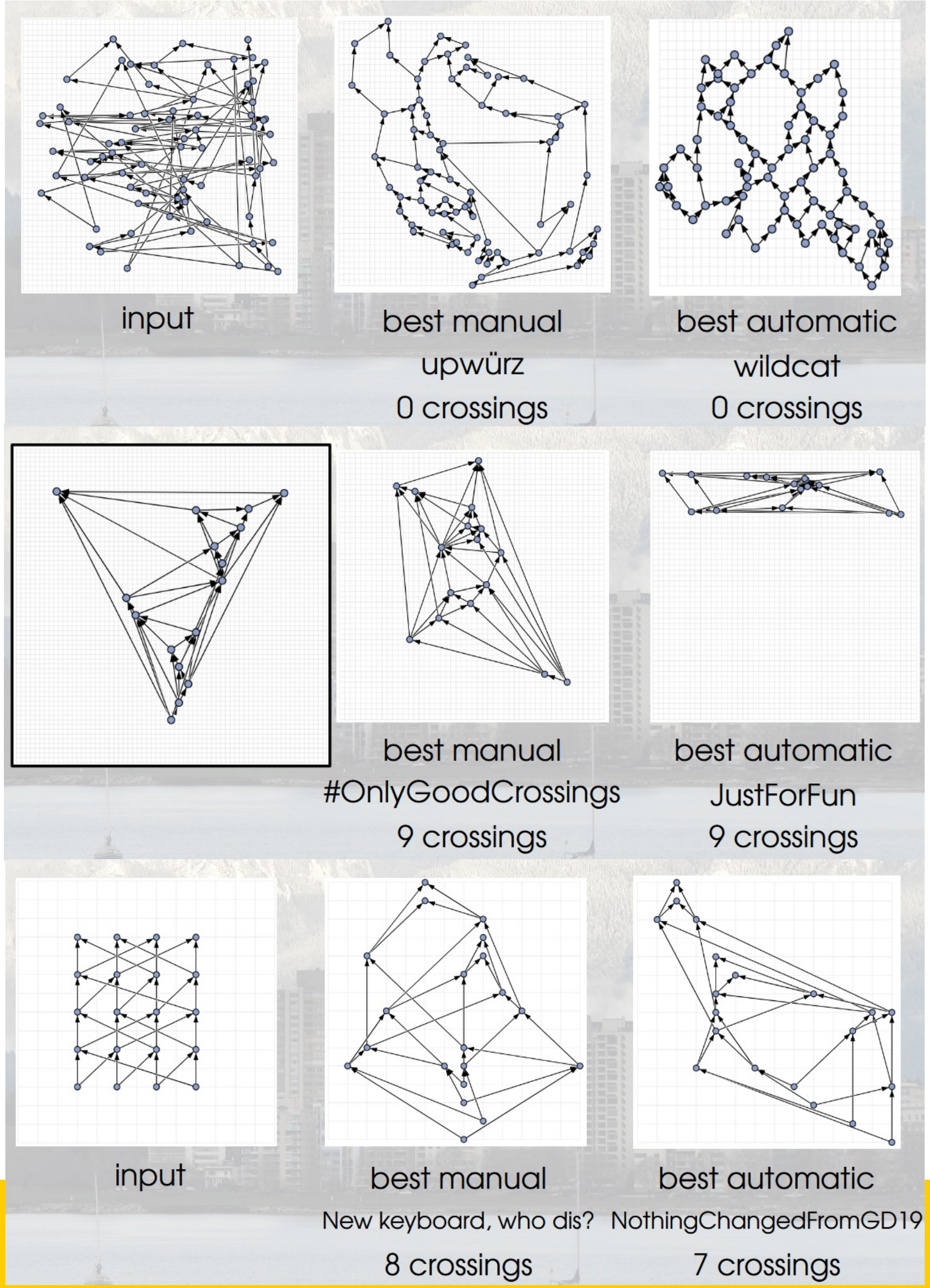

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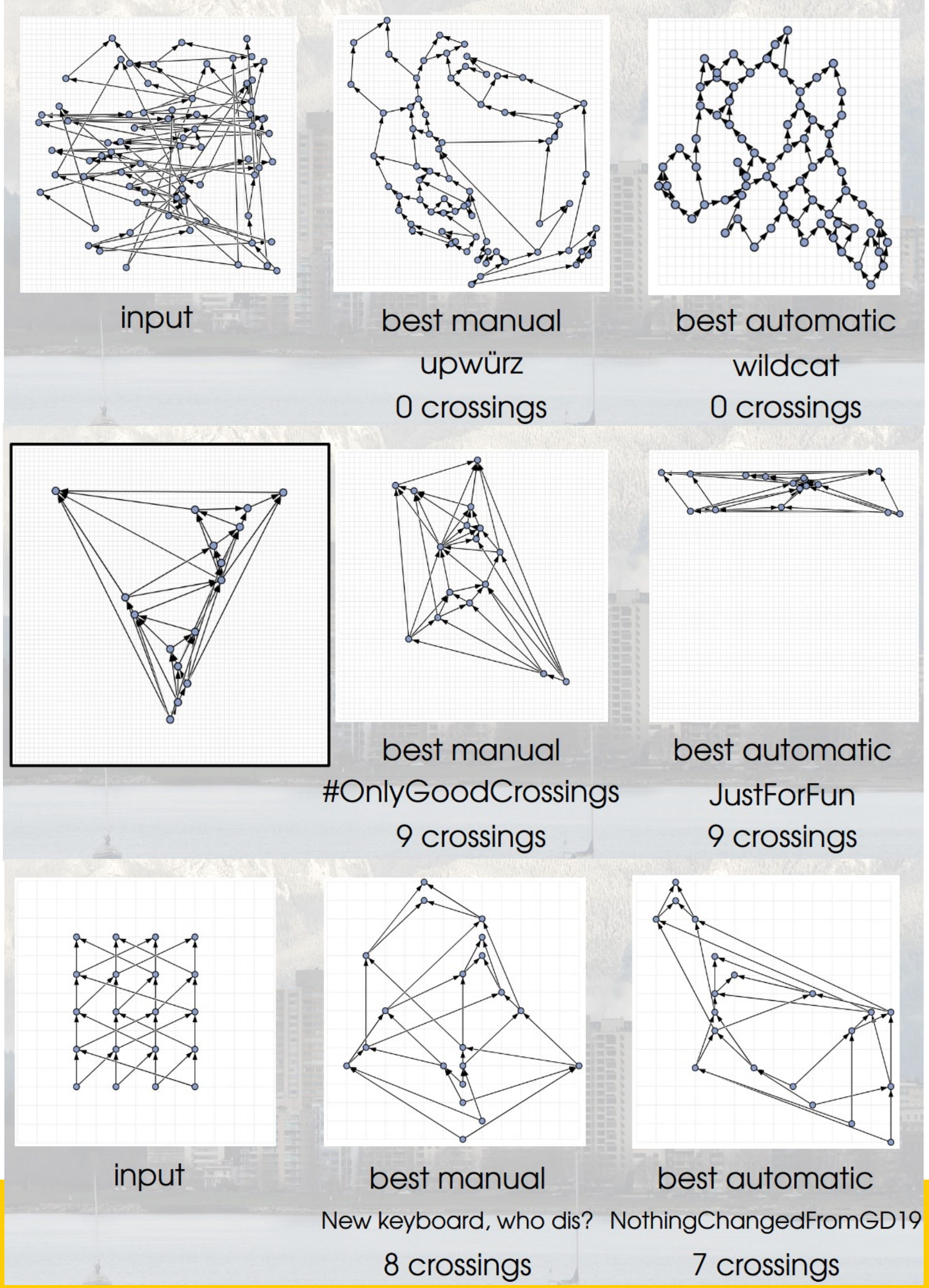
RQ: Can we **systematically morph** a given drawing **into** a **target** shape while **keeping** one or more **quality metric(s)** the **same**?



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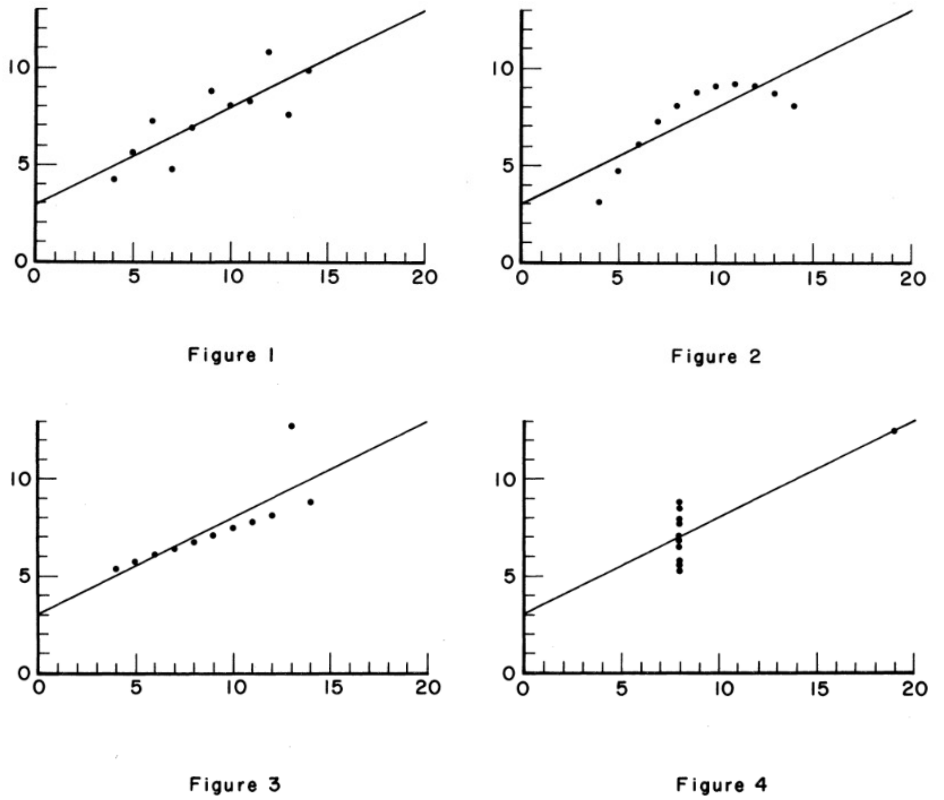

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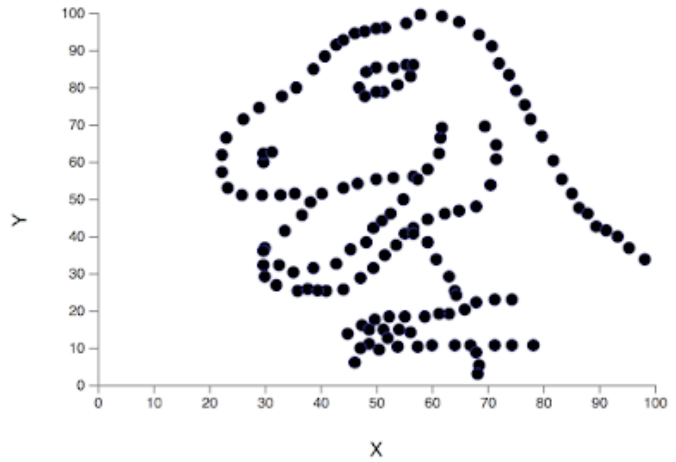
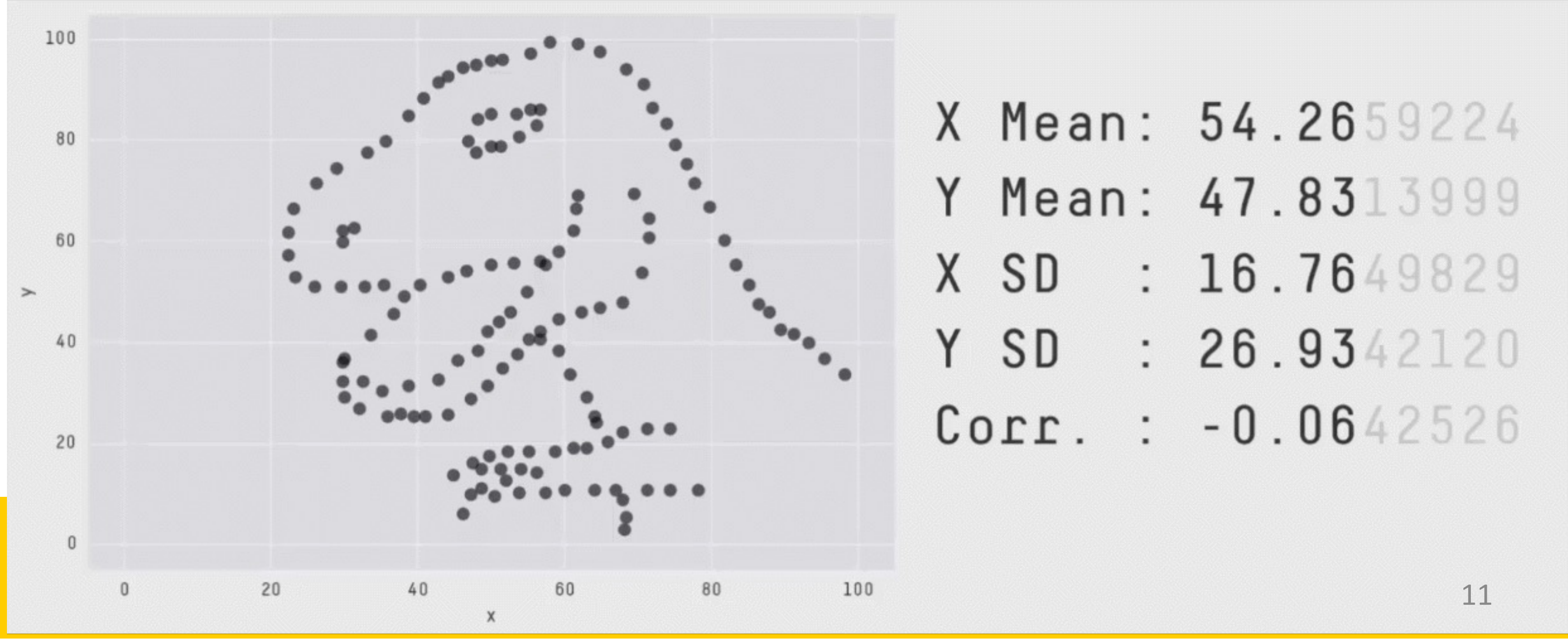
- **Same Stats, Different Graphs**: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing [5]
  - (Not to be confused with '**Same Stats, Different Graphs**: Exploring the Space of Graphs in Terms of Graph Properties' [6])





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- Dimensionality Reduction [7, 8, 9]
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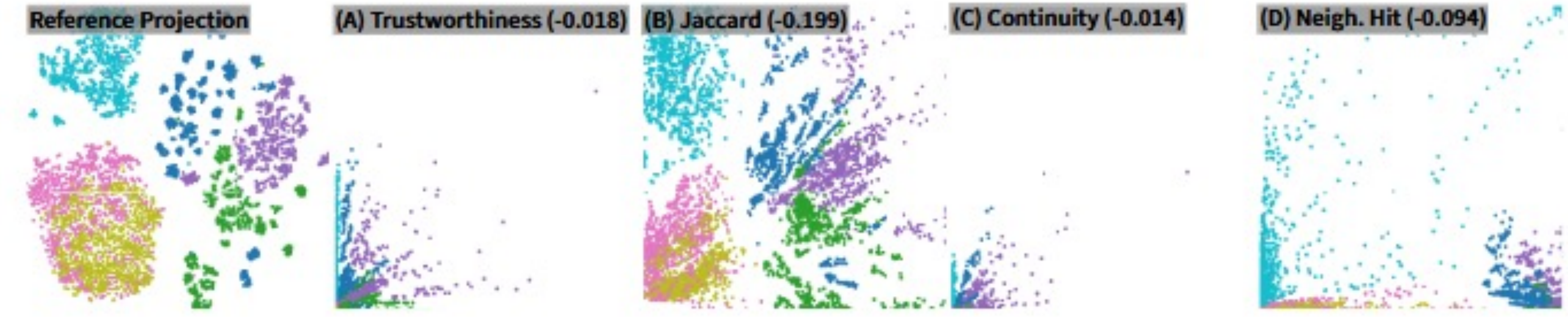

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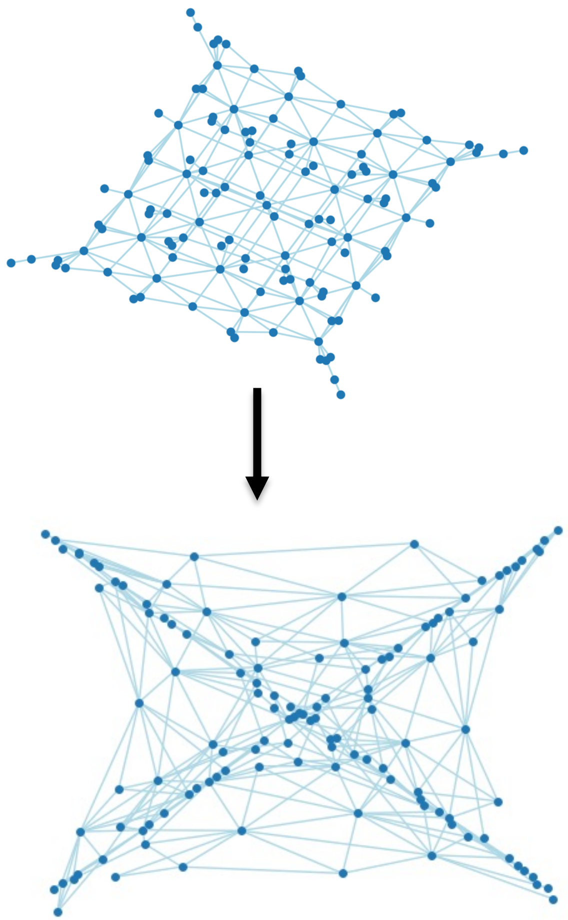
Use similar approach as [5]:

Same **Stats**, Different Graphs → Same **Quality Metrics**, Different Graph **Drawings**

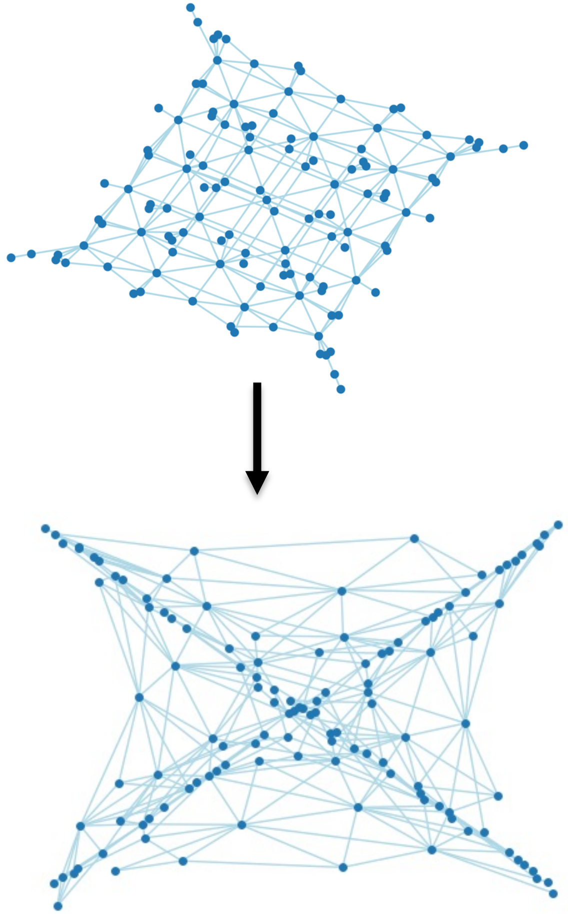
Goal: Morph drawing into a target shape while keeping metric(s) the same



Goal: Morph drawing into a target shape while keeping metric(s) the same

Input:

graph **G**, initial graph drawing of **G** with coordinates **X**, a target shape **Y**, quality metric(s) **Q**, and initial quality metric value(s) **q**



Alg. Simulated Annealing Morphing

1. Repeat: Create **X’** by jittering **X**
   - **Stop if X’ is <u>more similar</u> to Y than X**
   - **Stop with a random probability**

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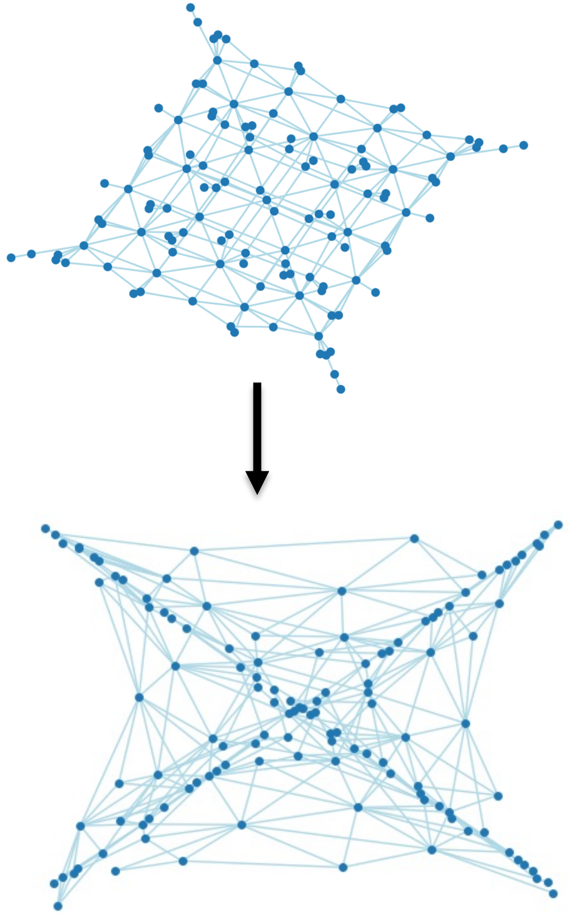
Alg. Simulated Annealing Morphing

1. Repeat: Create **X'** by jittering **X**
    - **Stop if X' is <u>more similar</u> to Y than X**
    - **Stop with a random probability**
2. If |**Q(G, X') – q**| <= 0.0025, accept jittered coordinates **X = X'**,

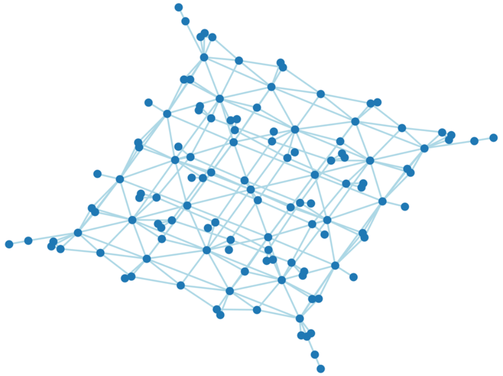
Repeat step 1-2 to acquire target shape **Y**

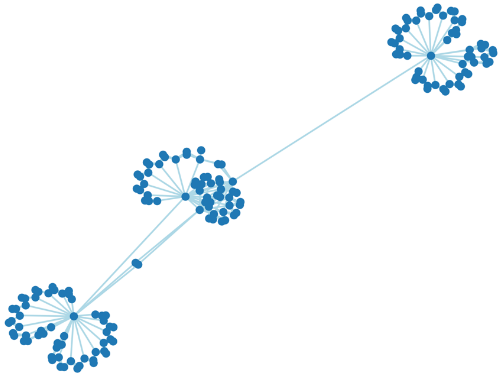


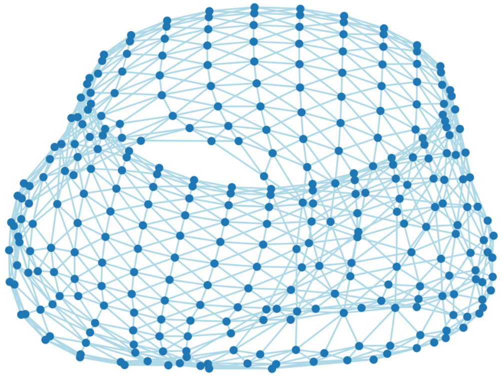
Goal: Morph drawing into a target shape while keeping metric(s) the same

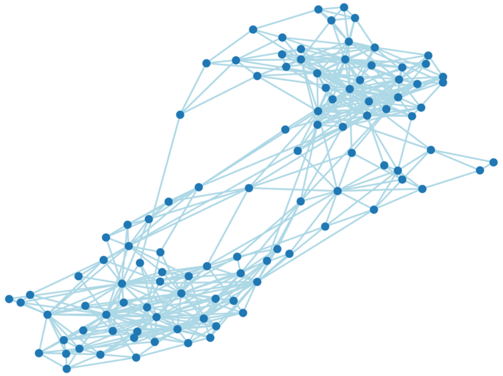
Data:

- 5 different Graphs



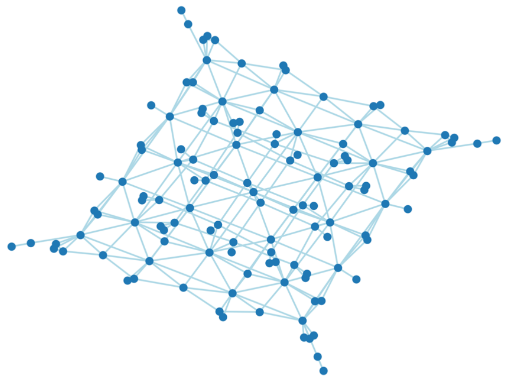


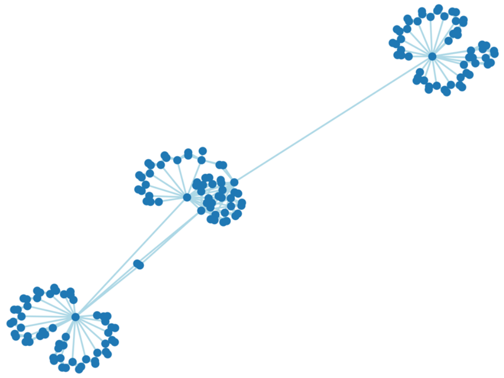


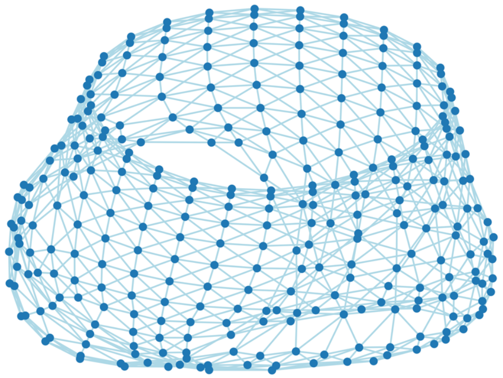


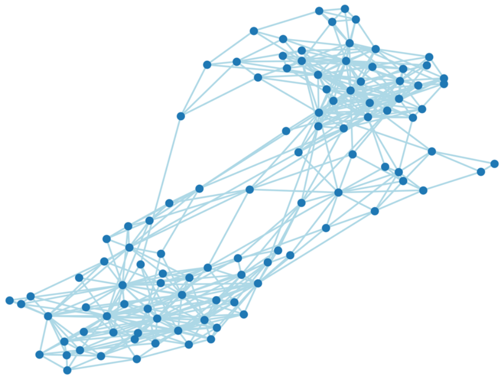
Goal: Morph drawing into a target shape while keeping metric(s) the same

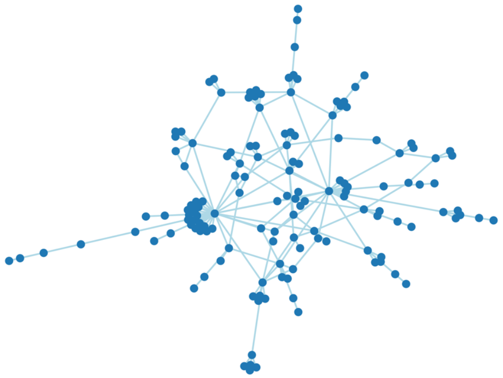
Data:
- 5 different Graphs
- 4 Quality metrics
  - Stress (ST)
  - Edge Length Deviation (ELD)
  - Crossings (CN)
  - Angular Resolution (AR)











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Data:

- 5 different Graphs
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  - Stress (ST)
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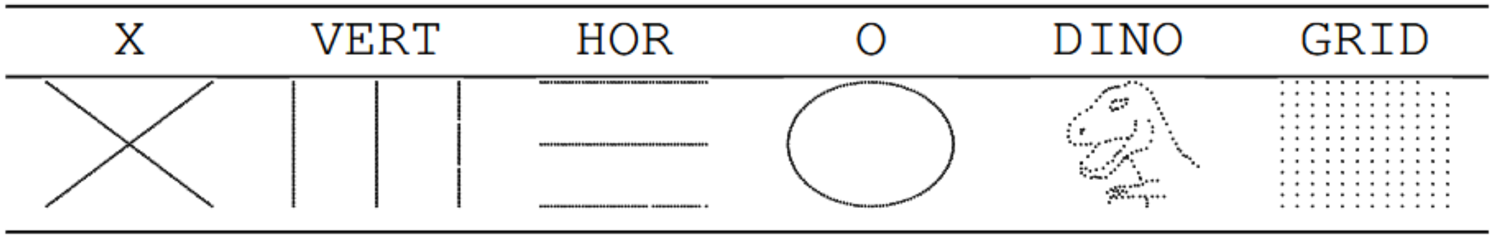
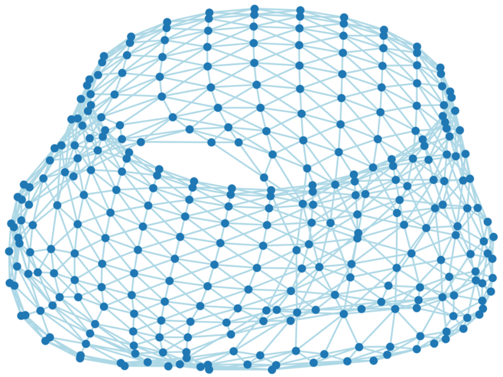
- 6 different target shapes for any number of nodes





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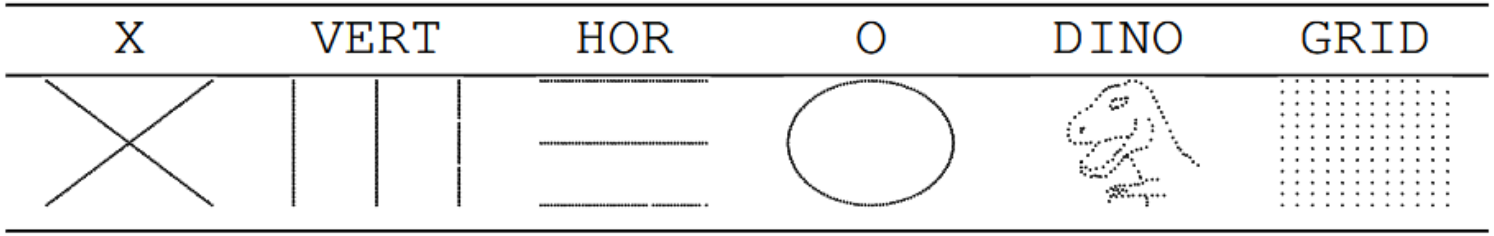
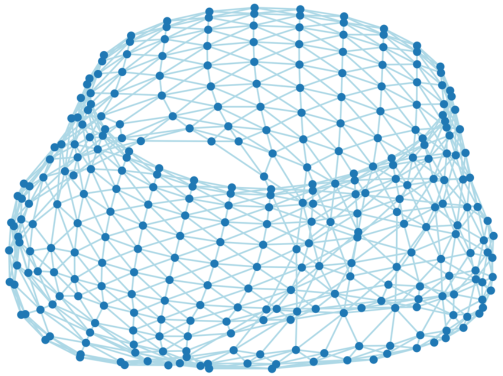
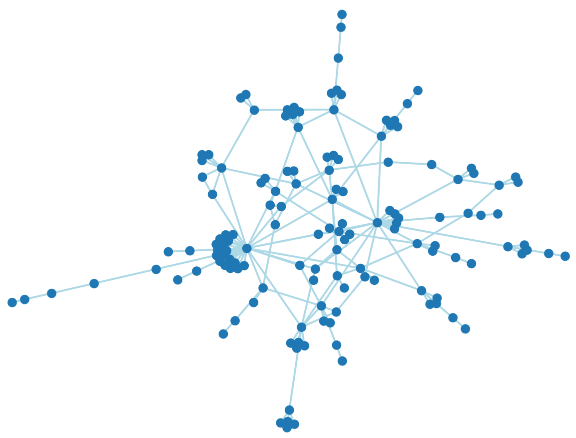


- Run the algorithm for **30,000** iterations with a **metric tolerance** of **0.0025** for ST, ELD, AR and 5% for CN



Original drawing with CN: 150



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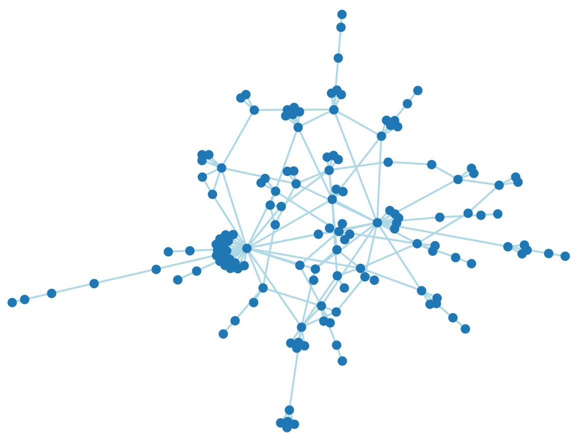
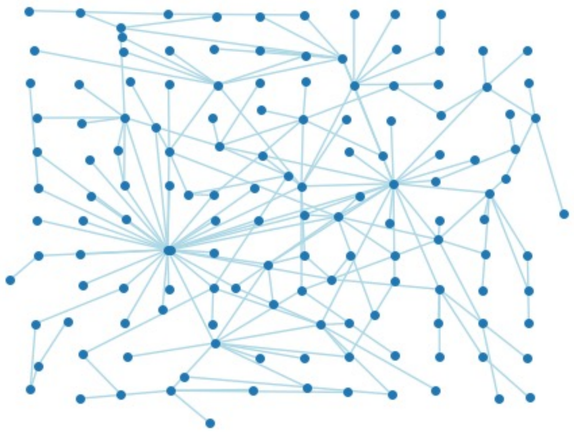
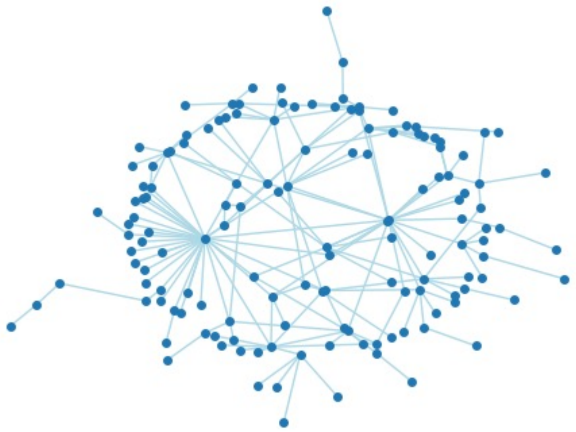


Original CN
current CN



Original -CN
current -CN

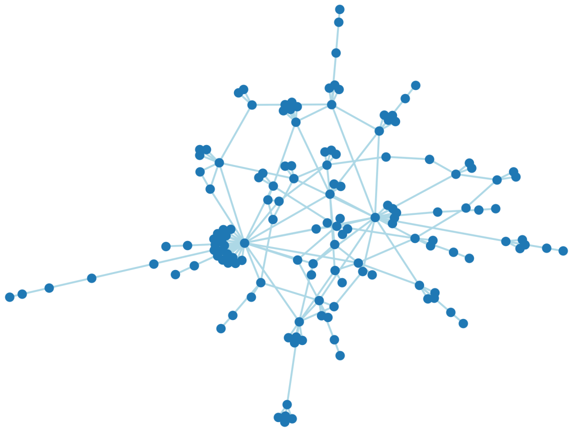


Original CN
current CN

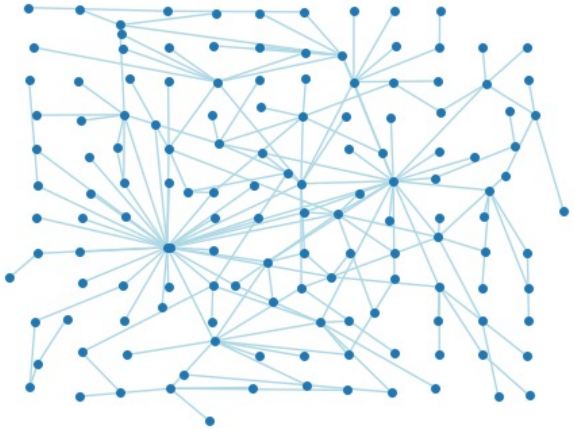
Number of **crossings** the **same** in **all** 4 **drawings**?

?

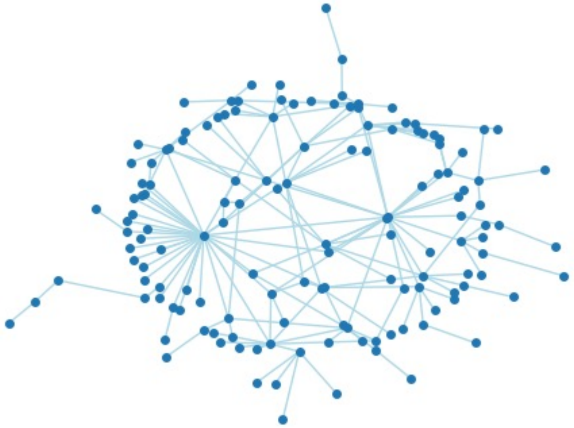
Original drawing with CN: 150



Original ·CN . 150.
current CN 156.



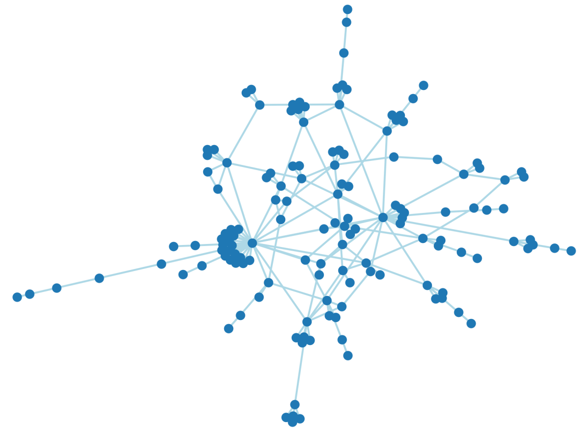
Original :-CN 150.
current -CN 156.



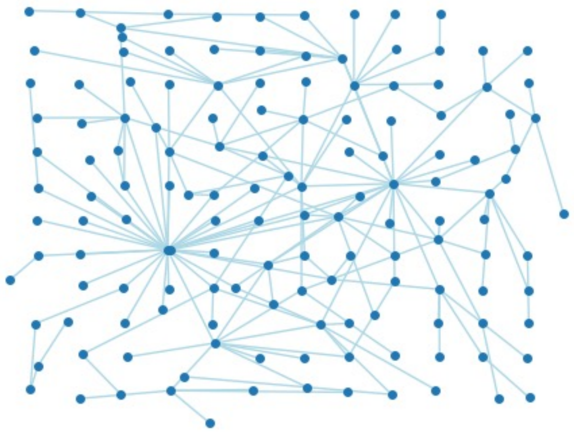
Original ·CN 150.
current ·CN 156.

Number of **crossings** remains **similar**

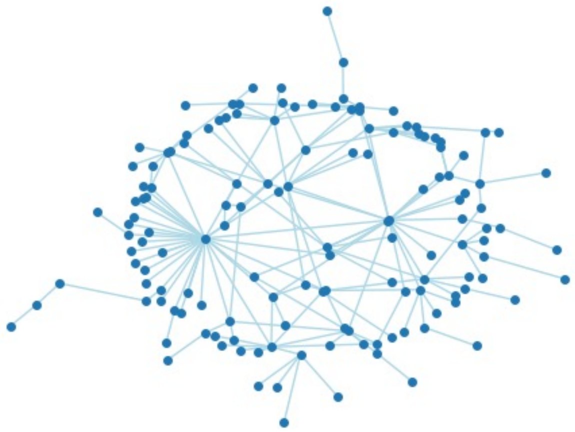
Original drawing with CN: 150



Original ·CN . 150.
current CN 156.



Original ·CN . 150.
current CN· 156.



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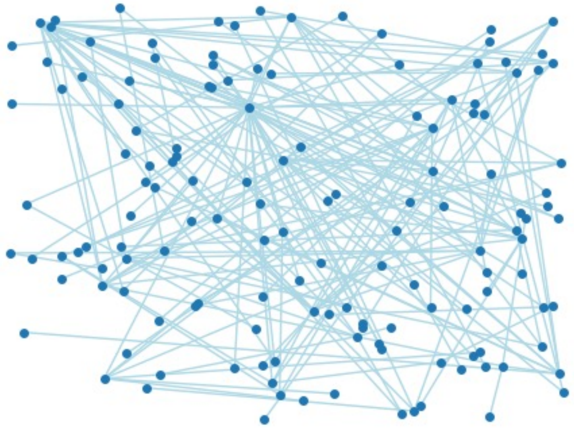
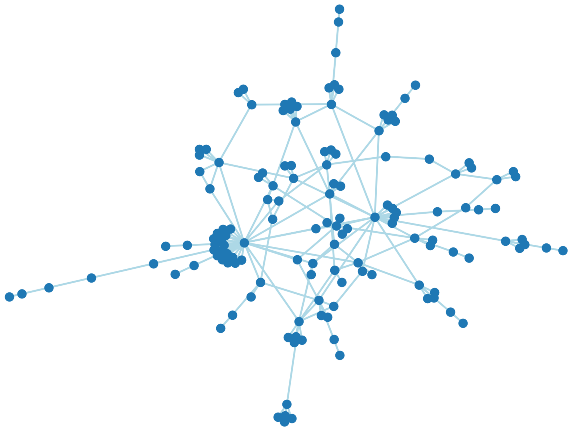
Original CN·
current ·CN



Number of **crossings similar** to all other **drawings**?

?

Original drawing with CN: 150



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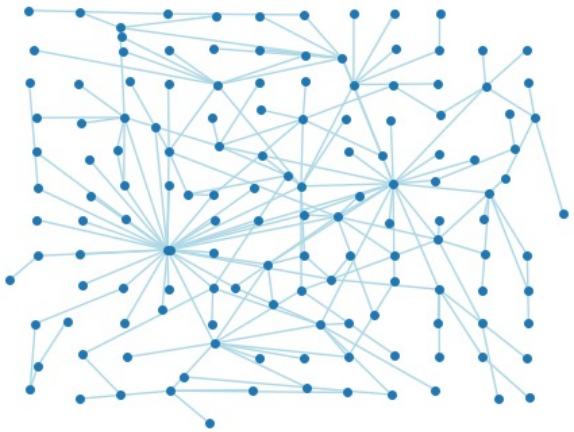

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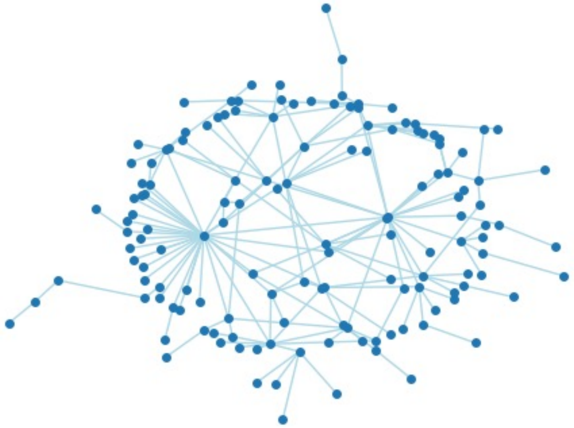
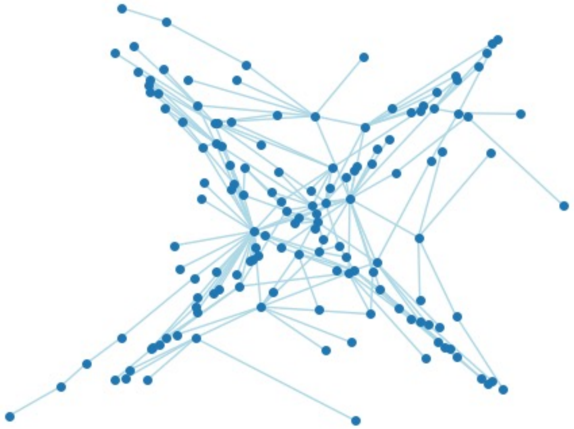
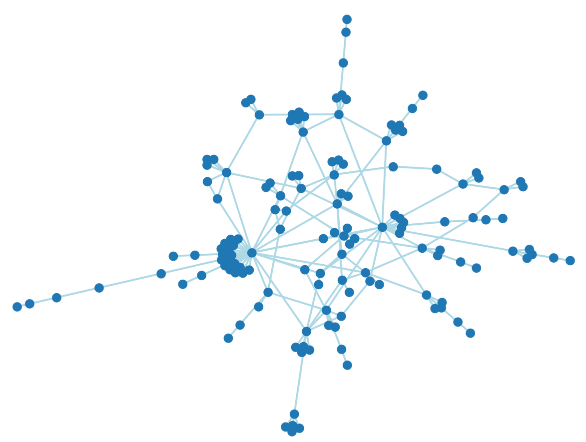
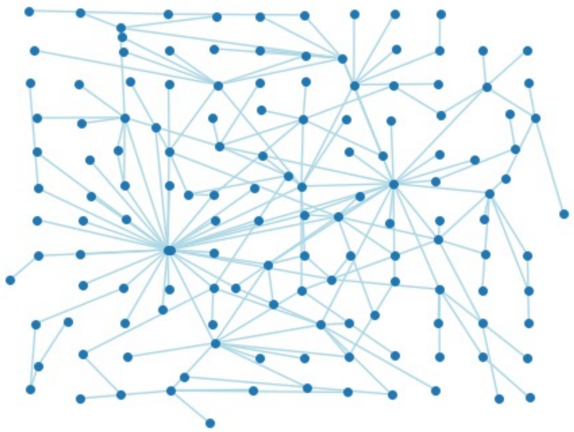


Original ·CN 150.
current ·CN 156.

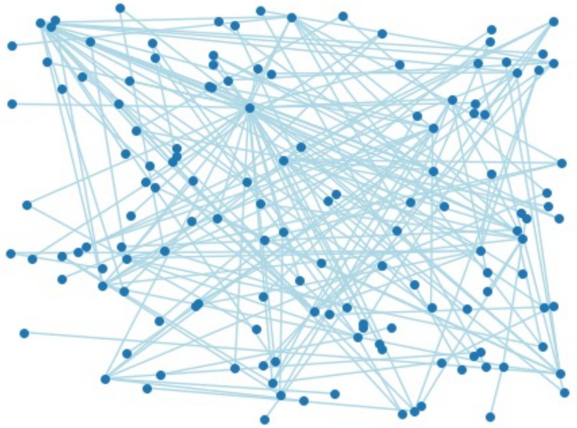


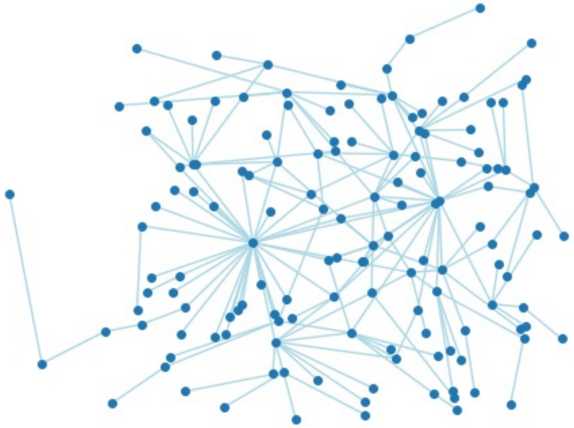
Original CN· 150.
current ·CN 6740.



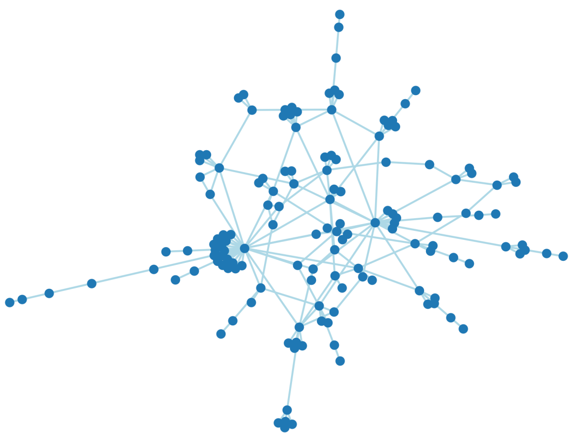


Even for **randomly** distributed points as target shape: number of **crossings** remains **similar**

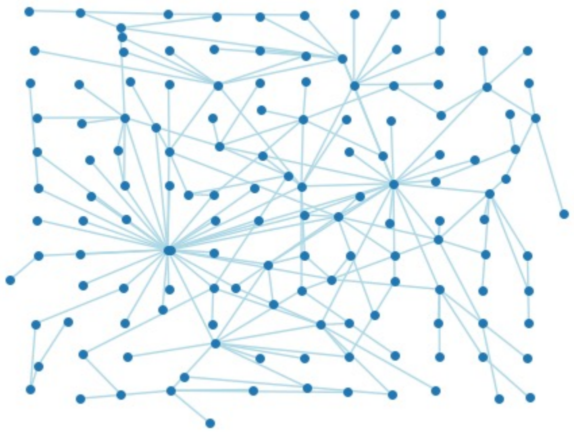




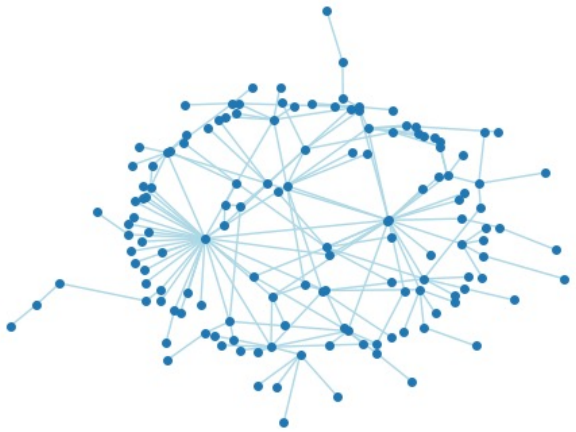
Original drawing with ST: 0.1338 | ELD: 0.0513 | CN: 150 | AR: 0.4791



Original ST-AR-CN-ELD: [0.1338 0.4791 150. 0.0513]
current ST-AR-CN-ELD: [0.1362 0.4815 156. 0.0527]
Similarity: 0.4224



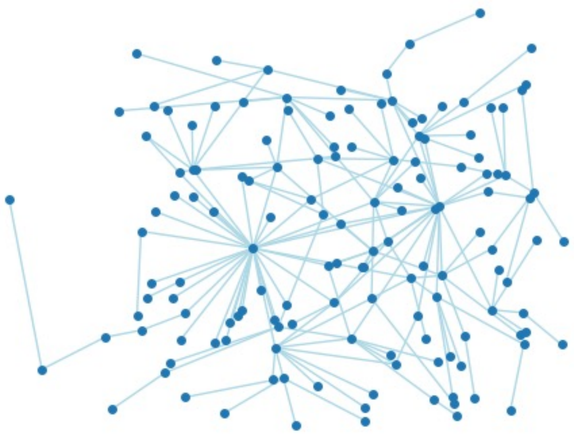
Original ST-AR-CN-ELD: [0.1338 0.4791 150. 0.0513]
current ST-AR-CN-ELD: [0.1362 0.4792 156. 0.0524]
Similarity: 2.176



Original ST-AR-CN-ELD: [0.1338 0.4791 150. 0.0513]
current ST-AR-CN-ELD: [0.1363 0.4816 156. 0.052]
Similarity: 1.725

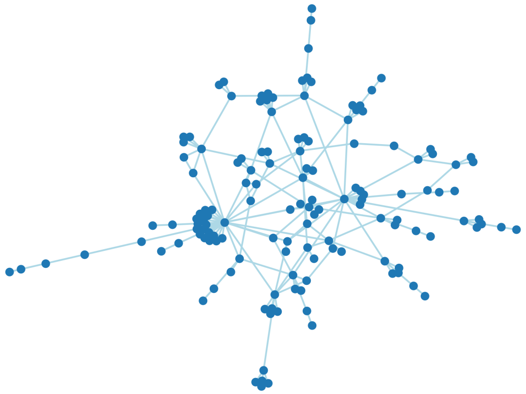
All **metrics stay** nearly the **same** (+- 0.0025 and 5% for CN)

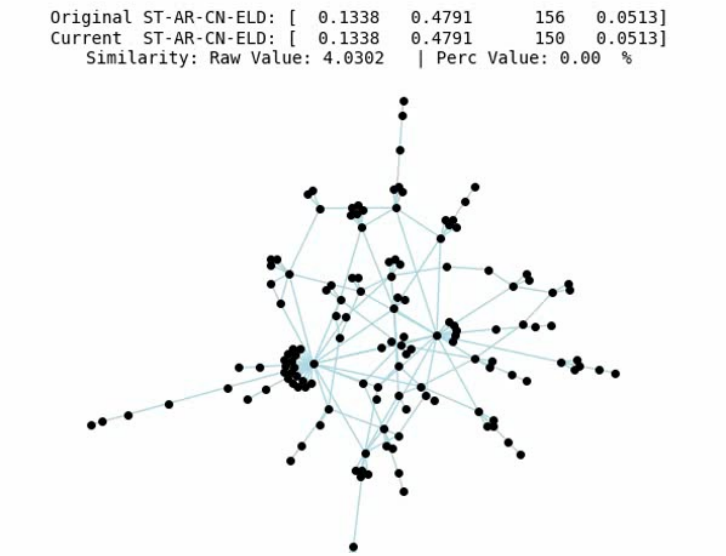
Original ST-AR-CN-ELD: [0.1338 0.4791 150. 0.0513]
current ST-AR-CN-ELD: [0.1362 0.4813 156. 0.0538]
Similarity: 0.8765

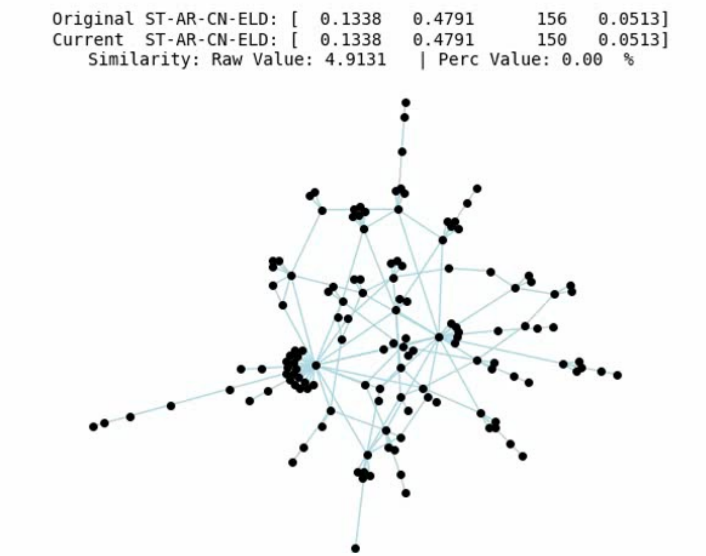


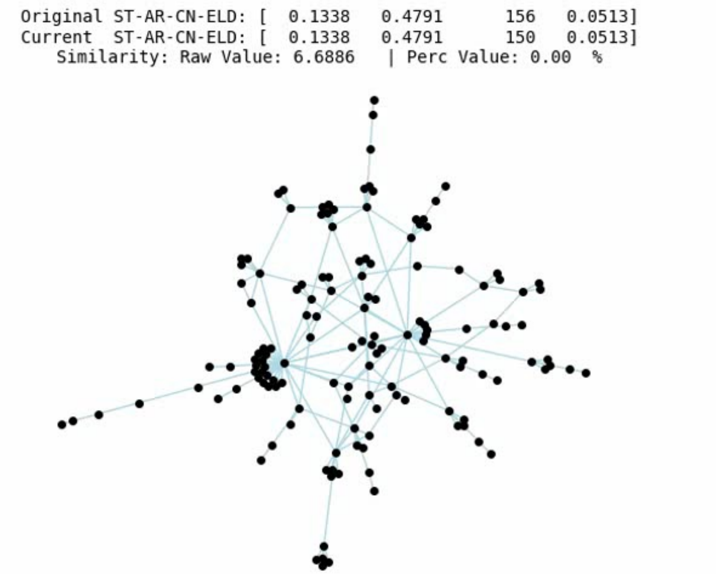
All **metrics stay** nearly the **same** (+- 0.0025 and 5% for CN)

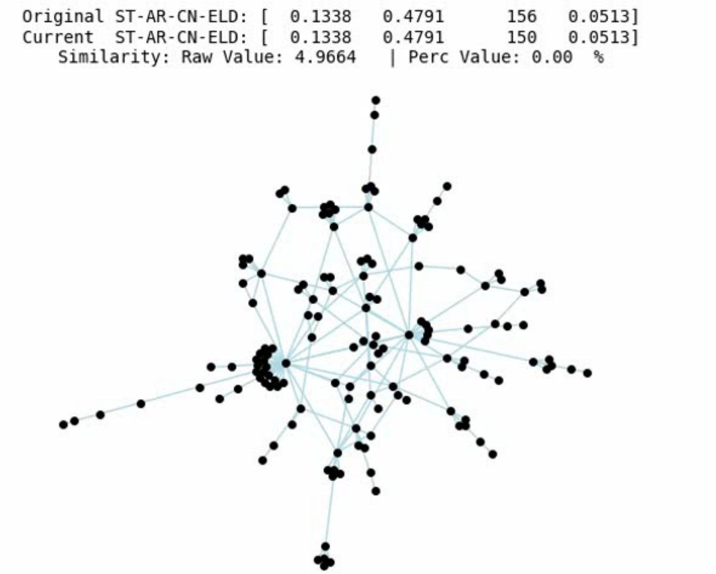
Original drawing with ST: 0.1338 | ELD: 0.0513 | CN: 150 | AR: 0.4791

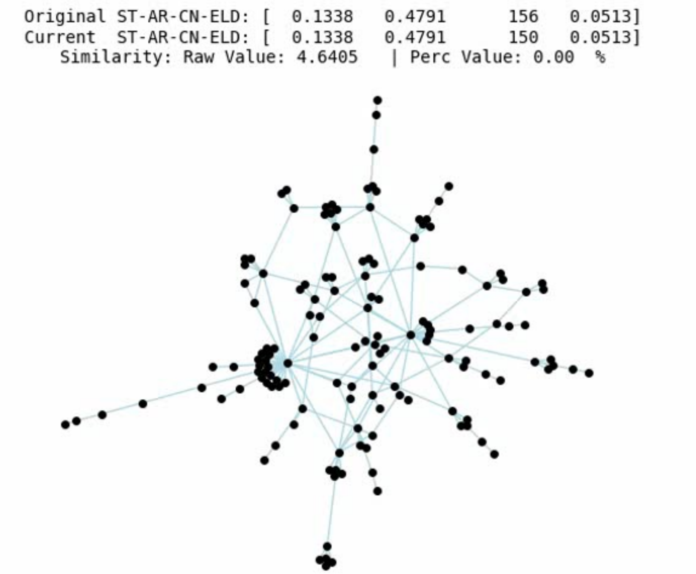




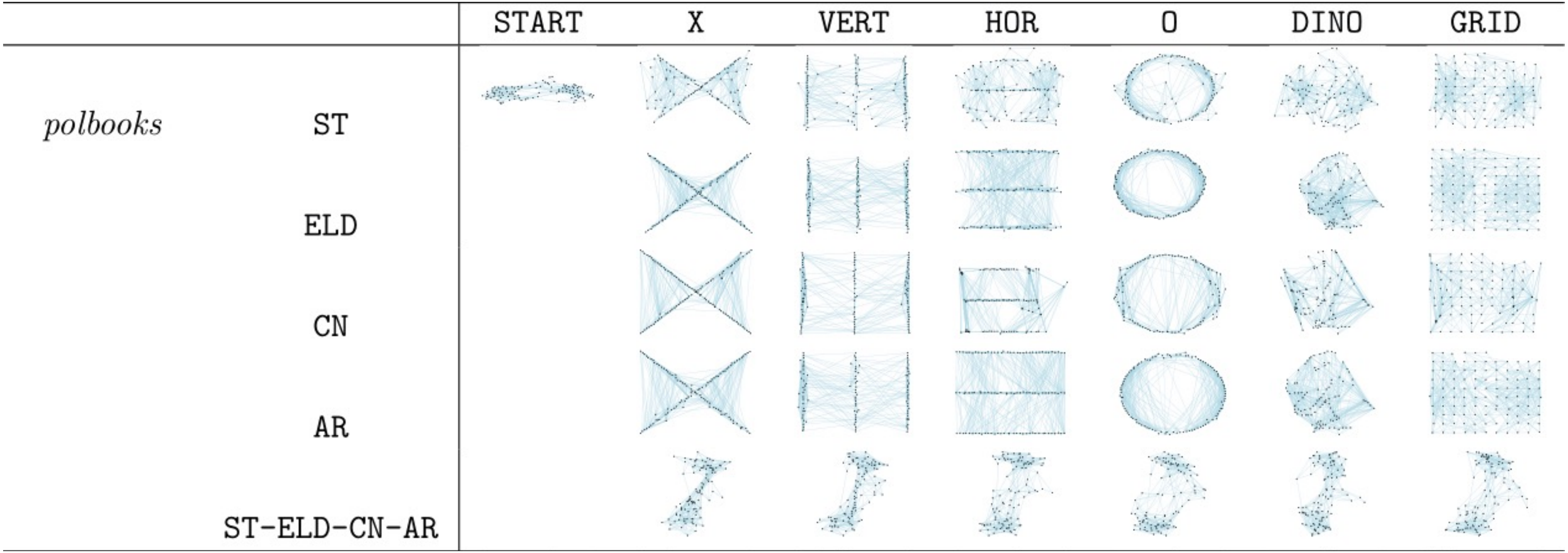




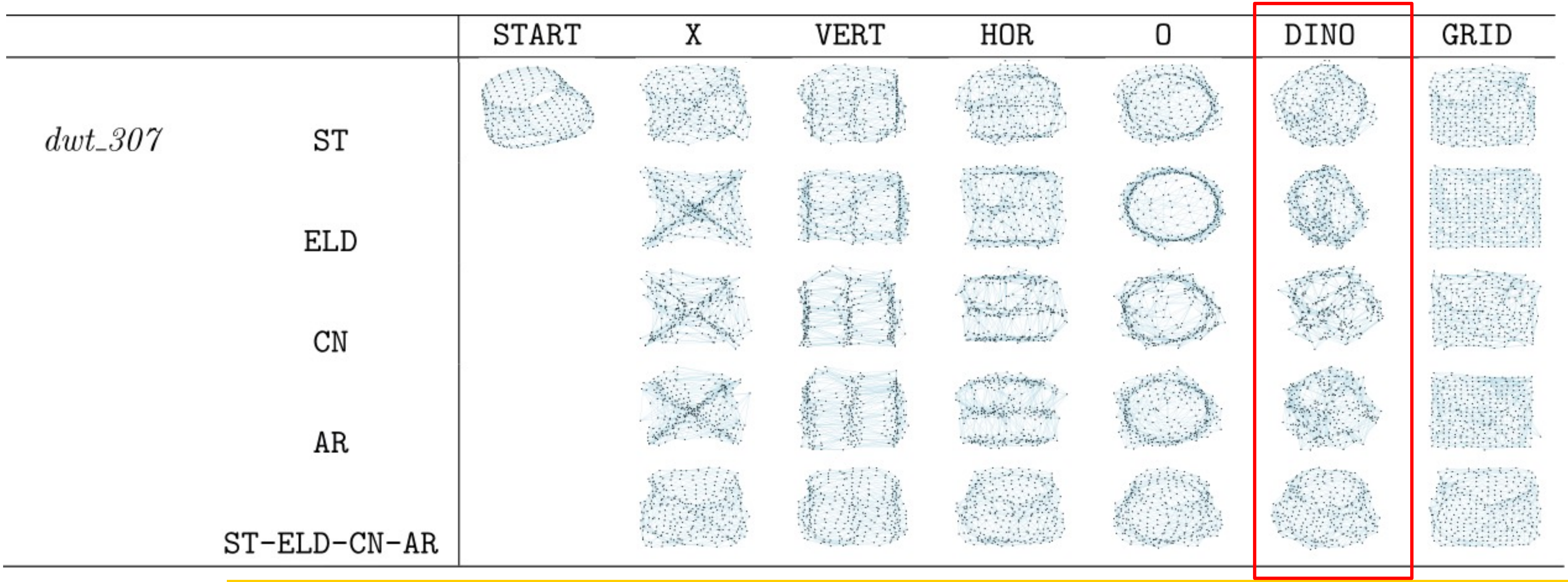




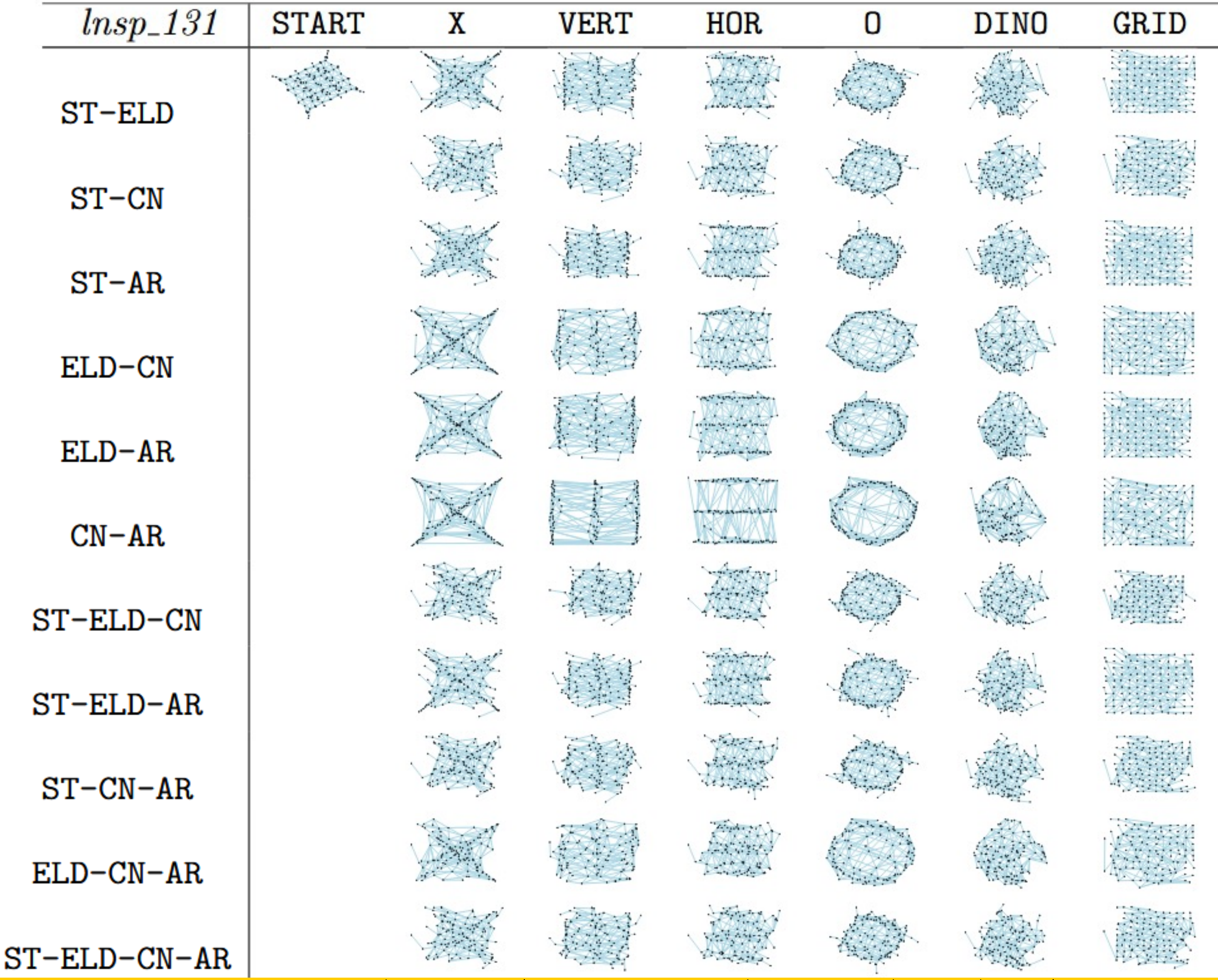
Graph **structure influences difficulty** of ‘fooling’ a drawing



Graph **structure influences difficulty** of 'fooling' a drawing; **Target shape** also **influences difficulty**



- Graph **structure influences difficulty** of ‘fooling’ a drawing
- **Target shape** also **influences difficulty**
- **Combinations** of metrics is more difficult to fool
- **Some metrics** are **more difficult** to fool than **others** (Faithfulness vs readability metrics)

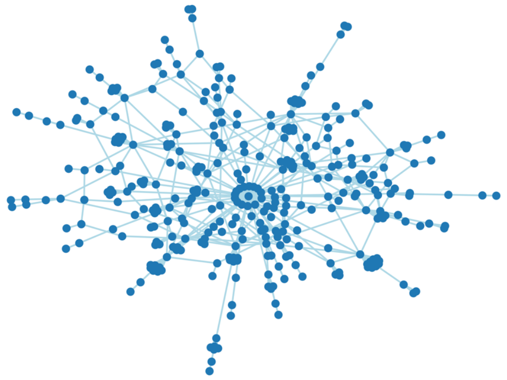


Utrecht University

Morphing graph **drawings** into a **video**

1. Extract **frames** from a video
2. Turn each **frame into** a **target** shape consisting of points
3. Morph a **drawing into** each **target** shape using the fooling algorithm
4. Stitch the resulting drawings into a video

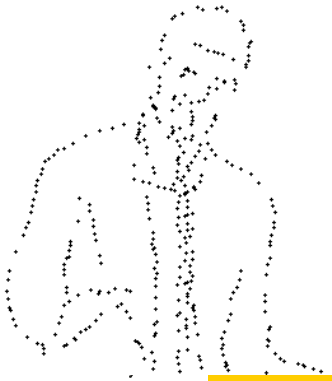
Original drawing with ST: 0.1555 | ELD: 0.0579 | CN: 1324 | AR: 0.4692



Morphing graph **drawings** into a **video**

1. Extract **frames** from a video
2. Turn each **frame into** a **target** shape consisting
3. Morph a **drawing into** each **target** shape using algorithm
4. Stitch the resulting drawings into a video
5. **Enjoy** the results!

Original drawing with ST: 0.1555 | ELD: 0.0579 | CN: 1324 | AR: 0.4692



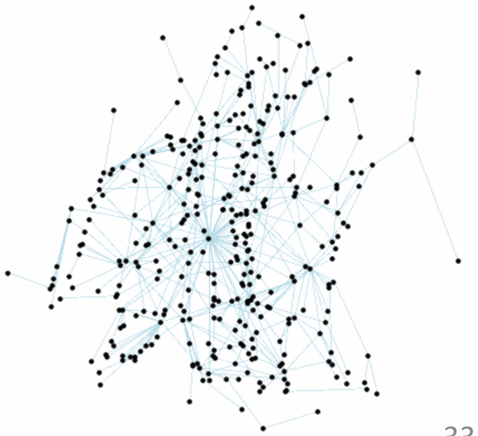
Original ST: 0.1555
Current ST: 0.1580

Original ELD: 0.0579
Current ELD: 0.0604

Original CN: 1324
Current CN: 1390

Original AR: 0.4692
Current AR: 0.4716

Original ['ST', 'ELD', 'CN', 'AR']:
[0.1555 0.0579 1324 0.4692]
Current ['ST', 'ELD', 'CN', 'AR']:
[0.1580 0.0601 1388 0.4711]



Conclusion

- Simple **algorithm** that can systematically **morph** graph **drawings into** any **arbitrary target shapes** while **keeping** one or more **metrics** the **same**
- **Fooling statistics/metrics** spans **multiple** types of **visualizations** (scatter plots, projections, graph drawings). Need **better metrics** e.g. **faithfulness** metrics for GD

Conclusion

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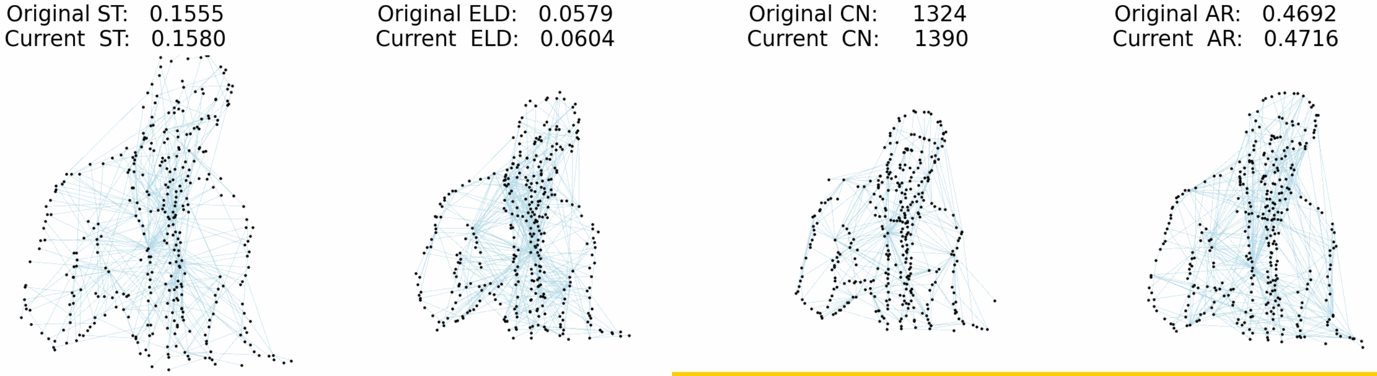
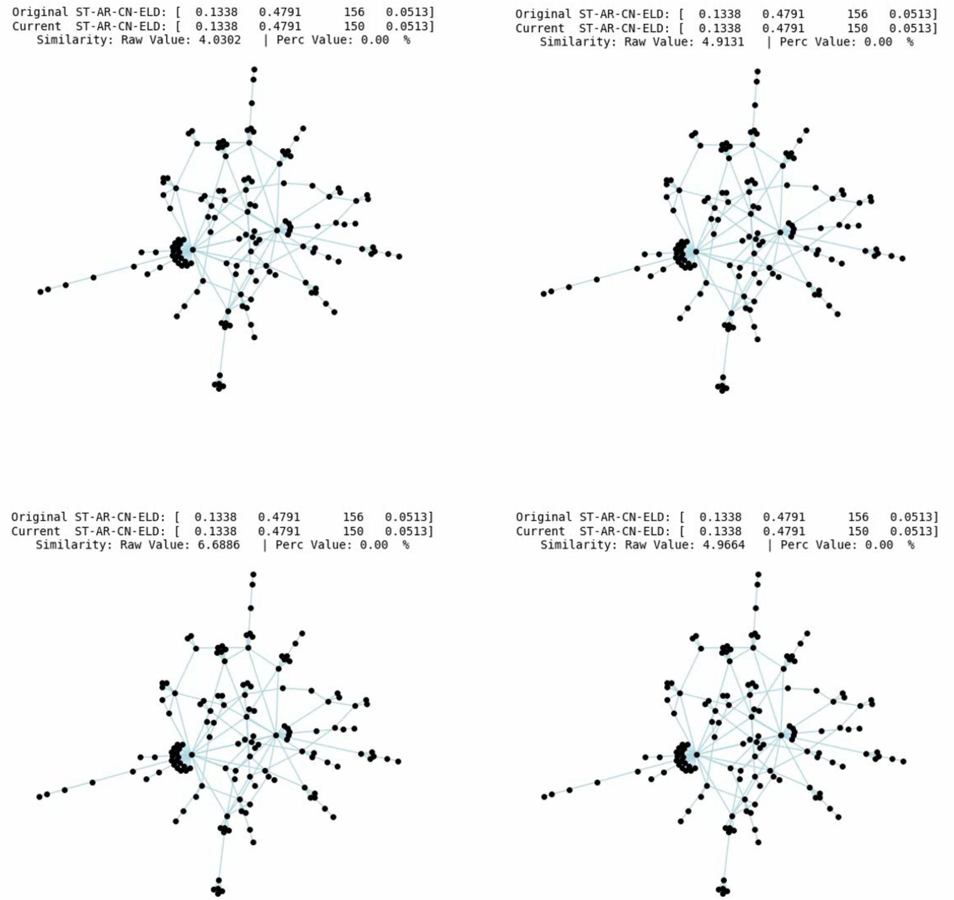
- **Fooling statistics/metrics** spans **multiple** types of **visualizations** (scatter plots, projections, graph drawings). Need **better metrics** e.g. **faithfulness** metrics for GD

Future work

- More sophisticated algorithm
- More metrics and graphs
- Perceptual user-study on readability of morphed drawings

Thank you!





GitHub

Videos

Utrecht University

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