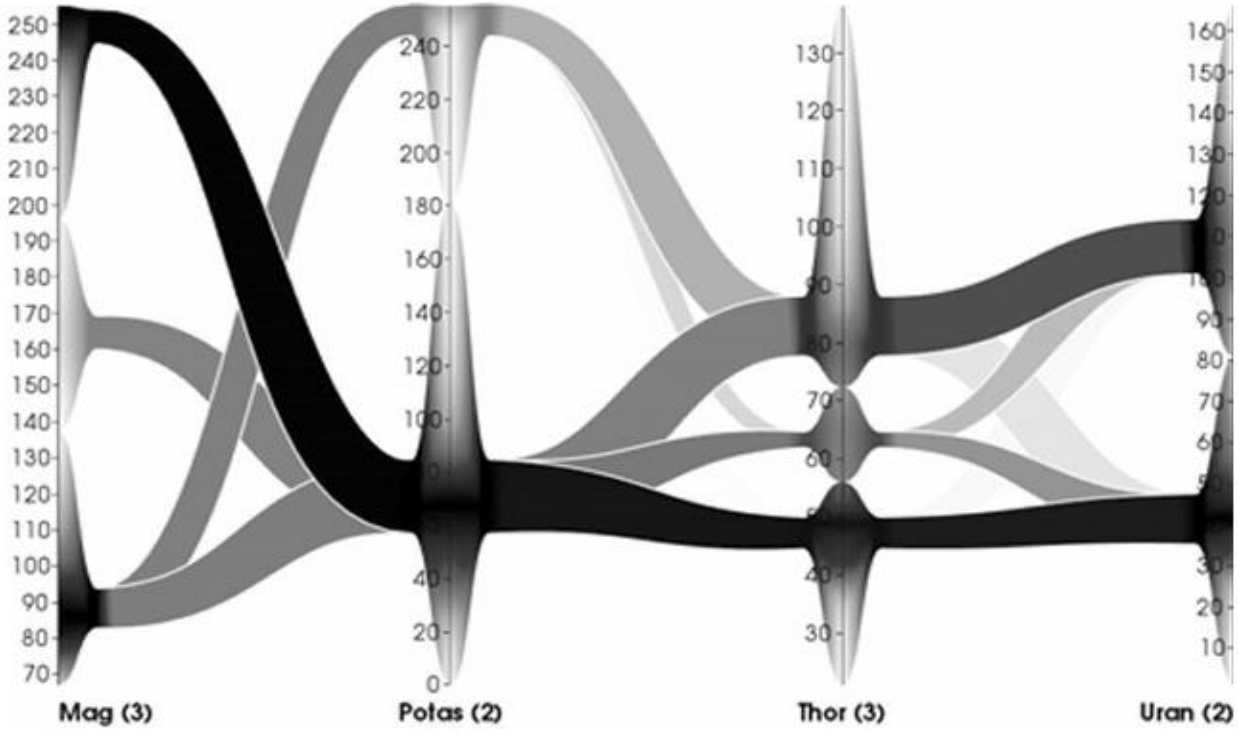
Edge bundling for Parallel Coordinates

Denise J. Rappold

Seminar Visualisierung Multidimensionaler Daten | Winter Term 2024/25 | 23.01.2025

The magic of

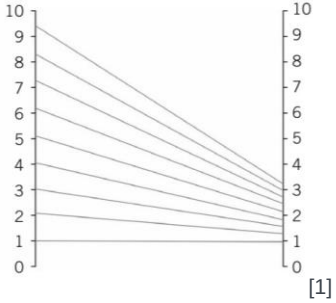
Edge bundling



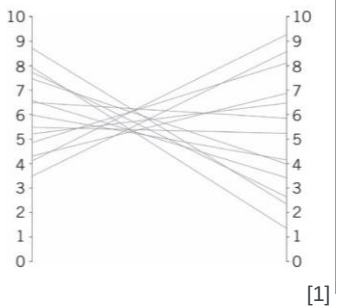
[3]

Parallel Coordinates (PCPs)

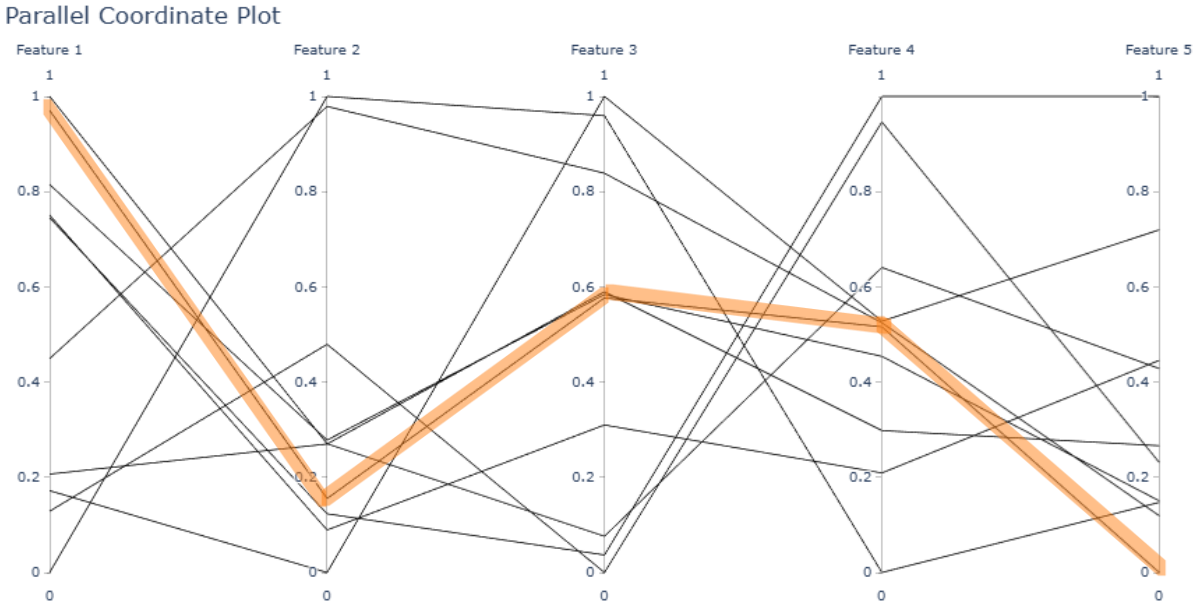
- Pattern recognition
- Connect dimensional relationships



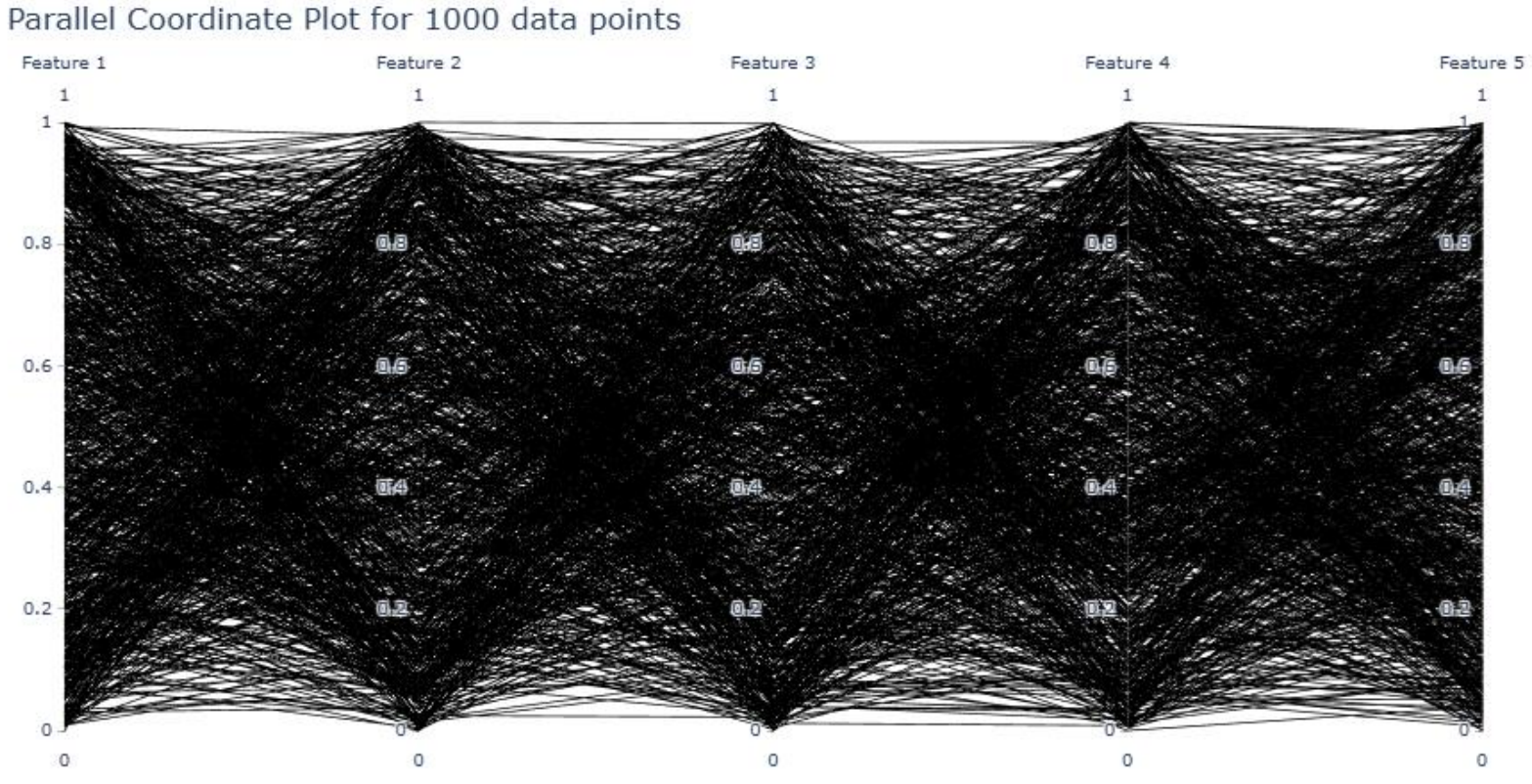
[1]



[1]

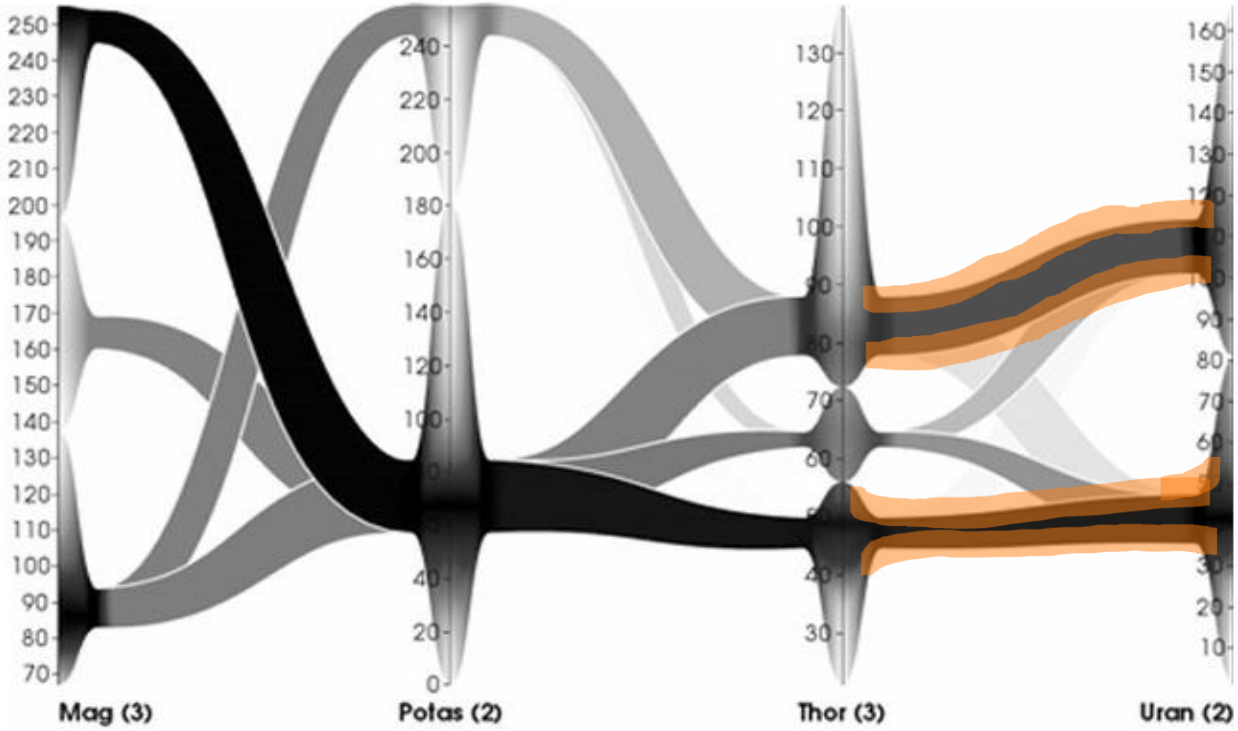


Visual Clutter



Edge bundling

Clutter Reduction

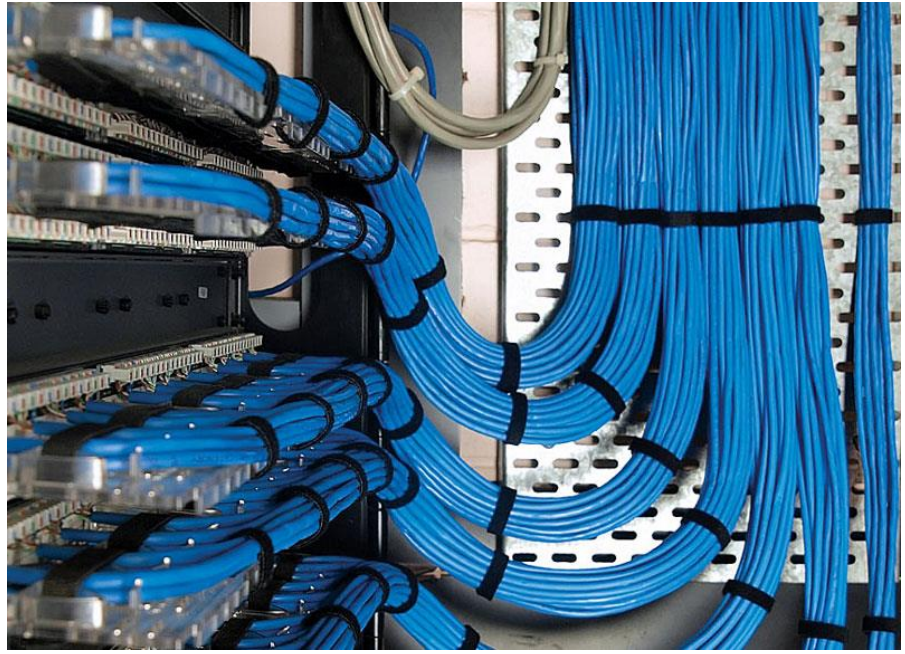


[3]

Background

- Origin in graph and network visualization
- Real-world inspiration network cables
- Visually merge “similar” edges

=> Trade visual clutter for information loss



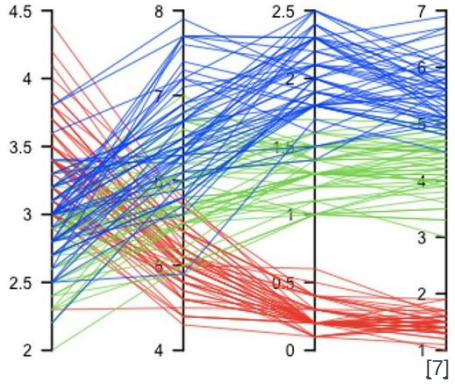
[4]

Gestalt laws

- Similarity

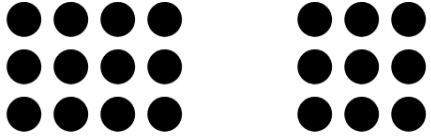
[8]

PCPs



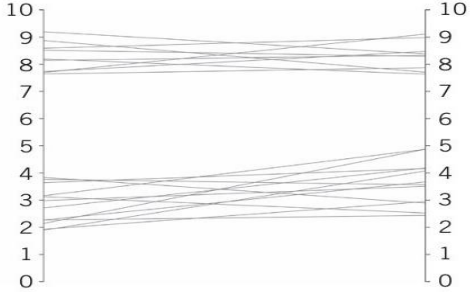
[7]

- Proximity



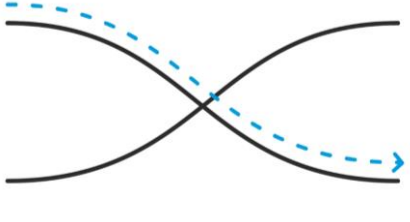
[8]

PCPs



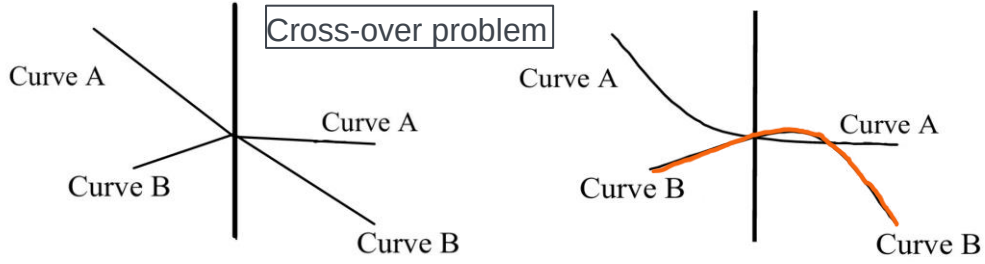
[1]

- Continuity



[8]

PCPs

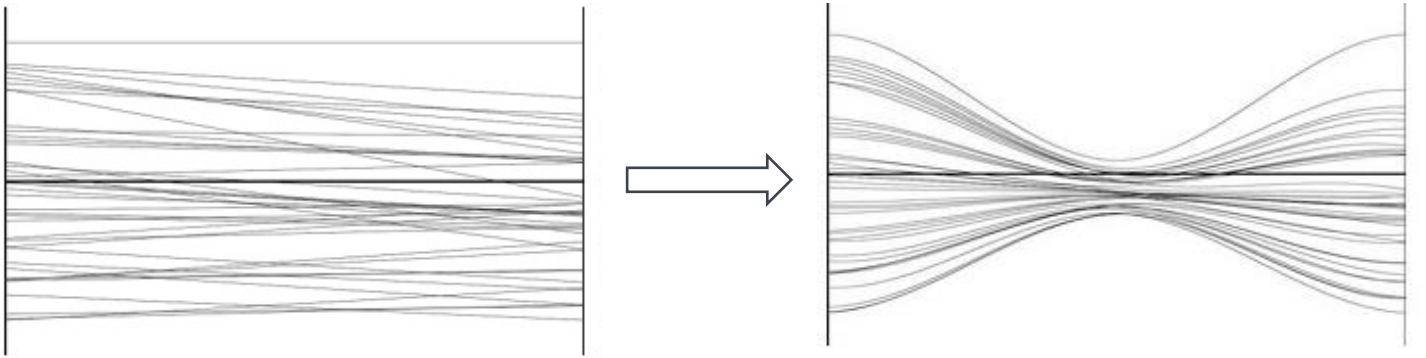


[5]

“Evaluation of a bundling technique for parallel coordinates“, Heinrich et al. (2011)

Data-centric

- Mulit-dimensional clustering of data assumed
- Polyline to piecewise cubic Bézier curve
- α : smoothness scale
- β : bundling strength

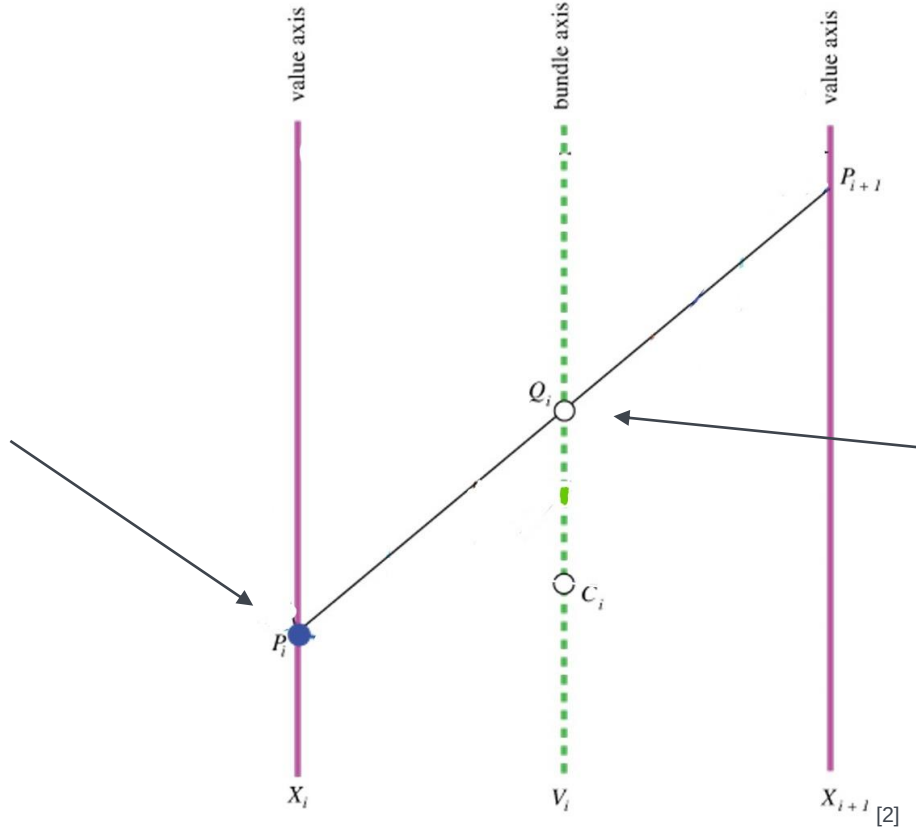


[2]

[2]

“Evaluation of a bundling technique for parallel coordinates“, Heinrich et al. (2011)

Data-centric



[2]

Starting point

No bundling:

$$Q_i' = (1-\beta)Q_i + \beta C_i$$

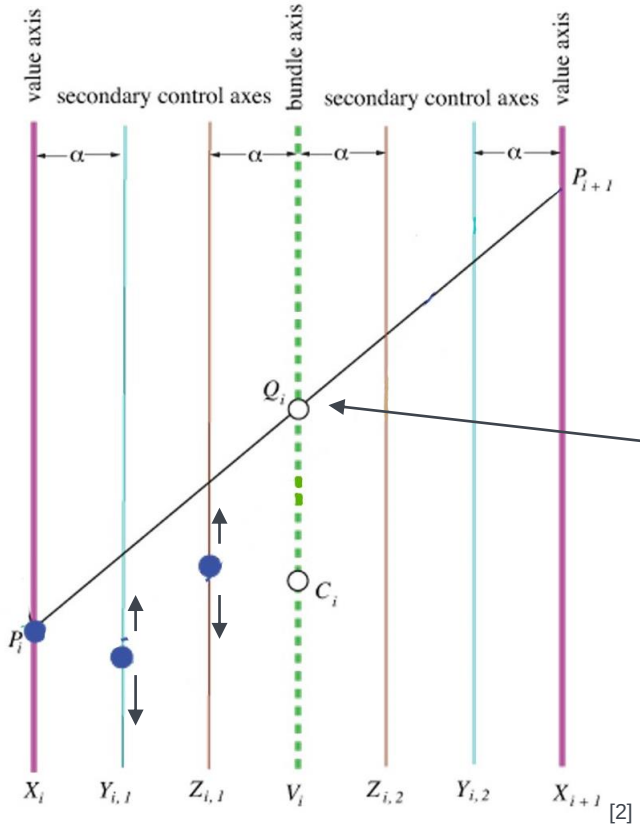
$$\beta = 0$$

$$Q_i' = (1-0)Q_i + 0 \times C_i$$

$$Q_i' = Q_i$$

“Evaluation of a bundling technique for parallel coordinates“, Heinrich et al. (2011)

Data-centric



[2]

No bundling:

$$Q'_i = (1-\beta)Q_i + \beta C_i$$

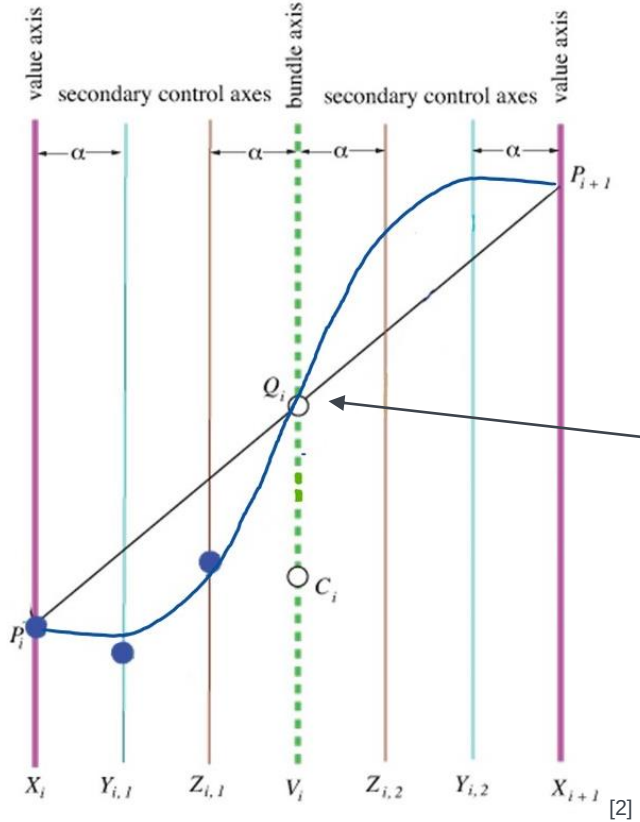
$$\beta = 0$$

$$Q'_i = (1-0)Q_i + 0 \times C_i$$

$$Q'_i = Q_i$$

“Evaluation of a bundling technique for parallel coordinates“, Heinrich et al. (2011)

Data-centric



[2]

No bundling:

$$Q'_i = (1-\beta)Q_i + \beta C_i$$

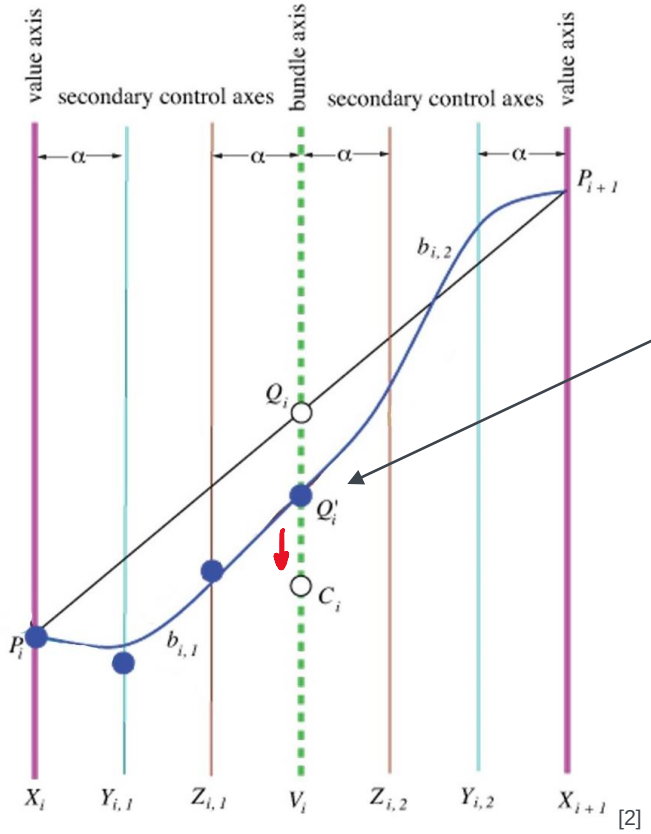
$$\beta = 0$$

$$Q'_i = (1-0)Q_i + 0 \times C_i$$

$$Q'_i = Q_i$$

“Evaluation of a bundling technique for parallel coordinates“, Heinrich et al. (2011)

Data-centric



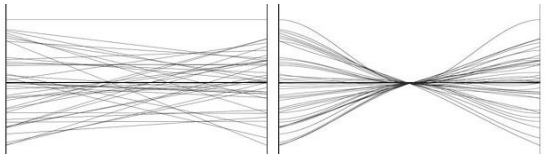
[2]

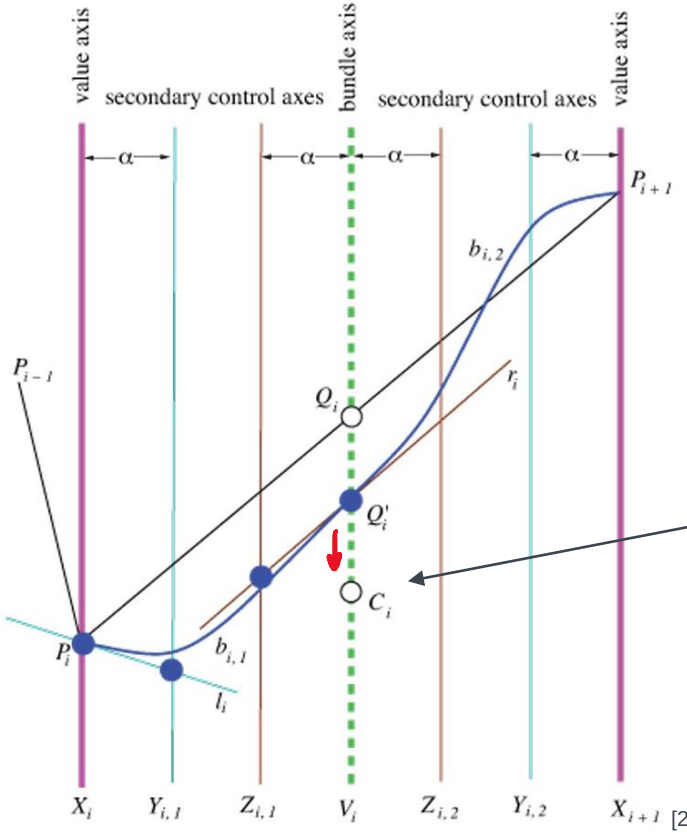
with bundling:

$$Q_i' = (1-\beta)Q_i + \beta C_i$$

“Evaluation of a bundling technique for parallel coordinates“, Heinrich et al. (2011)

Data-centric





[2]

Strict bundling:

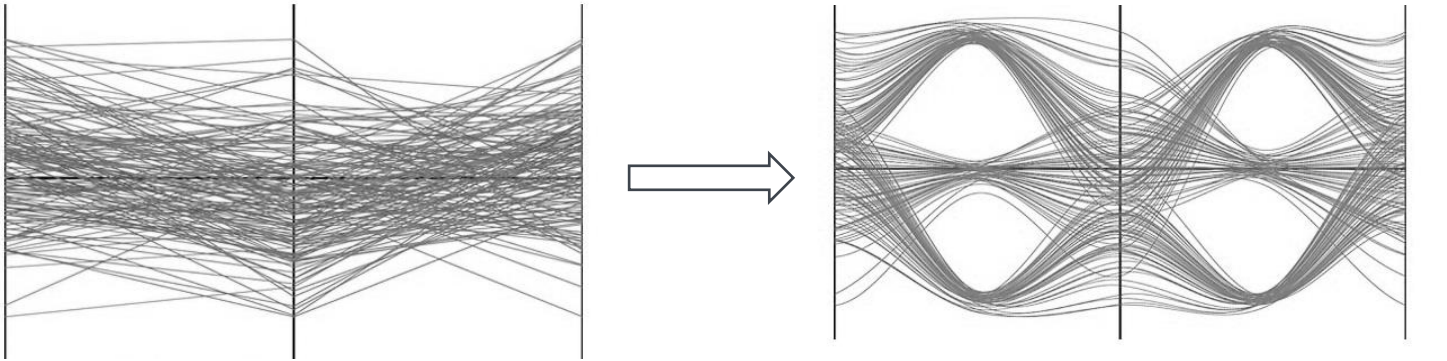
$$Q_i' = (1-\beta)Q_i + \beta C_i$$

$$\beta = 1$$
$$Q_i' = (1-1)Q_i + 1 \times C_i$$
$$Q_i' = 0 + C_i$$
$$Q_i' = C_i$$

“Evaluation of a bundling technique for parallel coordinates“, Heinrich et al. (2011)

Data-centric

- Two crucial steps for edge bundling:
- Transform polylines to smooth curves: Continuity
- Bundle “similar” data points: Proximity
- “similar”: based on data clustering

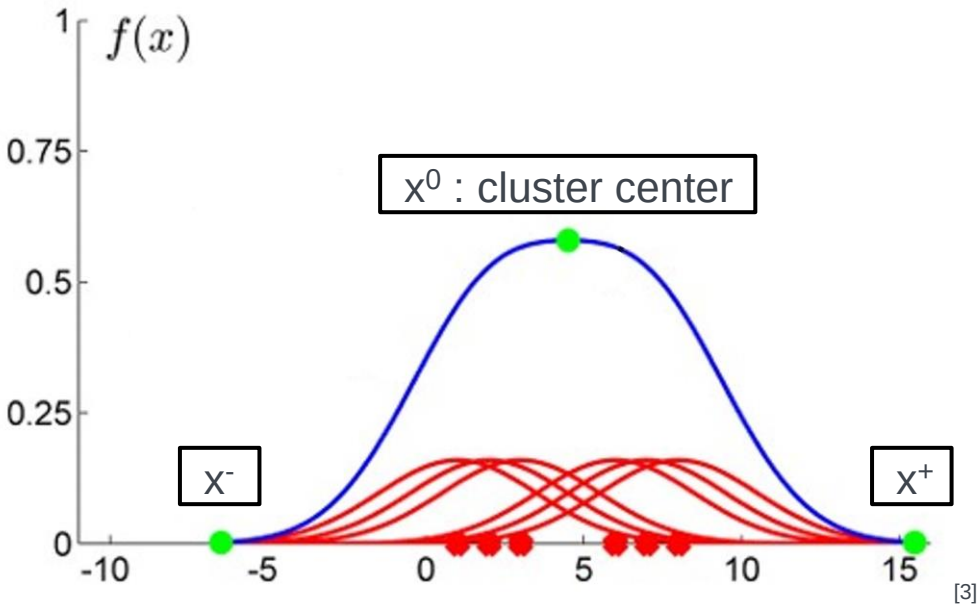


[2] [2]

“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

One dimensional clustering

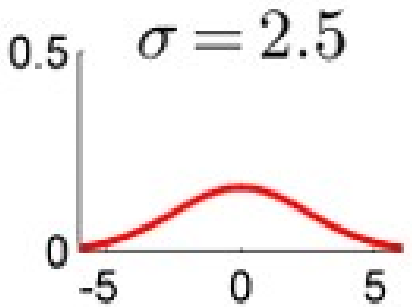
- Gaussian Kernel Density estimation
- σ: bandwidth
- Cluster position 3-Tupel (x^-,x^0,x^+)



[3]

Density for one data point x_1:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x_1 - x)^2}{2\sigma^2}}$$



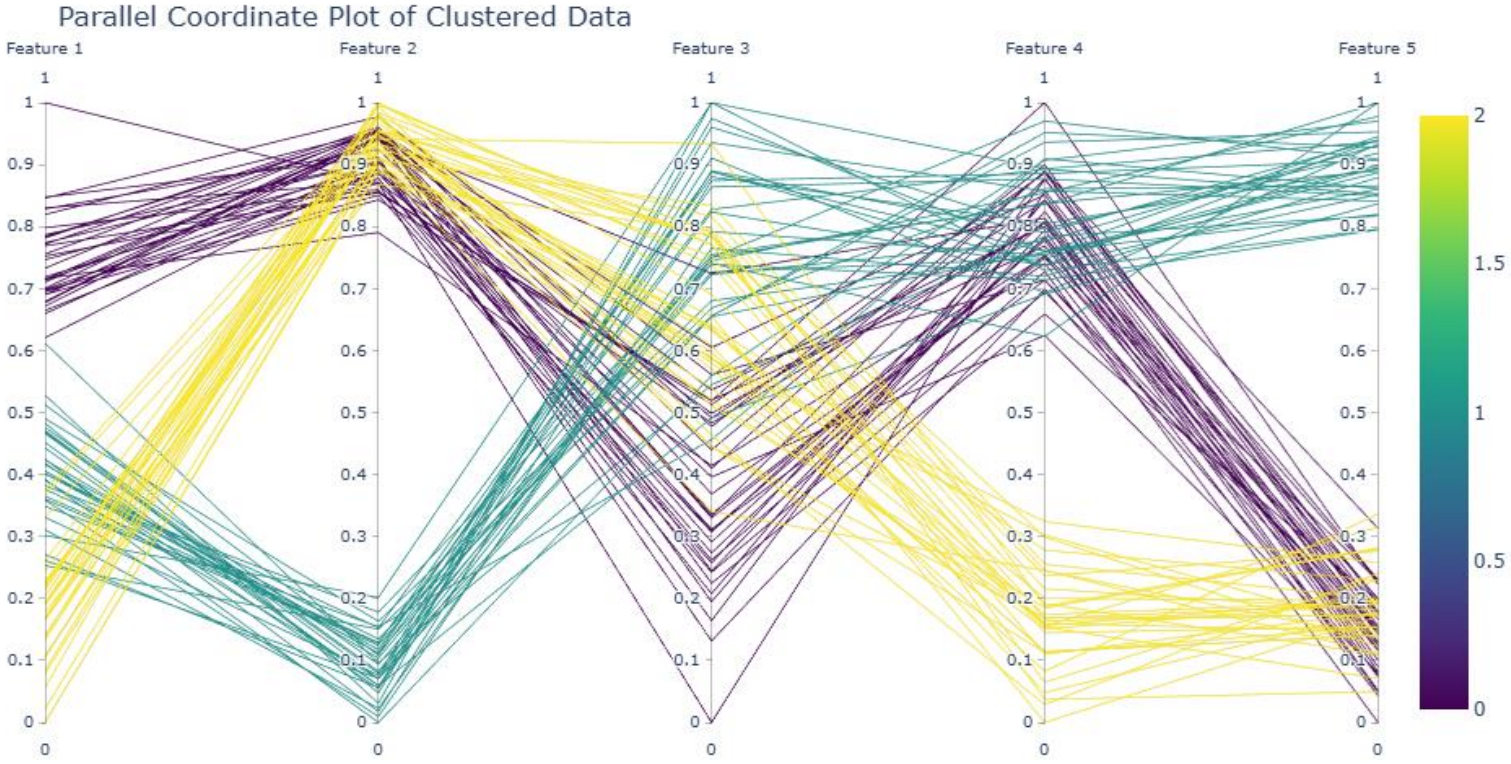
[3]

Density function: value of σ

[Gaussian_plot.html]

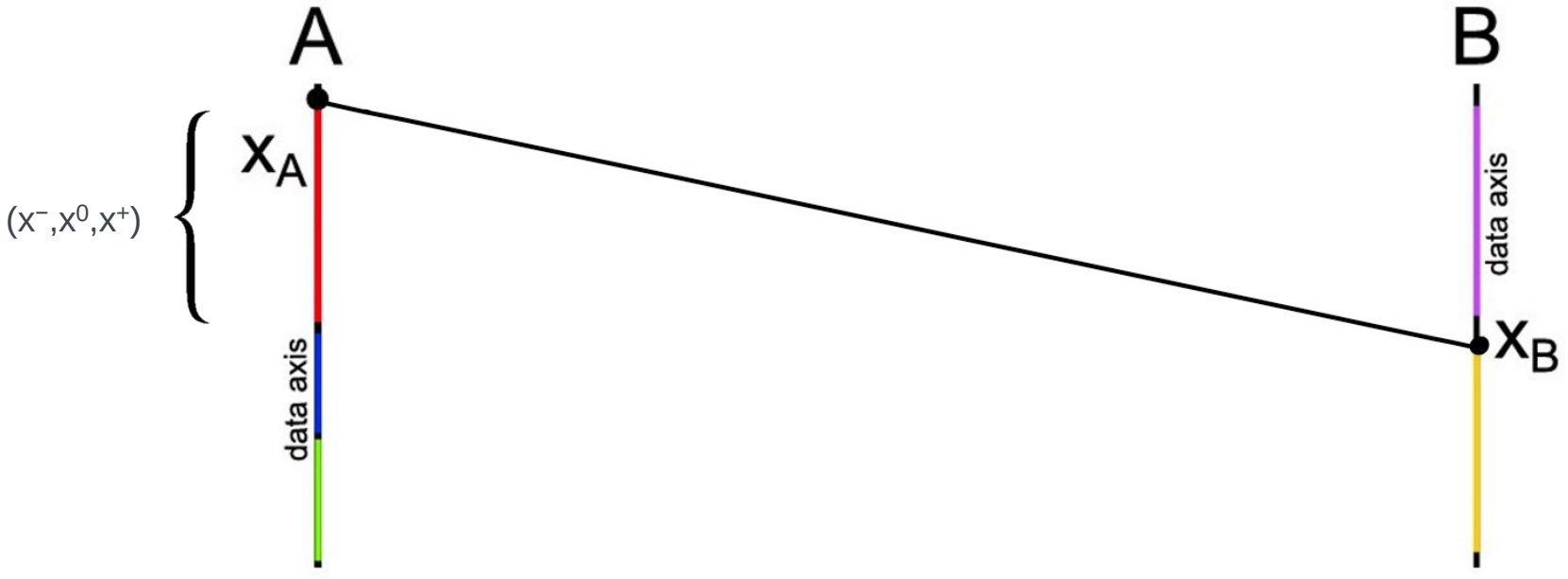
Cluster representation:

(x^{-},x^{0},x^{+})



“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

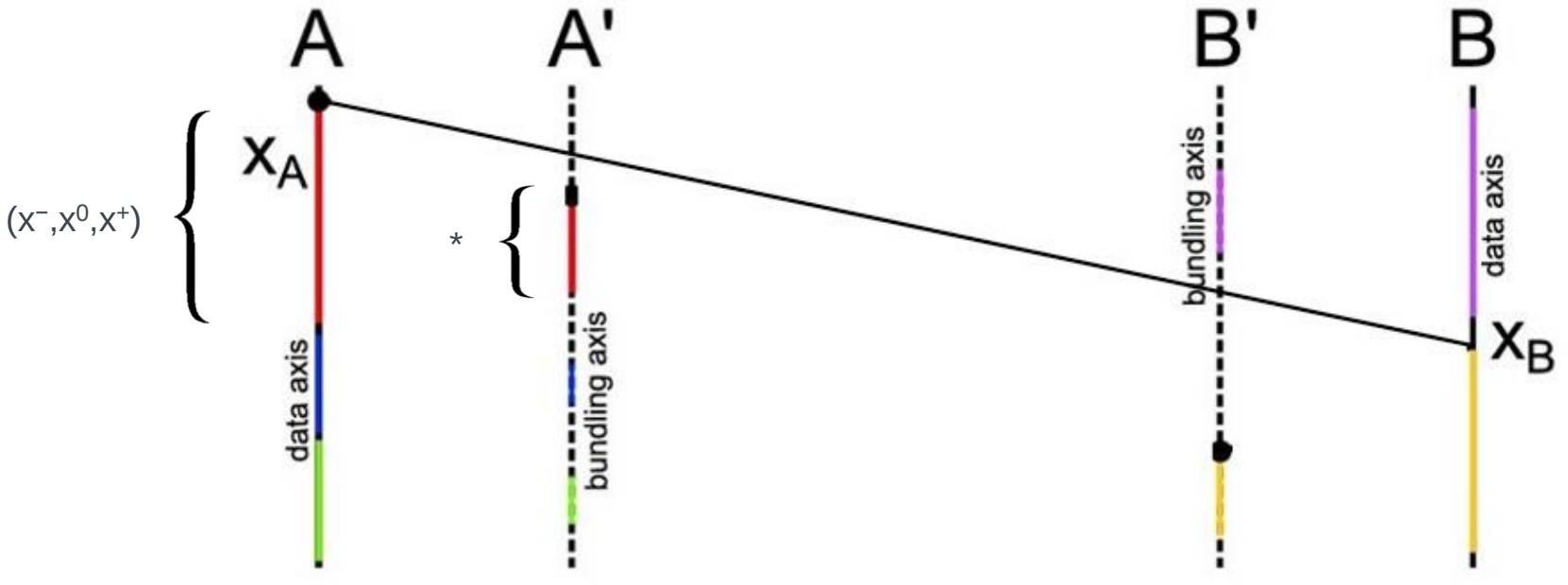
Edge bundling



[3]

“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

Edge bundling

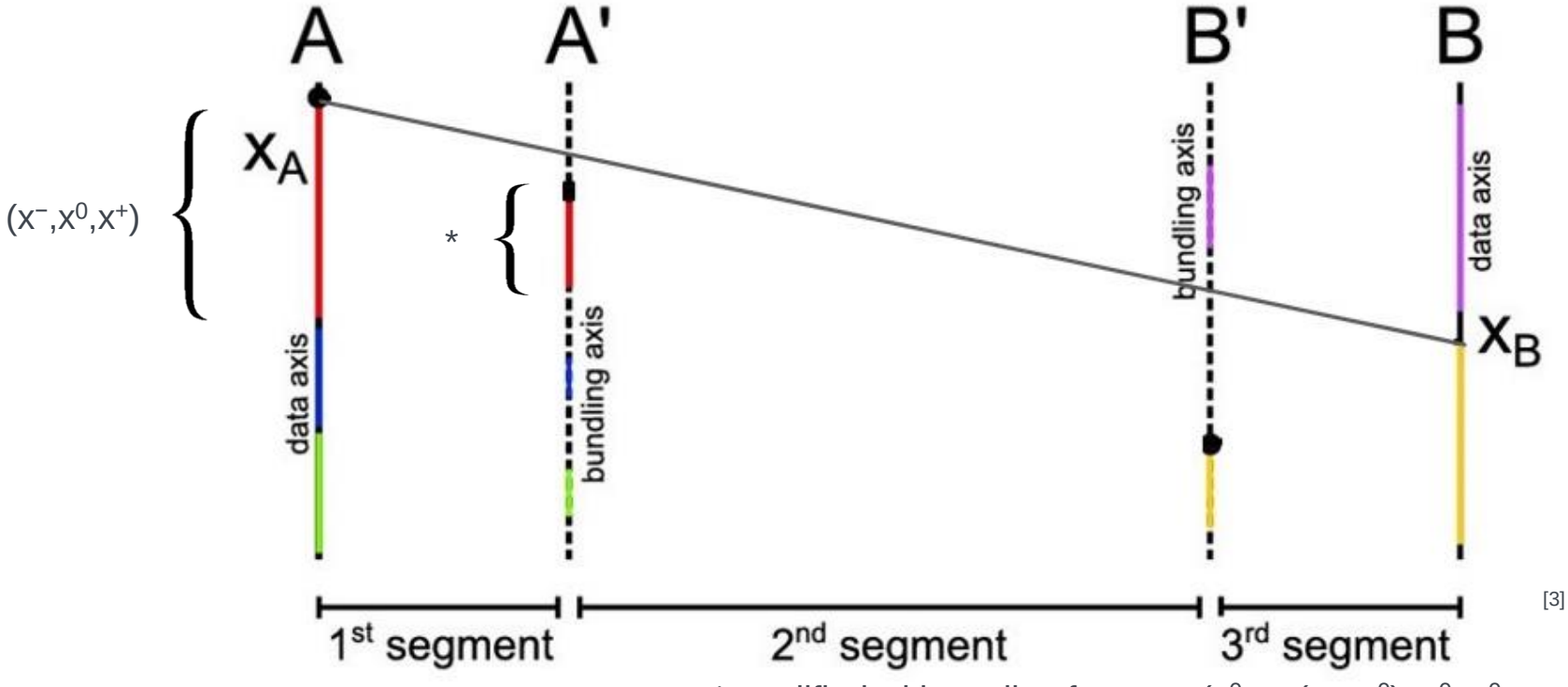


[3]

* modified with scaling factor s: $(x^0 + s(x^- - x^0), x^0, x^0 + s(x^+ - x^0))$

“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

Edge bundling

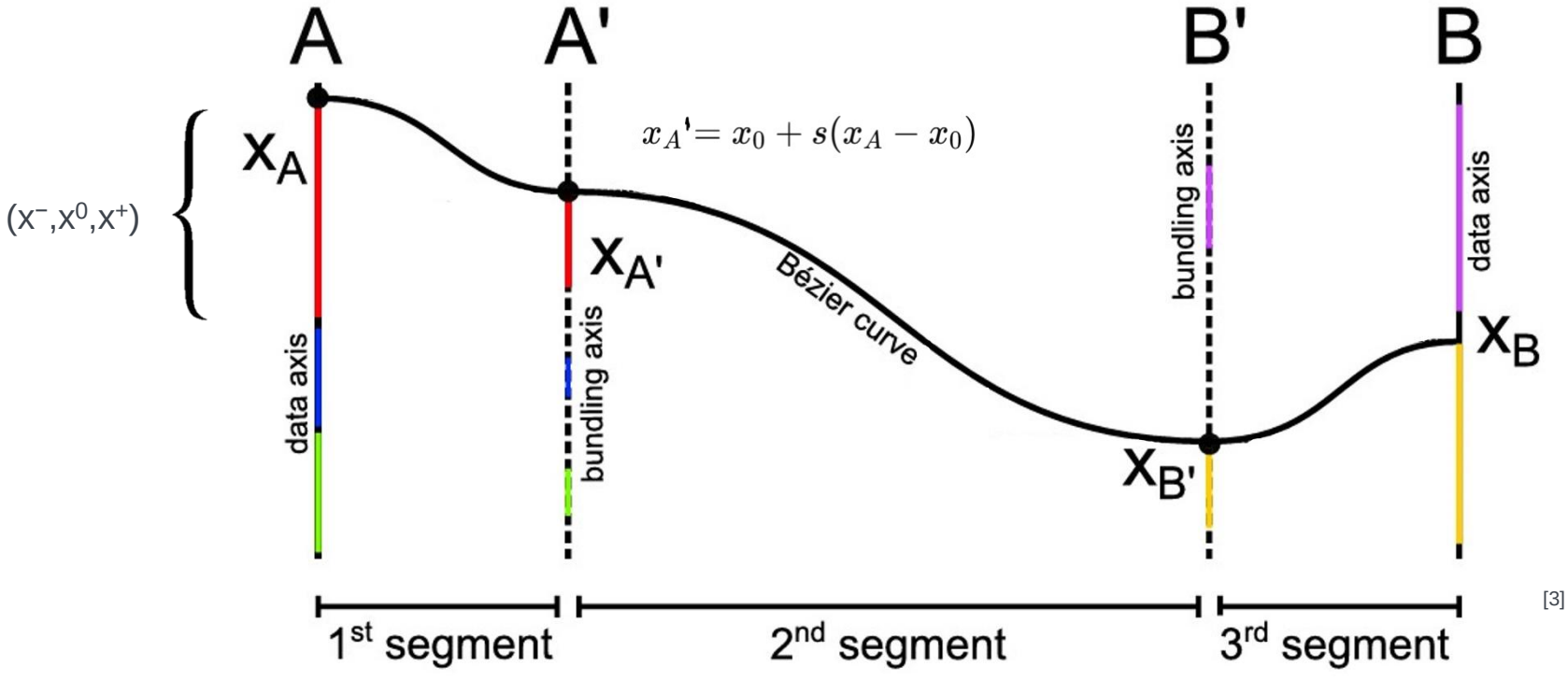


[3]

* modified with scaling factor s: $(x^0 + s(x^- - x^0), x^0, x^0 + s(x^+ - x^0))$

“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

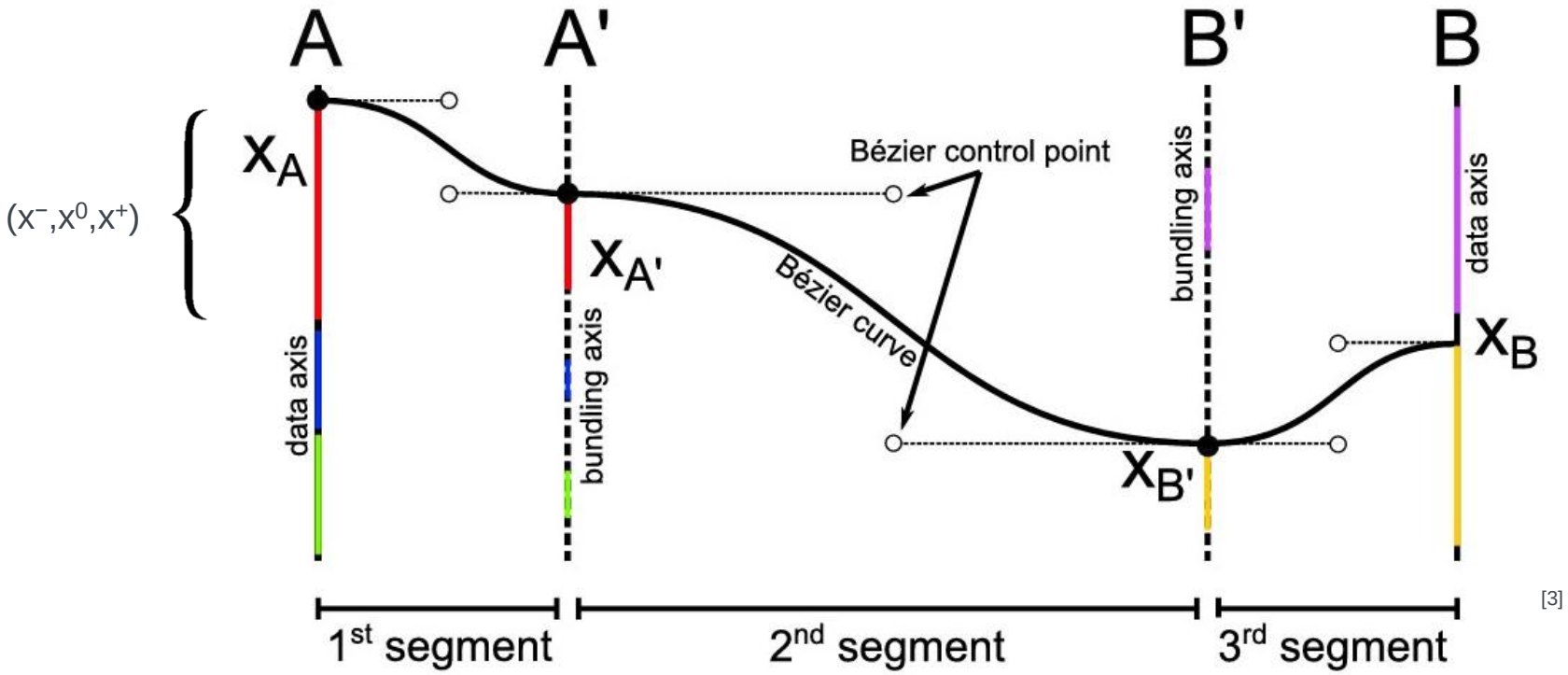
Edge bundling



[3]

“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

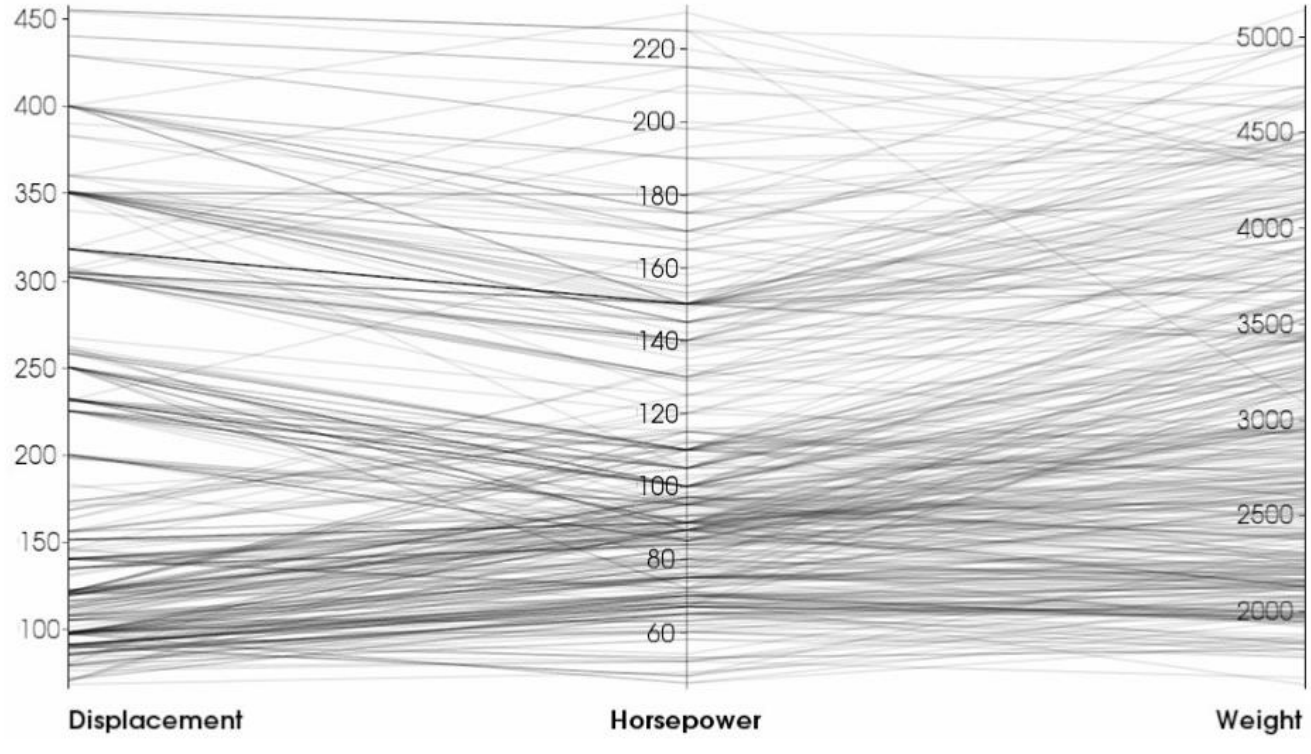
Edge bundling



[3]

“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

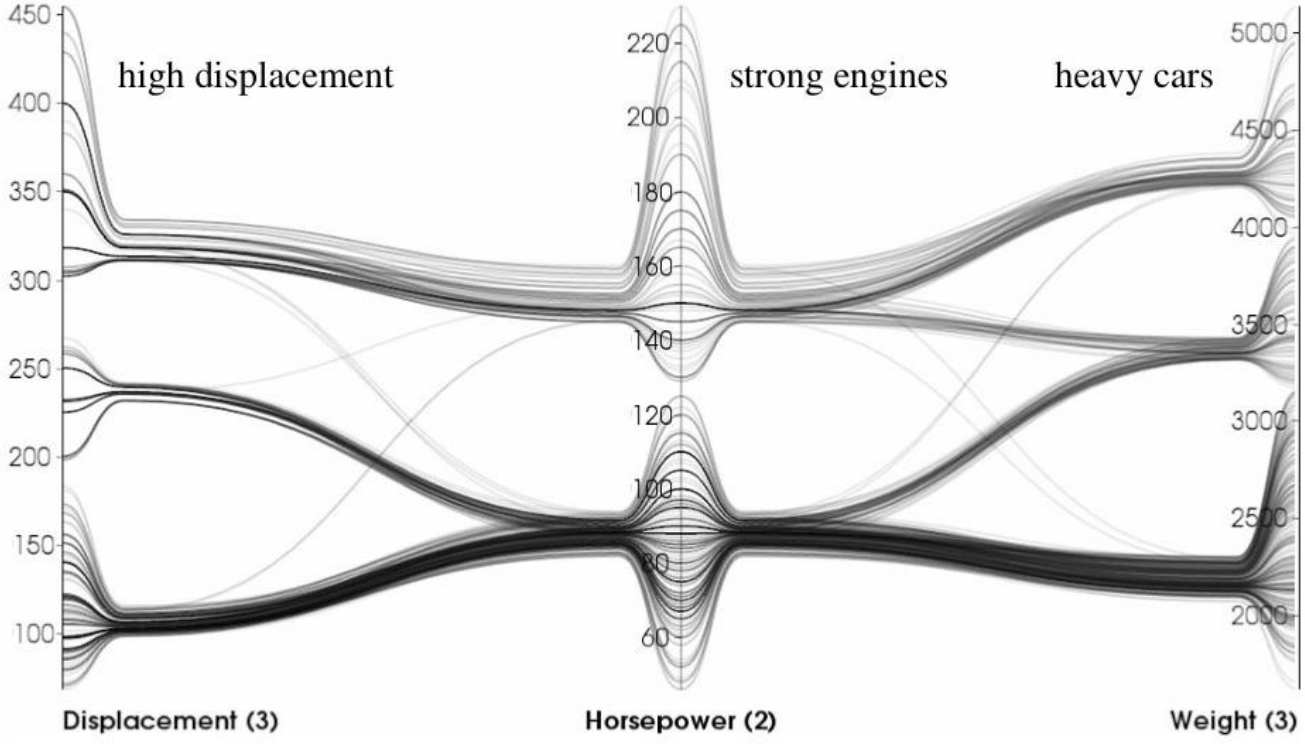
Original polyline-based PCP



[3]

“An Edge-Bundling Layout for Interactive PCs”, Palmas et al. (2014)

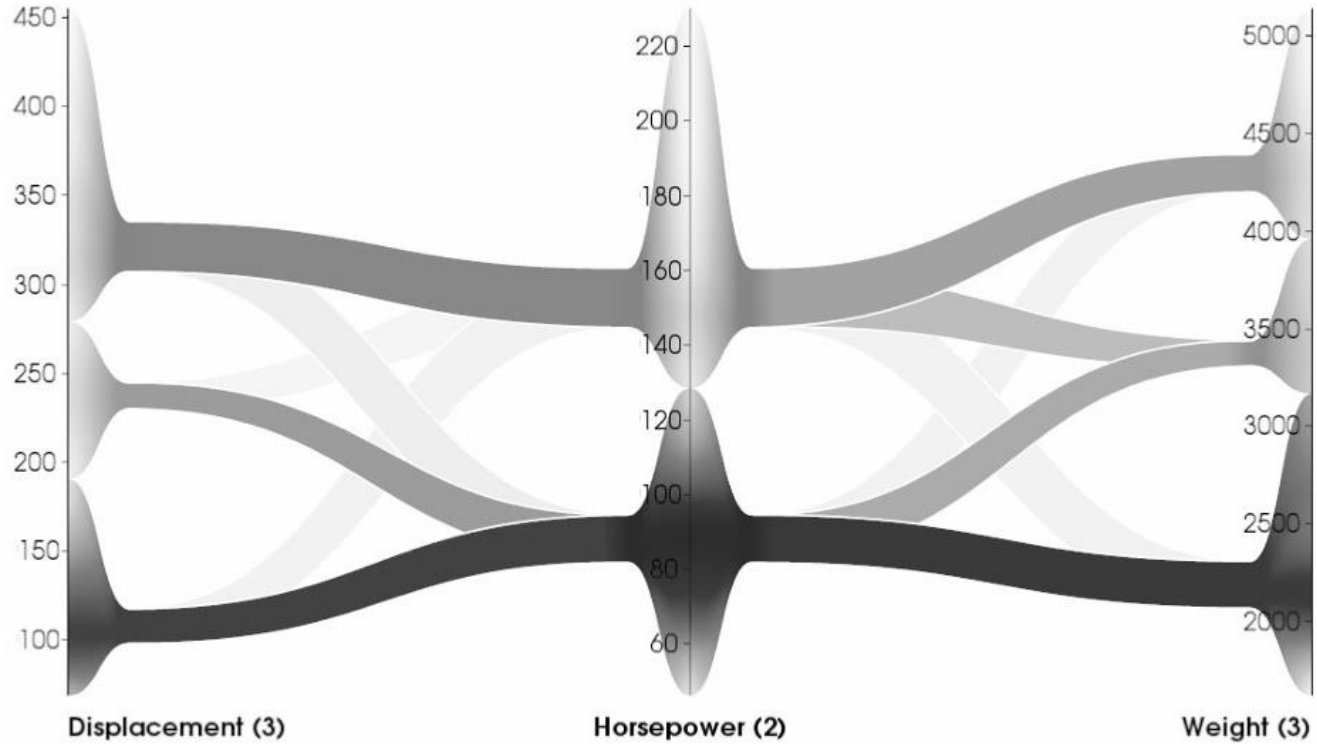
Implicit visualization of bundles



[3]

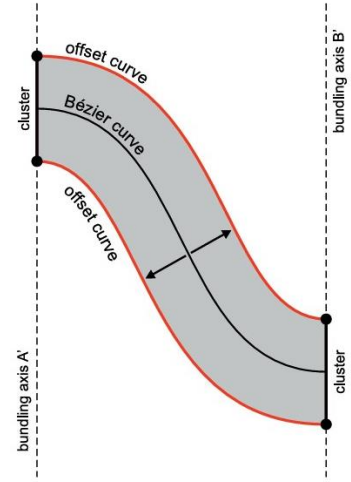
Data-centric approach

Polygonal strips – explicit visualization of bundles



(c) Parallel Coordinates Plot using our edge-bundling with strip rendering.

[3]



[3]

Conclusion

Advantages

- Reduced visual clutter
- Improved pattern recognition
- Visually identify clusters
- Curve smoothness: Intuitive due to continuity
- From detailed view to broader overview

Limitations

- Computational complexity

- Expert knowledge

- Clustering quality

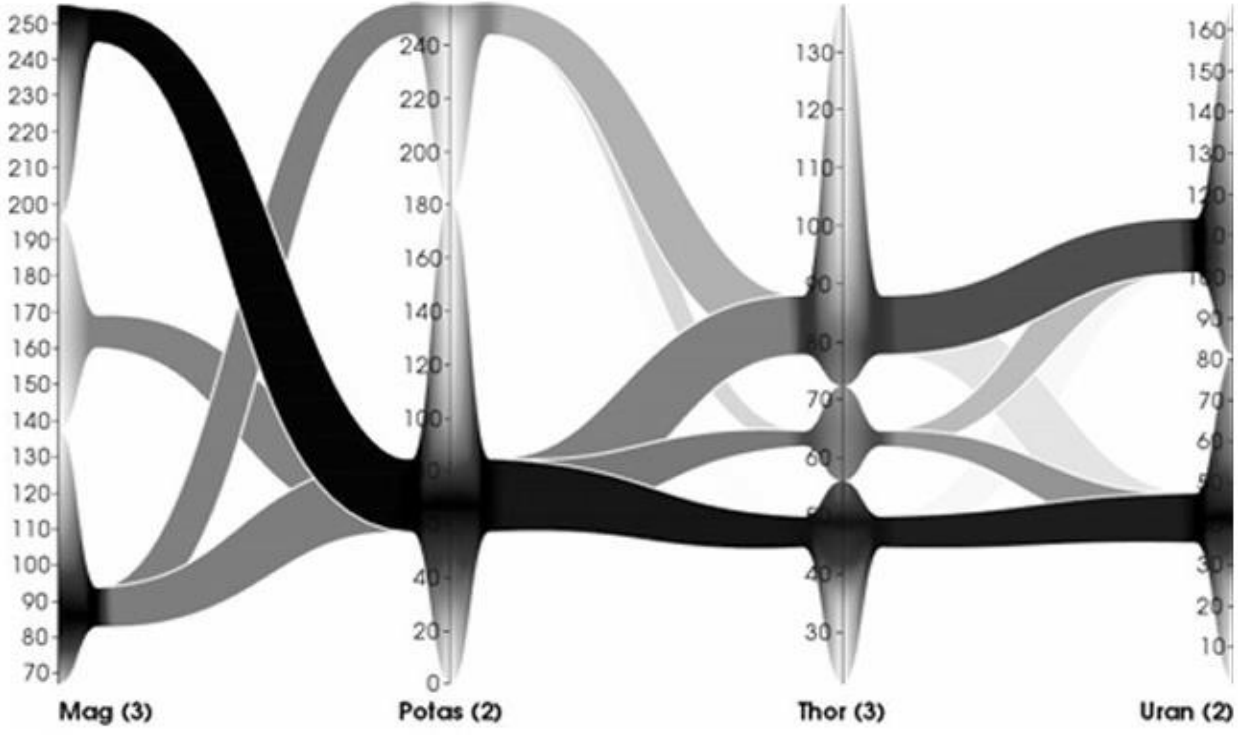
-> Cost-based approach „Visual Clustering in parallel coordinates“, Zhou et al. (2008)

- Clutter reduction vs. information preservation

⇨ Careful consideration needed

Magic?

Edge bundling



[3]

References

[1] J.Heinrich and D.Weiskopf. ”Parallel Coordinates for Multidimensional Data Visualization: Basic Concepts“, Computing in Science & Engineering, 17(03):70–76, May 2015

[2] J. Heinrich, Y. Luo, A. E. Kirkpatrick, H. Zhang, and D. Weiskopf. “Evaluation of a bundling technique for parallel coordinates“, 2011.

[3] G. Palmas, M. Bachynskyi, A. Oulasvirta ,H. P. Seidel, and T. Weinkauf. “An edge-bundling layout for interactive parallel coordinates“, 2014 IEEE Pacific Visualization Symposium, pages 57–64, 2014.

[4] https://corbansecure.com/structured-cabling/

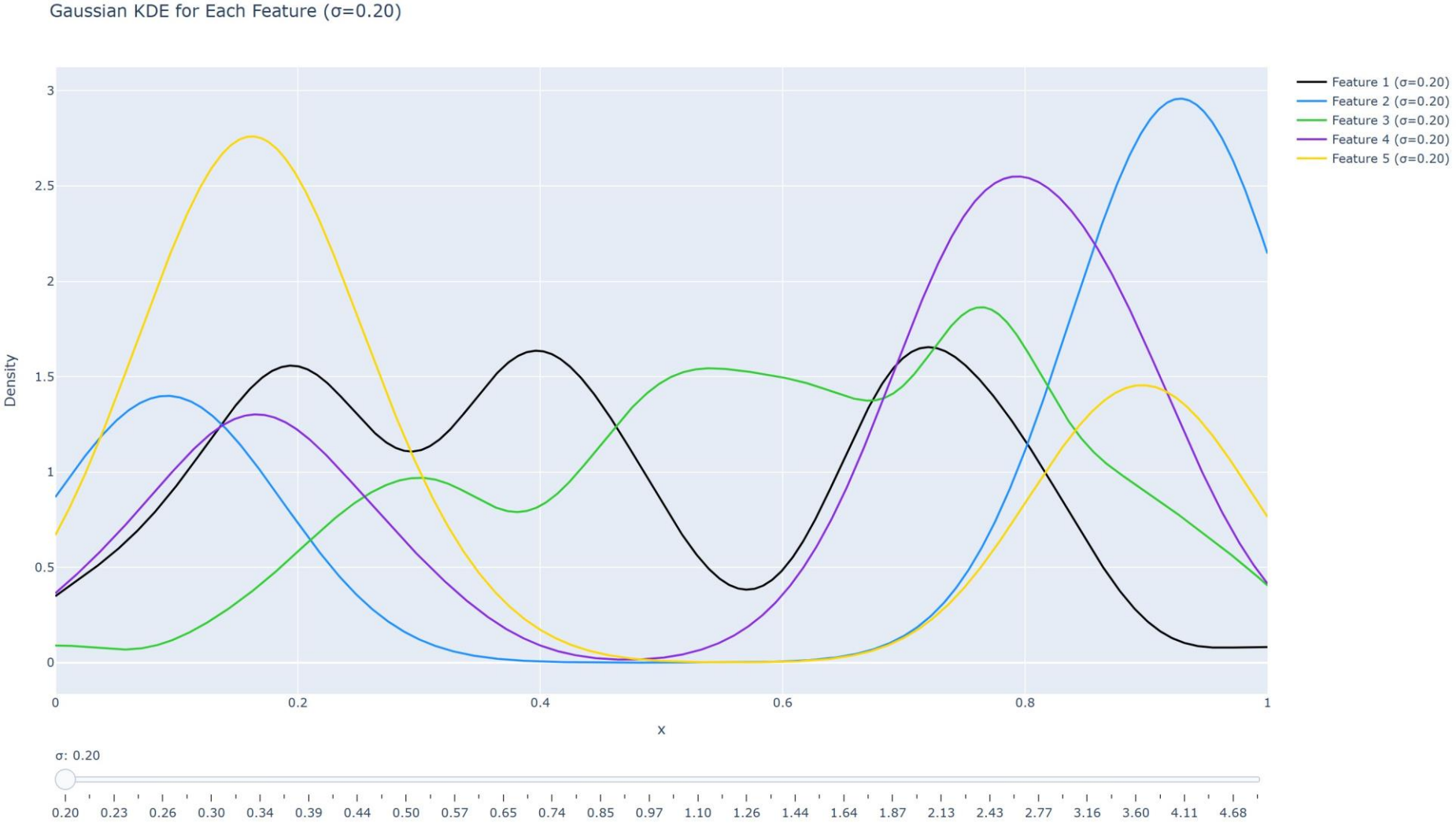
[5] M. Graham and J. Kennedy, "Using curves to enhance parallel coordinate visualisations," *Proceedings on Seventh International Conference on Information Visualization, 2003. IV 2003.*, London, UK, 2003, pp. 10-16, doi: 10.1109/IV.2003.1217950.

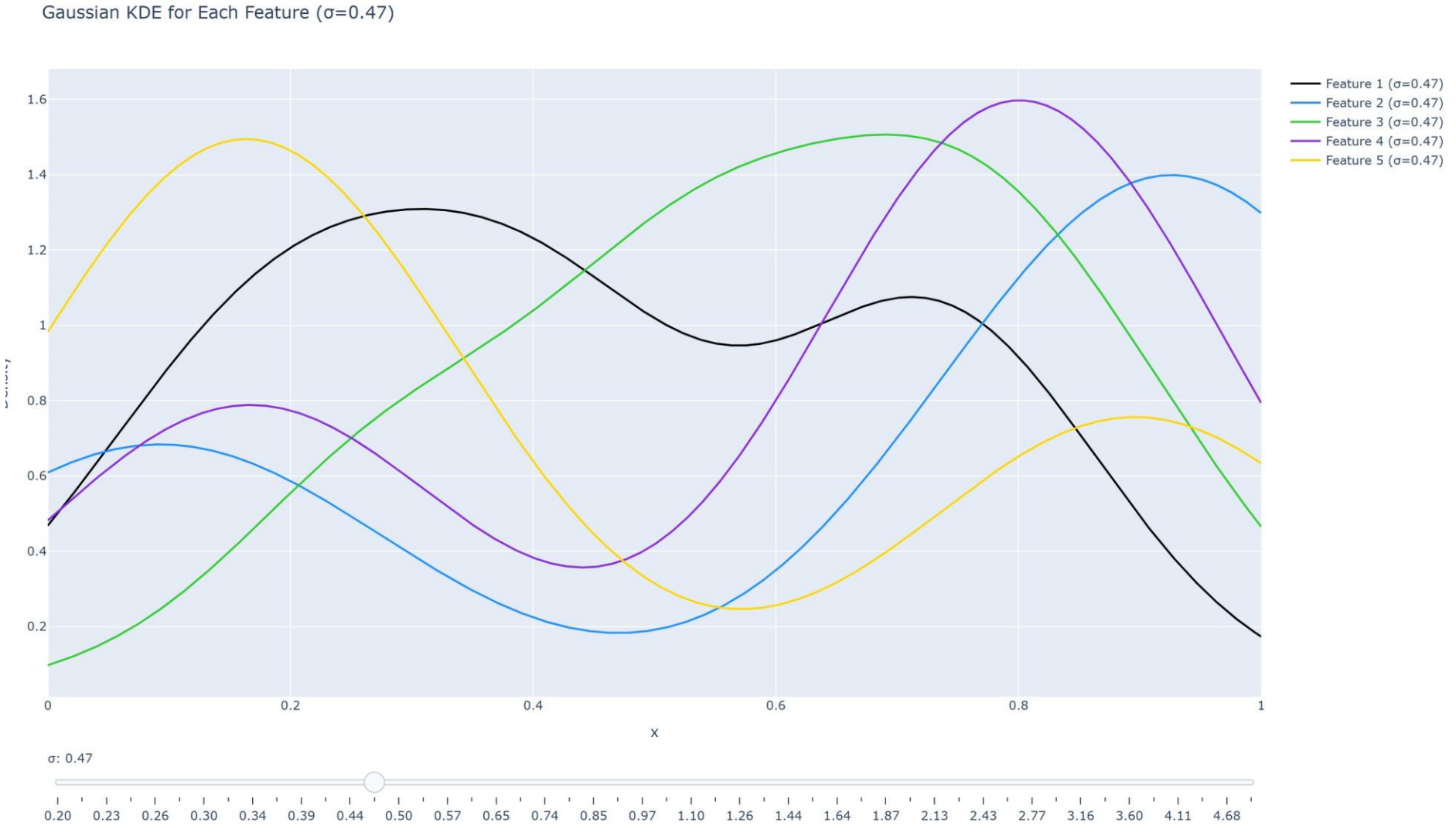
[6] J.Heinrich and D.Weiskopf. ”Parallel Coordinates for Multidimensional Data Visualization: Basic Concepts“, Computing in Science & Engineering, 17(03):70–76, May 2015

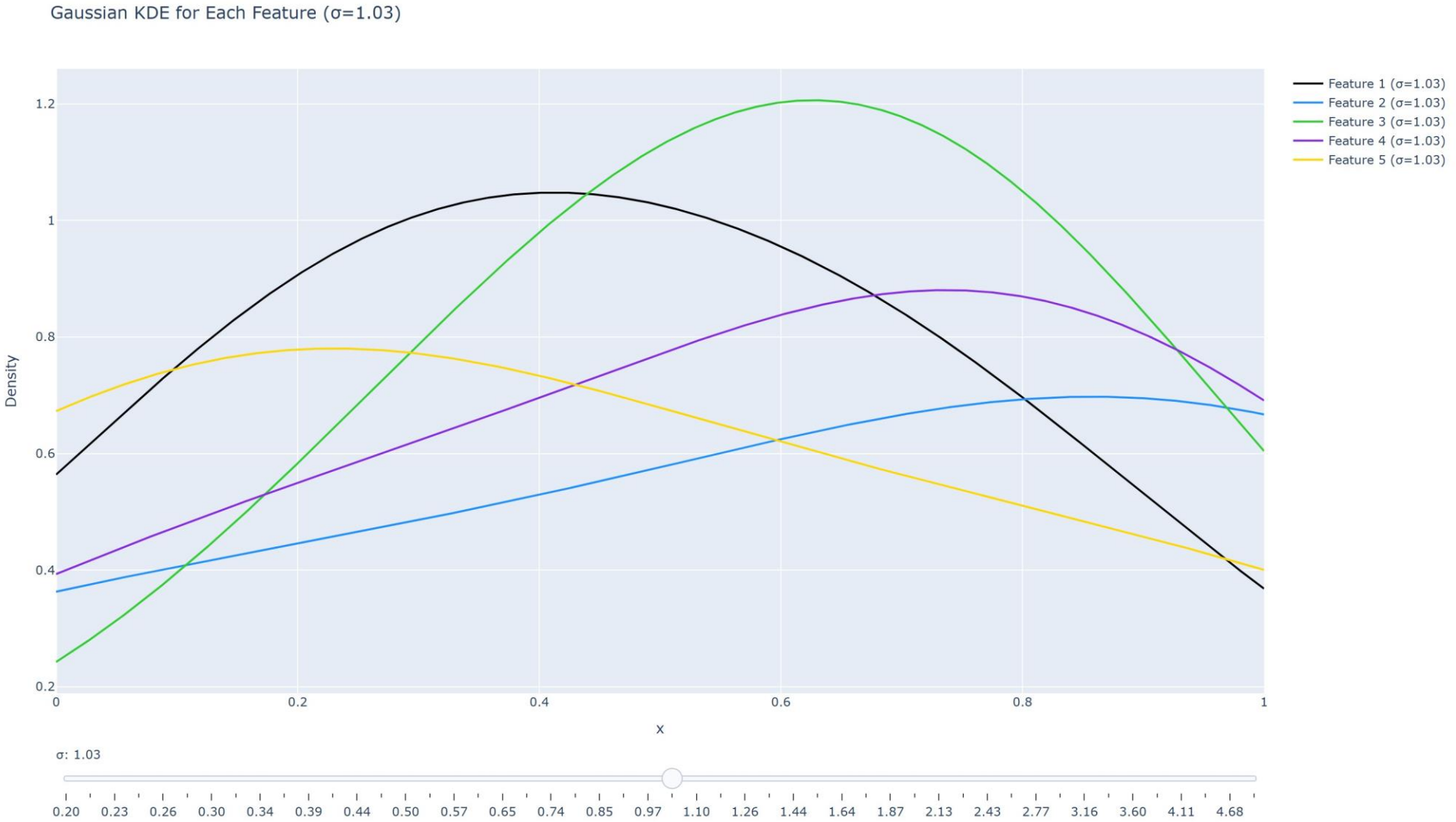
[7] https://en.wikipedia.org/wiki/Parallel_coordinates

[8] https://www.interaction-design.org/

Backup in case animation isn‘t working


Gaussian KDE for Each Feature (σ=0.20)
Feature 1 (σ=0.20)
Feature 2 (σ=0.20)
Feature 3 (σ=0.20)
Feature 4 (σ=0.20)
Feature 5 (σ=0.20)
Density
X
σ: 0.20
0.20 0.23 0.26 0.30 0.34 0.39 0.44 0.50 0.57 0.65 0.74 0.85 0.97 1.10 1.26 1.44 1.64 1.87 2.13 2.43 2.77 3.16 3.60 4.11 4.68


Gaussian KDE for Each Feature (σ=0.47)
Feature 1 (σ=0.47)
Feature 2 (σ=0.47)
Feature 3 (σ=0.47)
Feature 4 (σ=0.47)
Feature 5 (σ=0.47)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1
x
σ: 0.47
0.20 0.23 0.26 0.30 0.34 0.39 0.44 0.50 0.57 0.65 0.74 0.85 0.97 1.10 1.26 1.44 1.64 1.87 2.13 2.43 2.77 3.16 3.60 4.11 4.68


Gaussian KDE for Each Feature (σ=1.03)
Feature 1 (σ=1.03)
Feature 2 (σ=1.03)
Feature 3 (σ=1.03)
Feature 4 (σ=1.03)
Feature 5 (σ=1.03)
Density
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1
X
σ: 1.03
0.20 0.23 0.26 0.30 0.34 0.39 0.44 0.50 0.57 0.65 0.74 0.85 0.97 1.10 1.26 1.44 1.64 1.87 2.13 2.43 2.77 3.16 3.60 4.11 4.68