

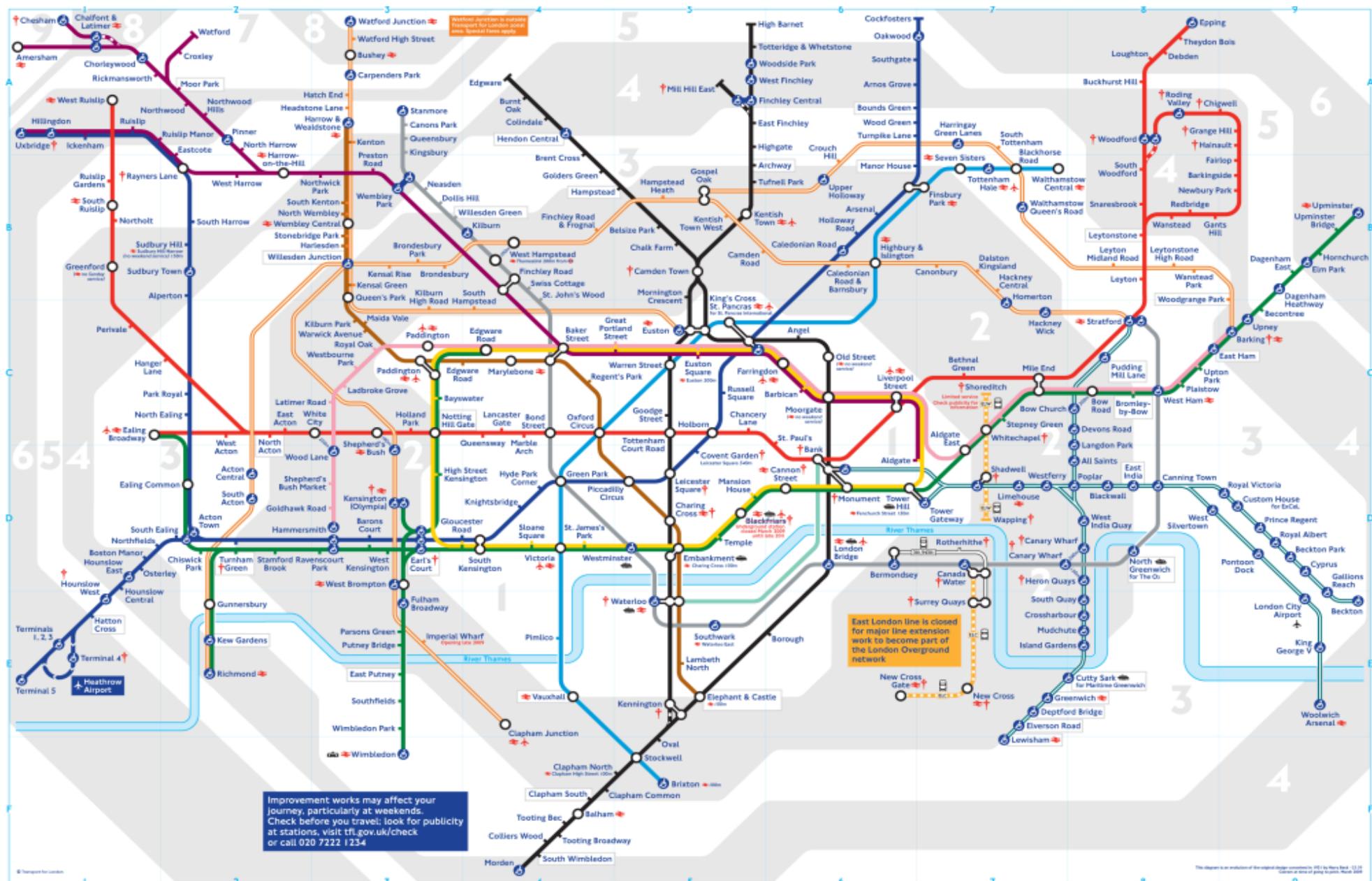
Winkelschematisierung im Graphenzeichnen



Philipp Kindermann



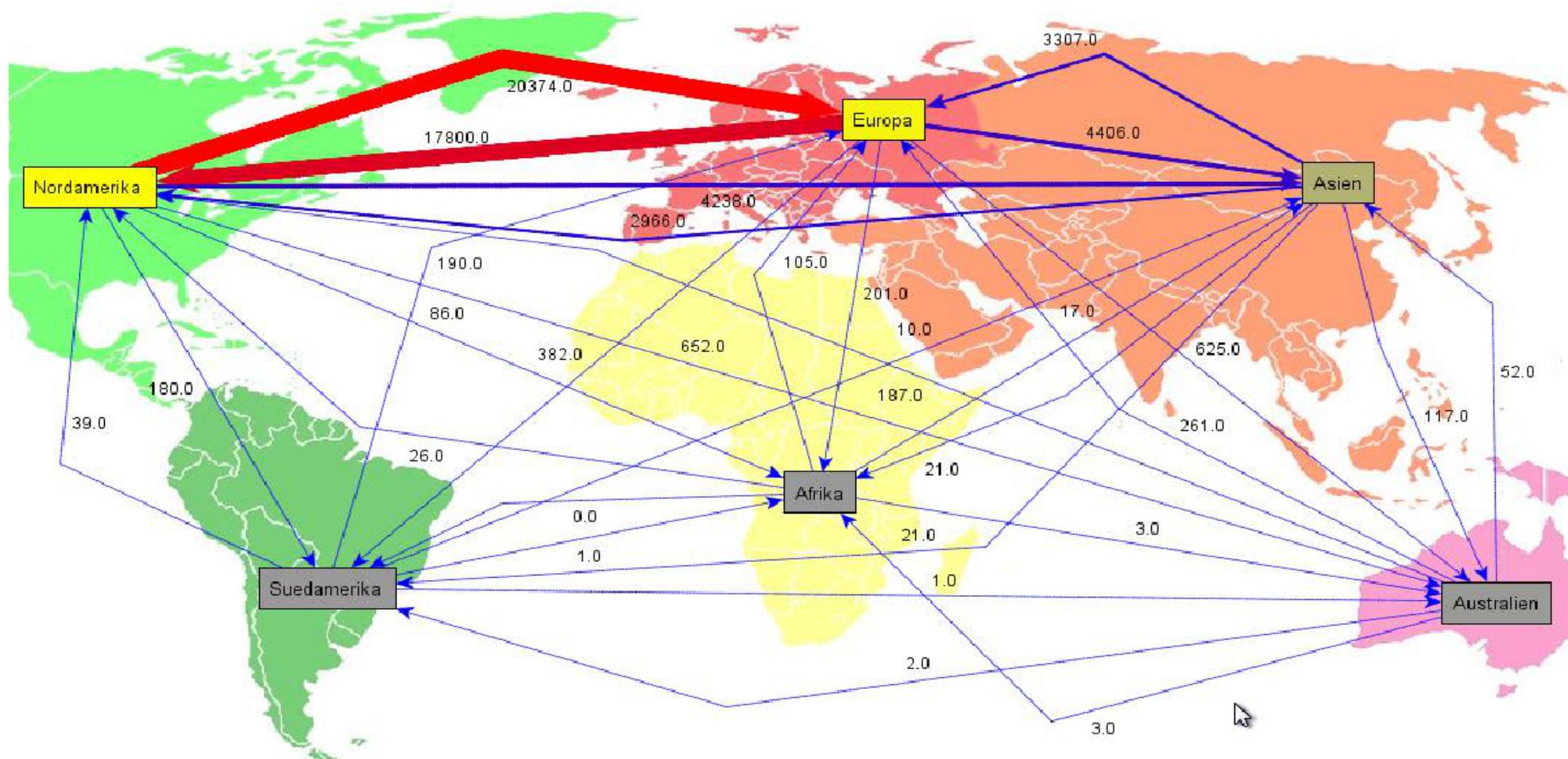
Graphenzeichnen?



Graphenzeichnen?

Kontinentale Aufteilung

2001 - 2005



Legende:

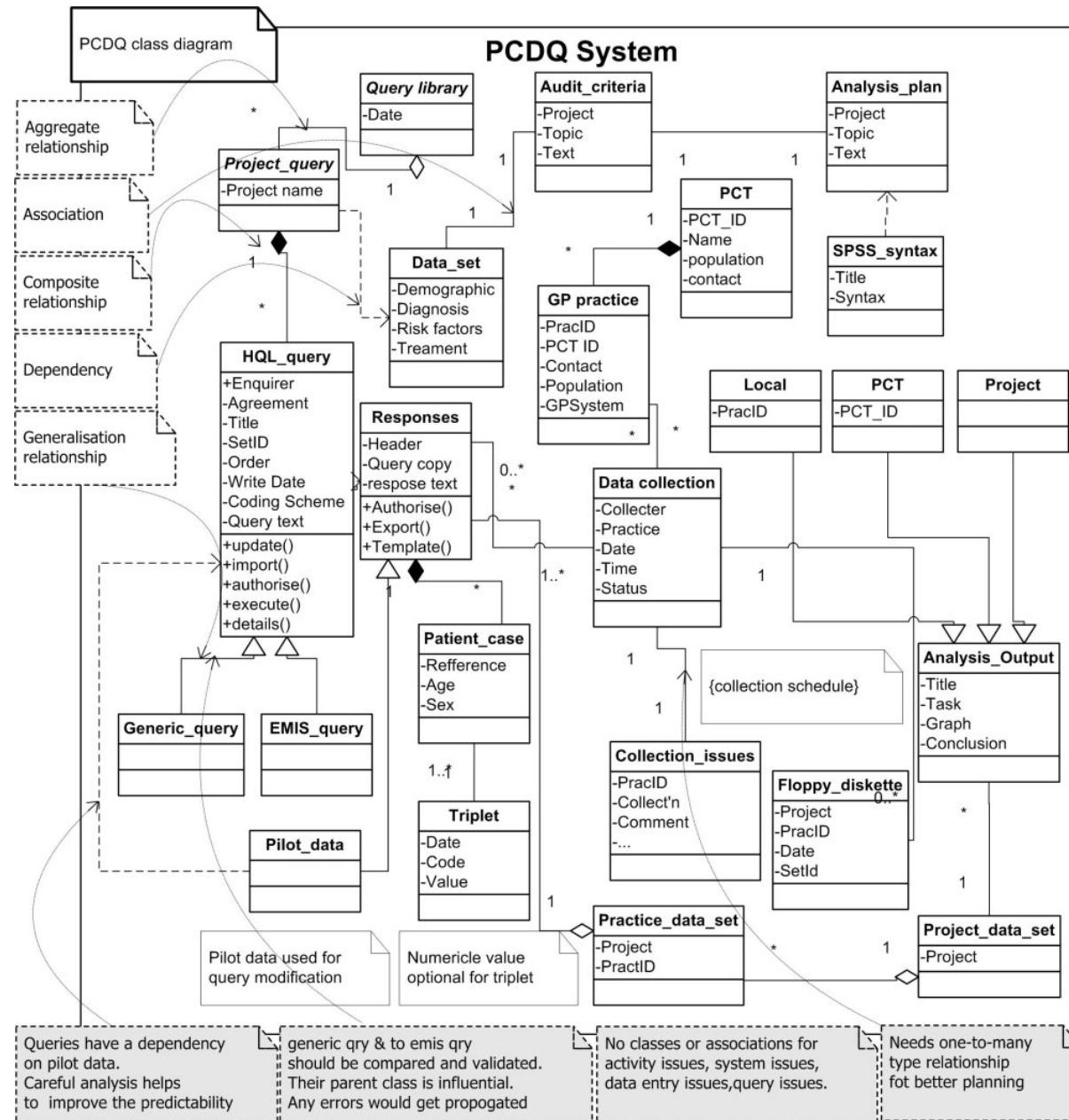
Kantengewicht:

- Maximum
- Minimum

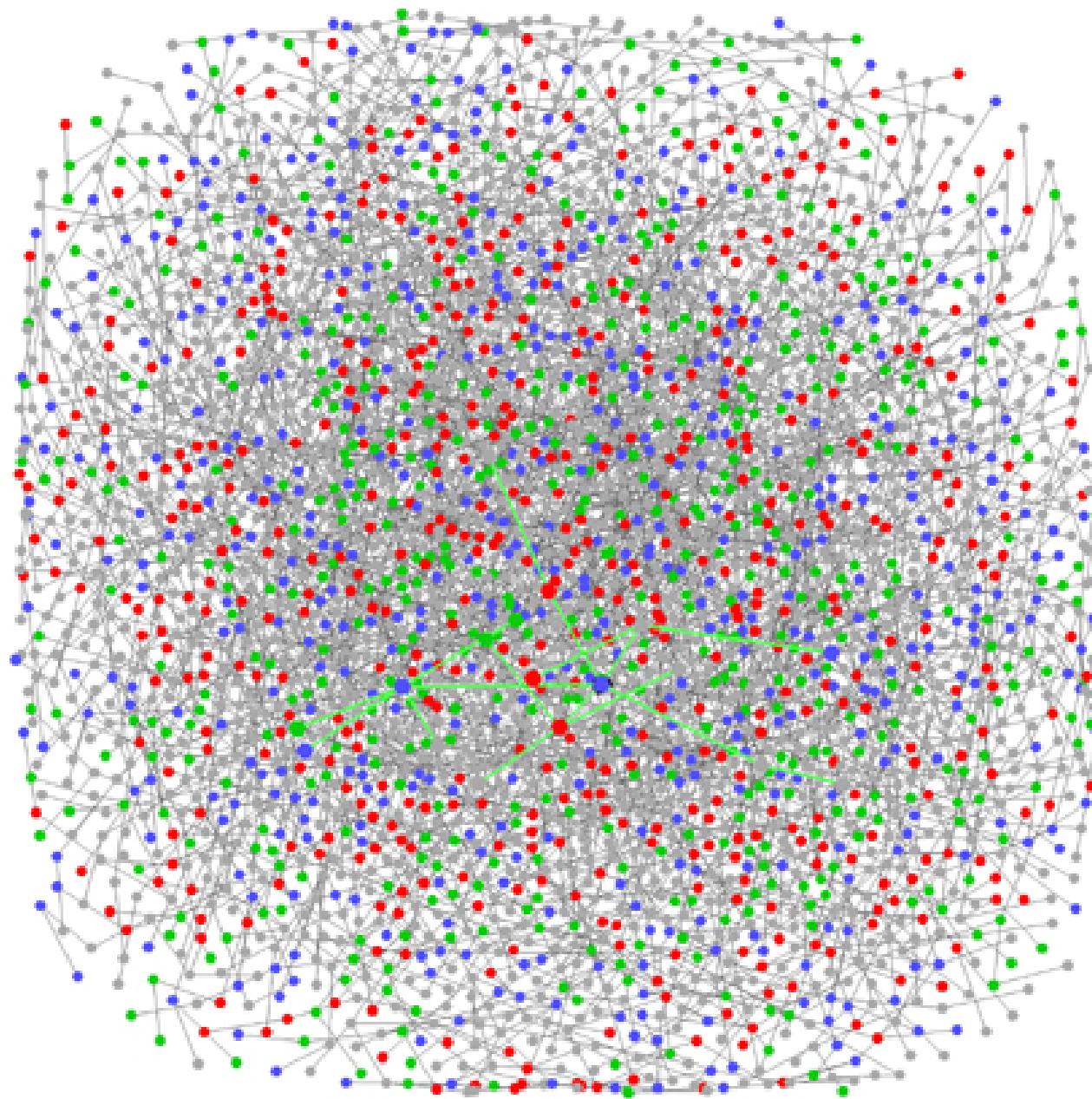
Ausgangsgrad:

- Maximum
- Minimum

Graphenzeichnen?



Graphenzeichnen?



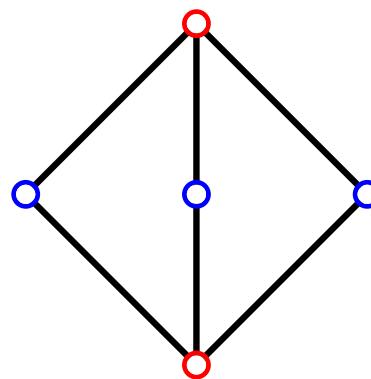
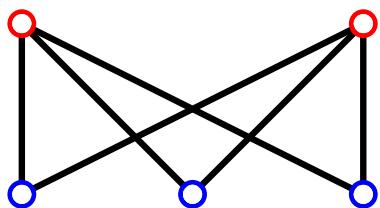
Winkelschematisierung

Schöne Zeichnungen?

Winkelschematisierung

Schöne Zeichnungen?

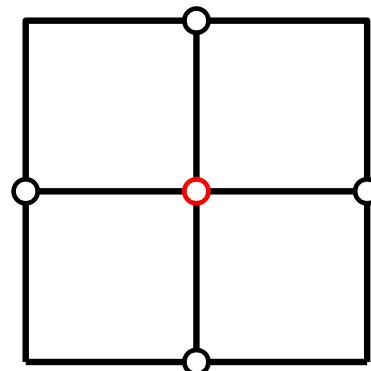
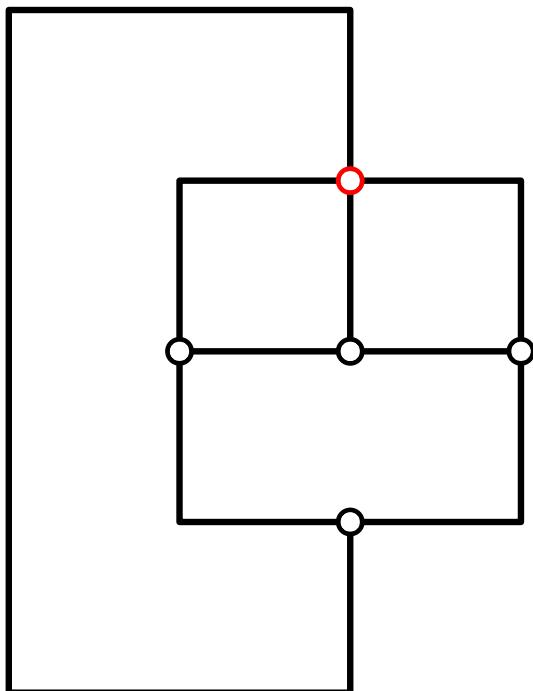
– Kreuzungsminimierung



Winkelschematisierung

Schöne Zeichnungen?

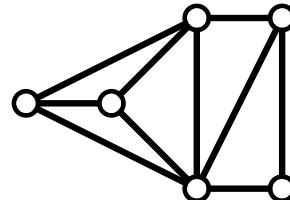
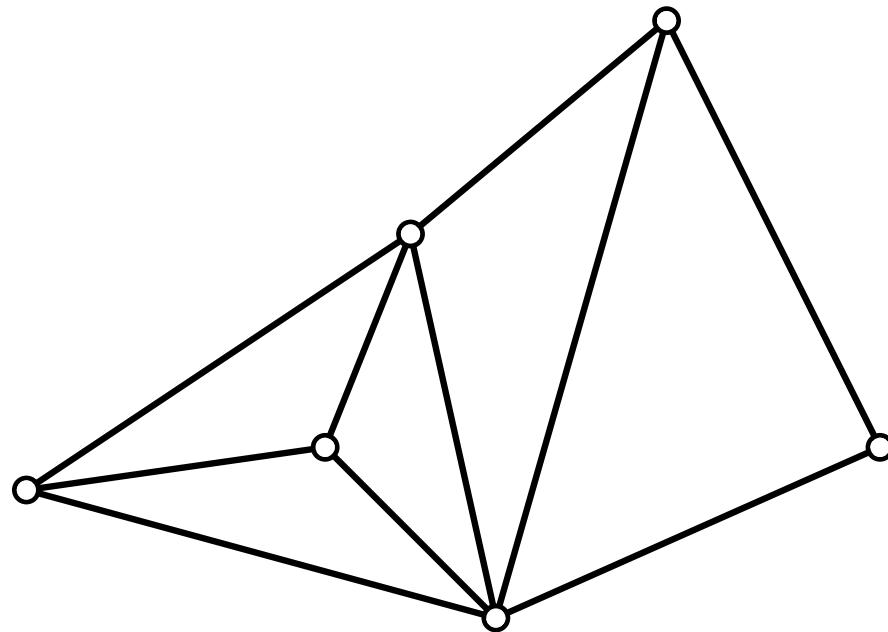
- Kreuzungsminimierung
- Knickminimierung



Winkelschematisierung

Schöne Zeichnungen?

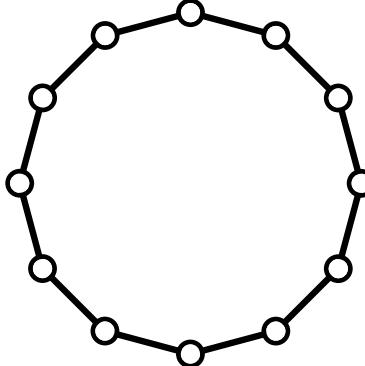
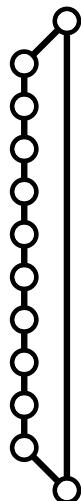
- Kreuzungsminimierung
- Knickminimierung
- minimale Fläche



Winkelschematisierung

Schöne Zeichnungen?

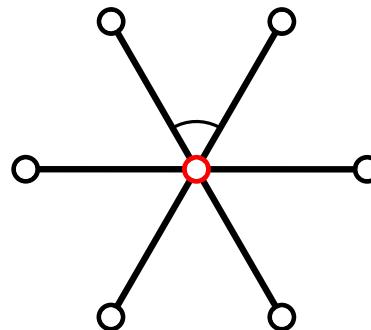
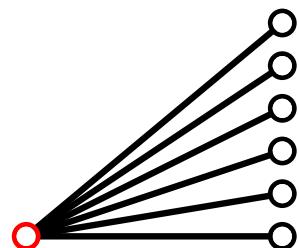
- Kreuzungsminimierung
- Knickminimierung
- minimale Fläche
- gleichmäßige Kantenlängen



Winkelschematisierung

Schöne Zeichnungen?

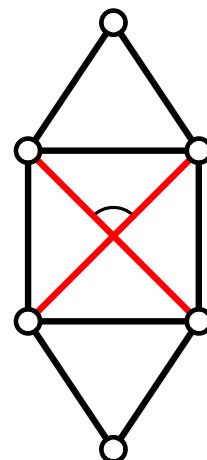
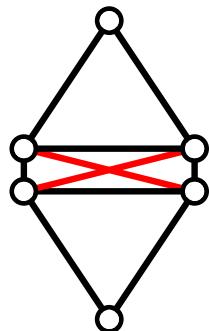
- Kreuzungsminimierung
- Knickminimierung
- minimale Fläche
- gleichmäßige Kantenlängen
- große Winkel
 - an Knoten



Winkelschematisierung

Schöne Zeichnungen?

- Kreuzungsminimierung
- Knickminimierung
- minimale Fläche
- gleichmäßige Kantenlängen
- große Winkel
 - an Knoten
 - an Kreuzungen



Gliederung

I. Platzieren von Boxen

- 1) Mehrseitige Randbeschriftungen
- 2) Approximationsalgorithmen für Rechtecks-Kontakt-Repräsentationen

II. Visuelle Führung

- 3) Glatt-orthogonale Darstellungen planarer Graphen
- 4) Monotone Zeichnungen von Bäumen

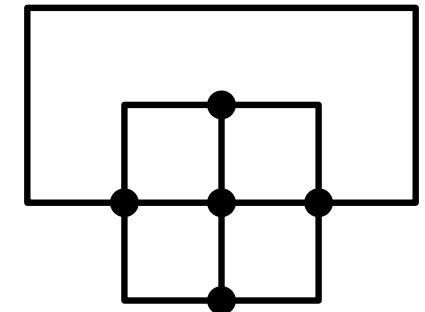
III. Kreuzungen mit großen Winkeln

- 5) Gleichzeitiges Zeichnen planarer Graphen mit rechtwinkligen Kreuzungen und wenig Knicken
- 6) Erkennen und Zeichnen von Graphen mit unabhängigen Kreuzungen

Glatt-orthogonale Darstellungen planarer Graphen

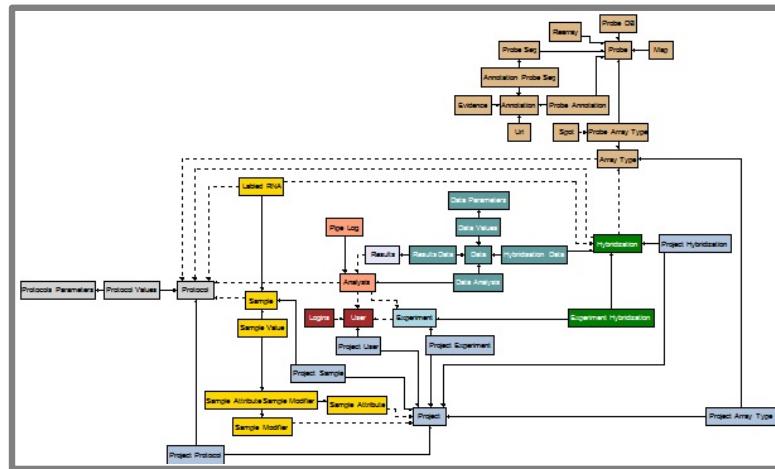
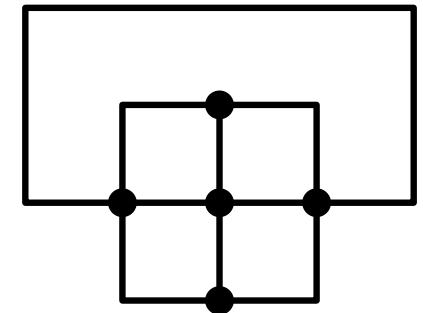
Orthogonale Darstellungen

- Alle Segmente sind horizontal oder vertikal
- Intensiv untersuchter Zeichenstil
- Viele Anwendungsbeispiele

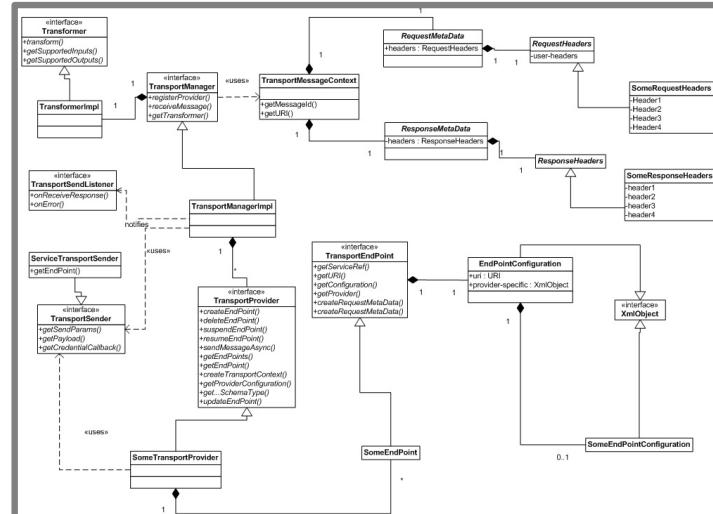


Orthogonale Darstellungen

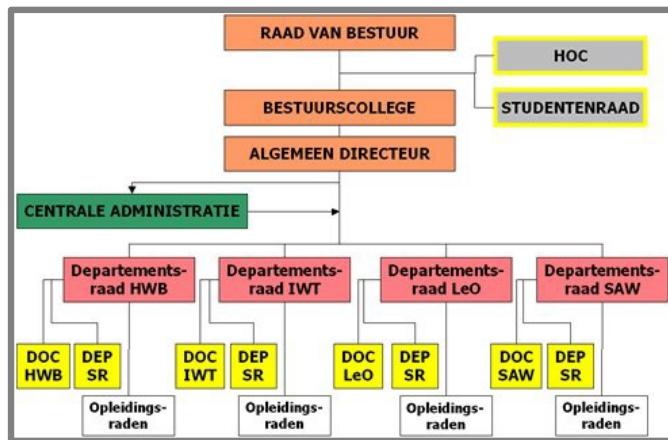
- Alle Segmente sind horizontal oder vertikal
- Intensiv untersuchter Zeichenstil
- Viele Anwendungsbeispiele



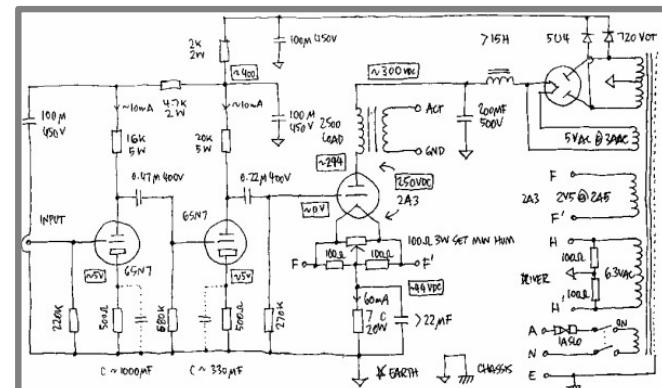
ER-Diagramm in OGDF



UML-Diagramm von Oracle



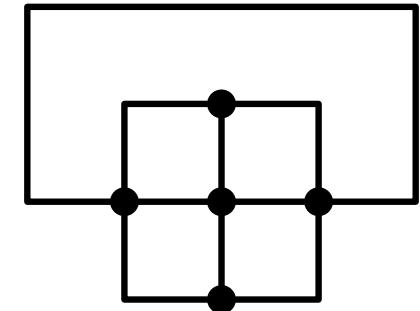
Organigramm von HS Limburg



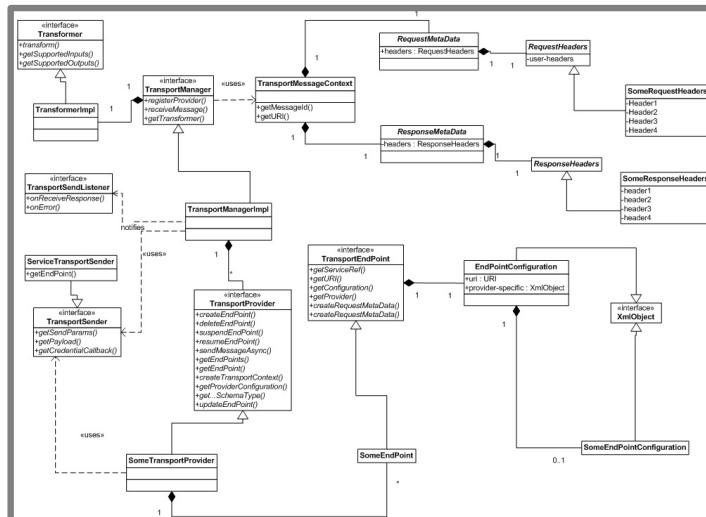
Schaltkreis-Diagramm von Jeff Atwood

Orthogonale Darstellungen

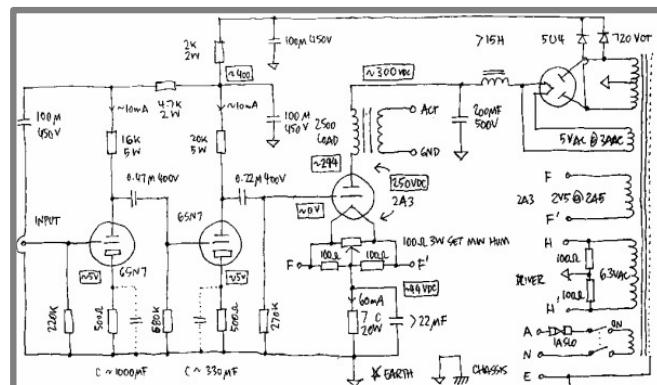
- Alle Segmente sind horizontal oder vertikal
 - Intensiv untersuchter Zeichenstil
 - Viele Anwendungsbeispiele



“Fused Grid” Stadtentwurf



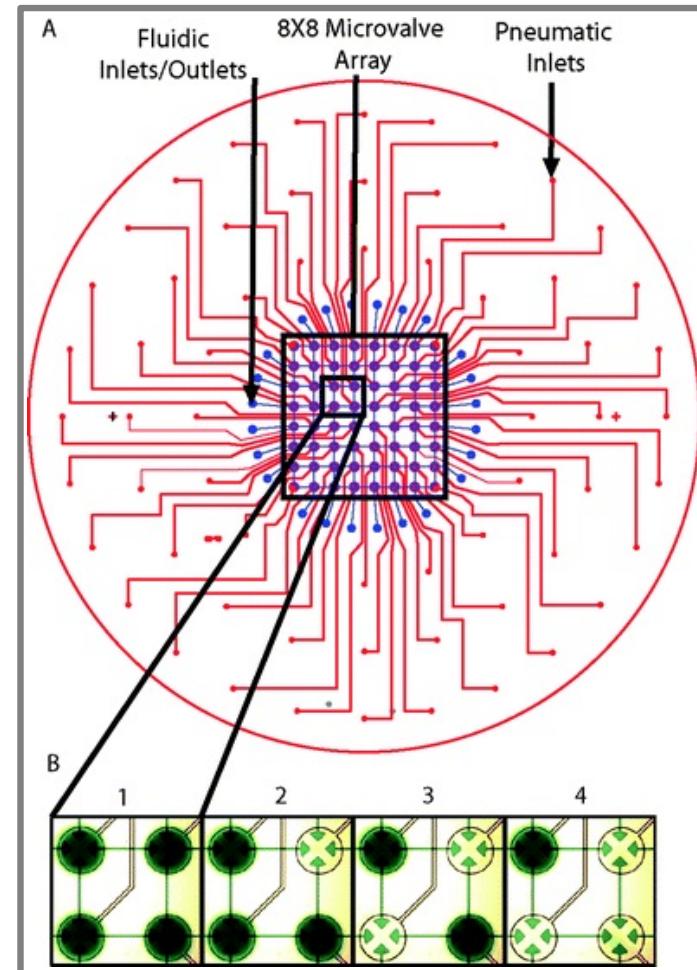
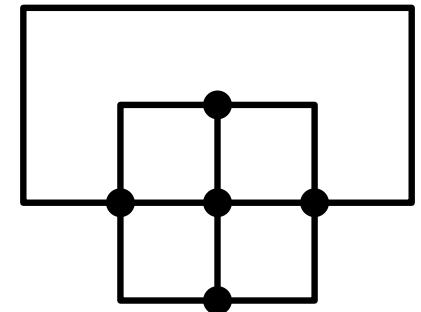
UML-Diagramm von Oracle



Schaltkreis-Diagramm von Jeff Atwood

Orthogonale Darstellungen

- Alle Segmente sind horizontal oder vertikal
- Intensiv untersuchter Zeichenstil
- Viele Anwendungsbeispiele



Glatte Zeichnungen



Mercedes W 114, 1967



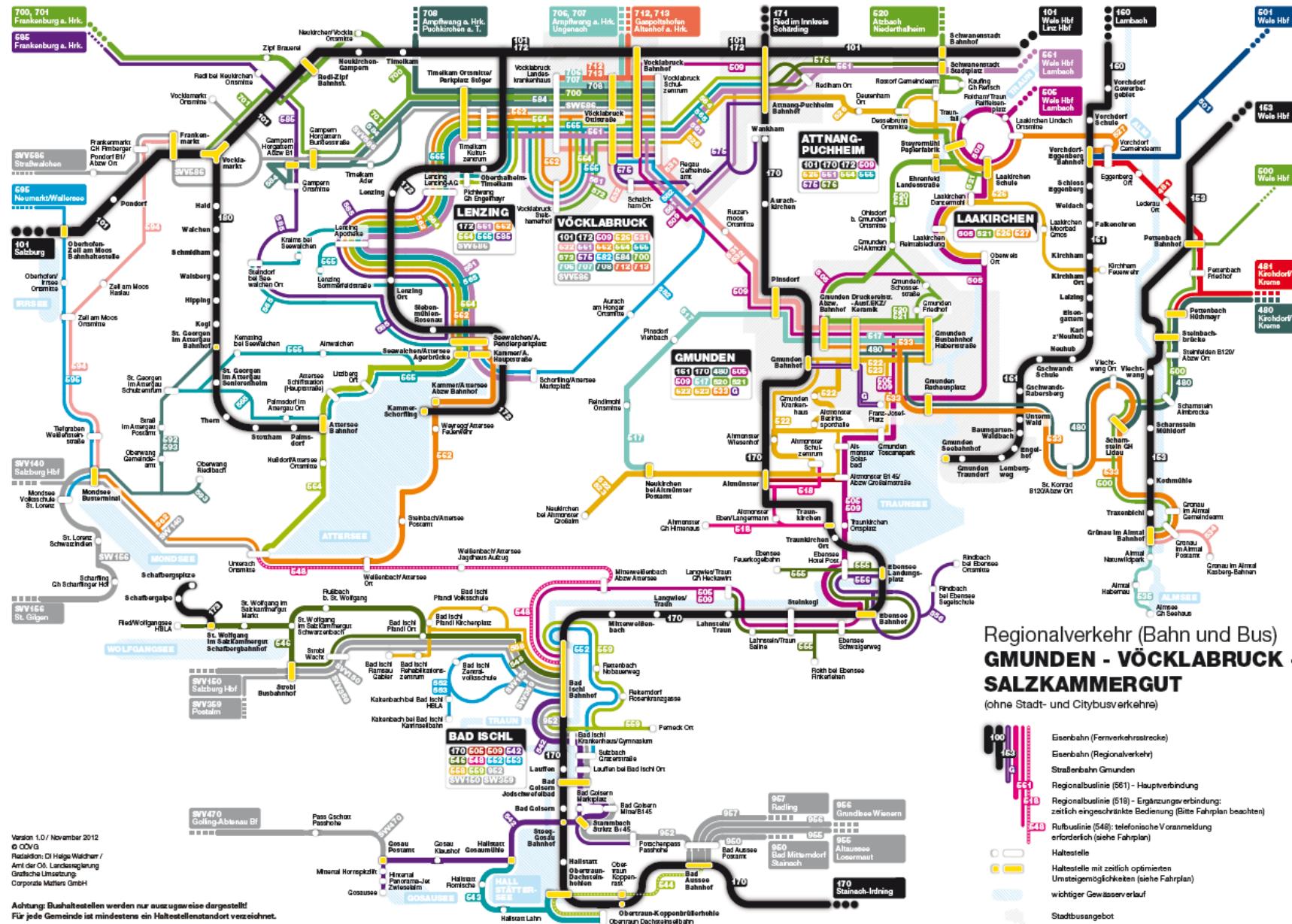
Nissan Friend-ME, 2013

Glatte Zeichnungen



Städtemodell

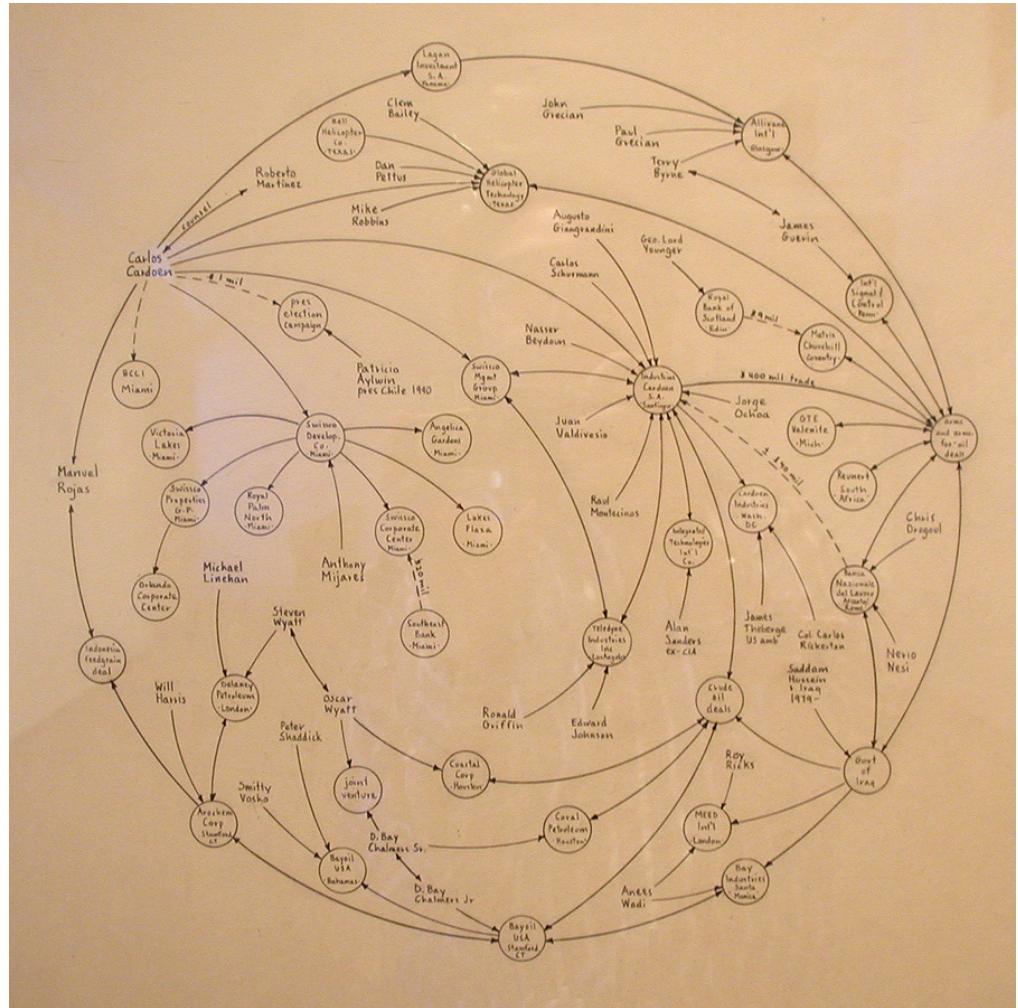
Glätte Zeichnungen



Glatte Zeichnungen

Lombardi-Zeichnungen

- Kreissegmente
- Perfekte
Winkelauflösung



Mark Lombardi
(1951–2000)

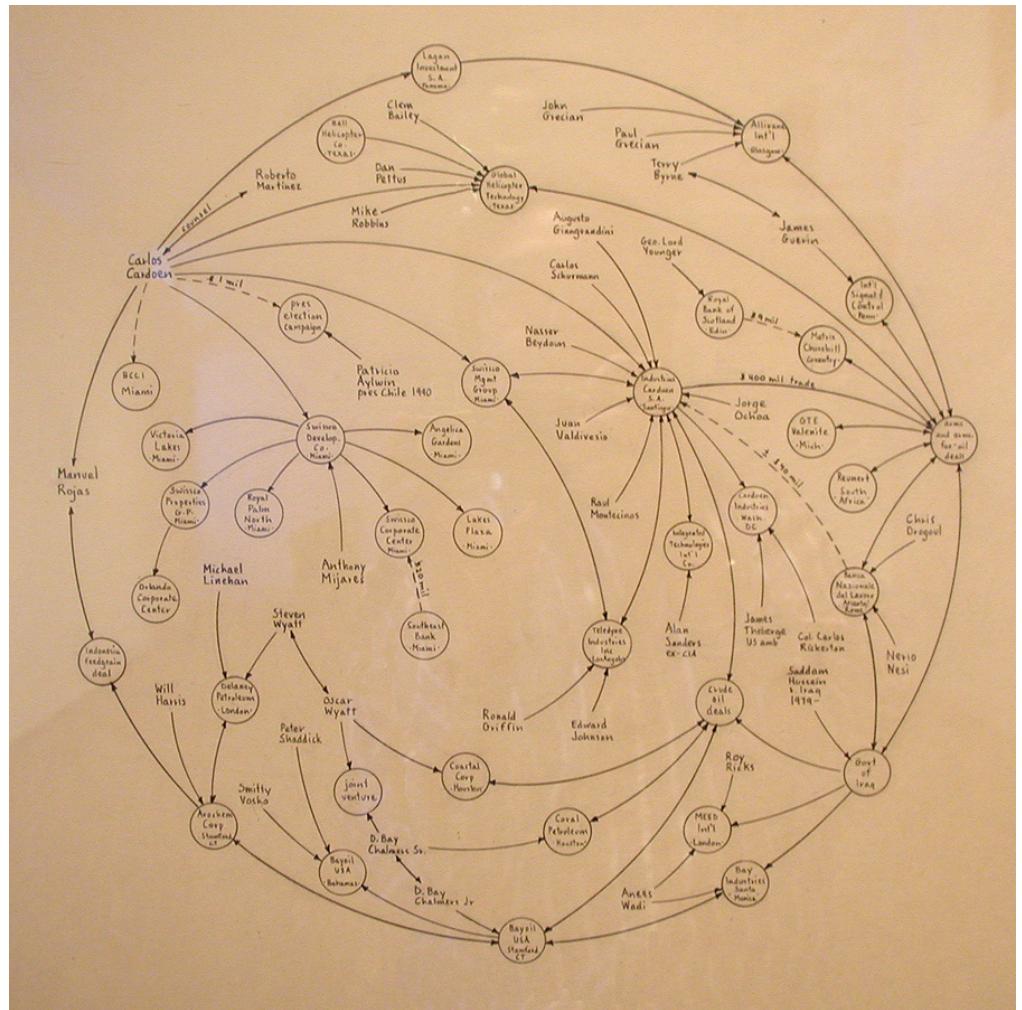
Glatte Zeichnungen

Lombardi-Zeichnungen

- Kreissegmente
- Perfekte
Winkelauflösung

k-Lombardi-Zeichnungen

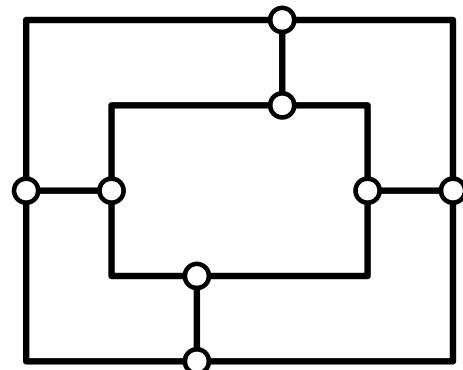
- Kanten bestehen aus k
Kreissegmenten



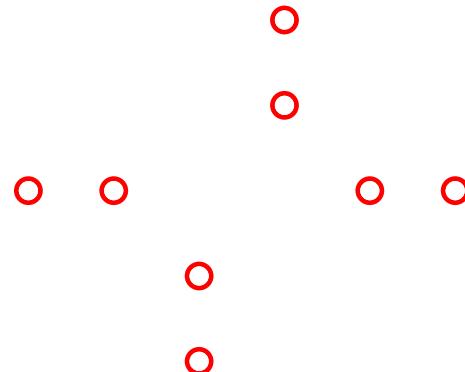
Mark Lombardi
(1951–2000)

Glatt-orthogonale Darstellungen

Vereine beide Welten:



orthogonal

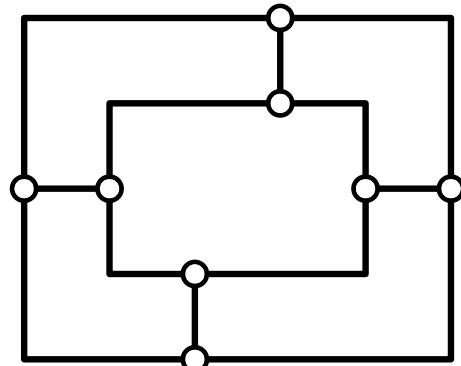


glatt-orthogonal

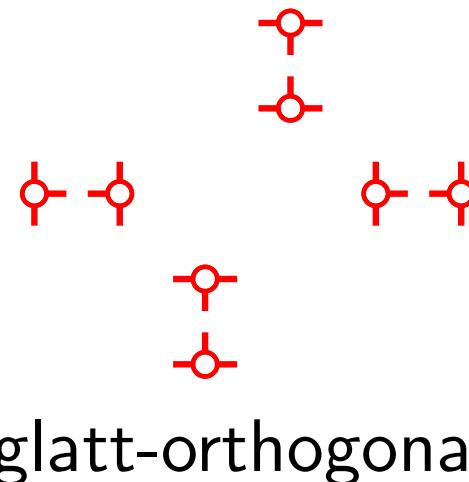
Glatt-orthogonale Darstellungen

Vereine beide Welten:

- Kanten treffen horizontal oder vertikal auf Knoten



orthogonal

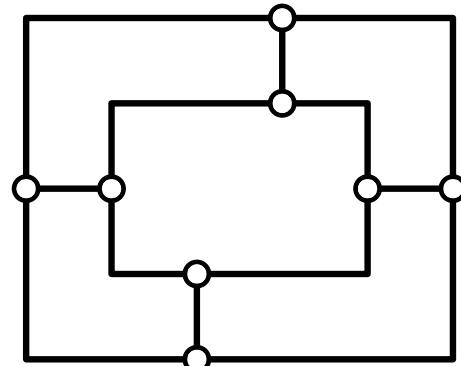


glatt-orthogonal

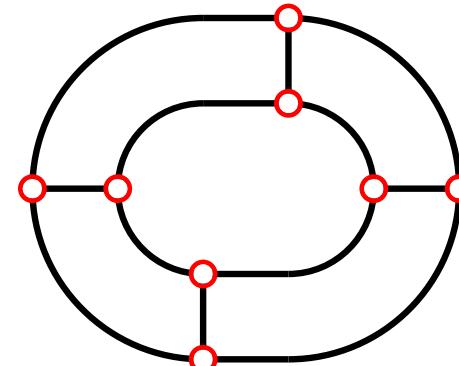
Glatt-orthogonale Darstellungen

Vereine beide Welten:

- Kanten treffen horizontal oder vertikal auf Knoten
- Kanten bestehen aus achsen-parallel Segmenten und Kreissegmenten ohne Knicke



orthogonal

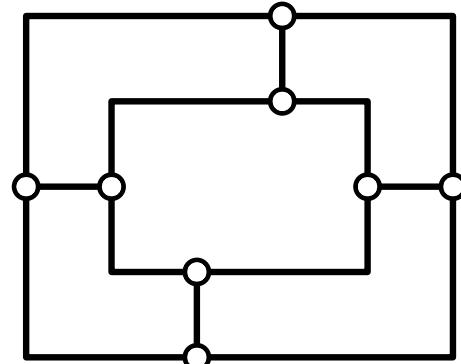


glatt-orthogonal

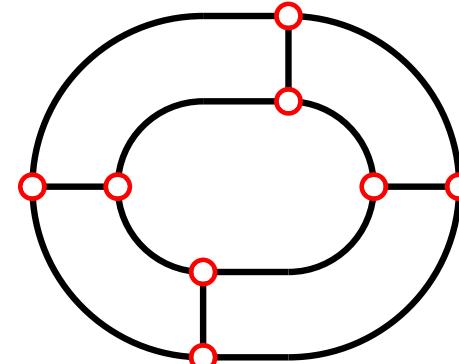
Glatt-orthogonale Darstellungen

Vereine beide Welten:

- Kanten treffen horizontal oder vertikal auf Knoten
 - Kanten bestehen aus achsen-parallelens Segmenten und Kreissegmenten ohne Knicke
 - Es gibt keine Kantenkreuzungen (für planare Graphen)

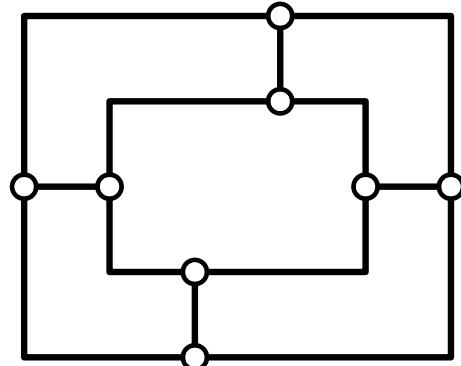


orthogonal

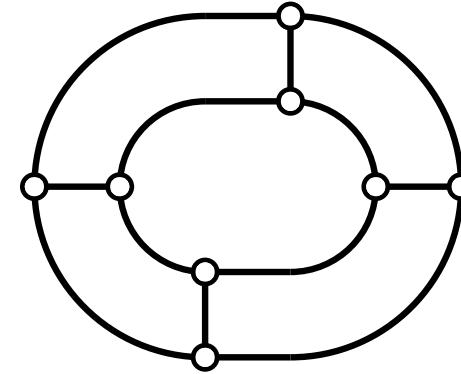


glatt-orthogonal

Kantenkomplexität



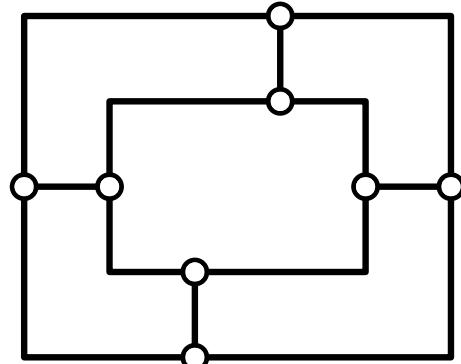
orthogonal



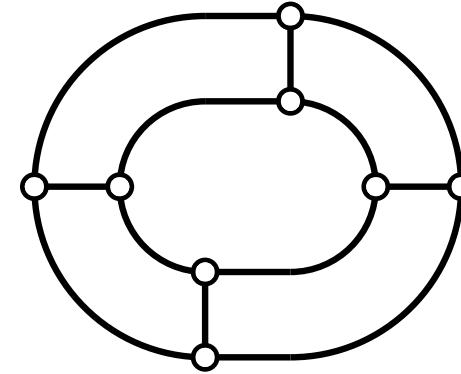
glatt-orthogonal

Kantenkomplexität

Komplexität einer Kante: Anzahl der Segmente



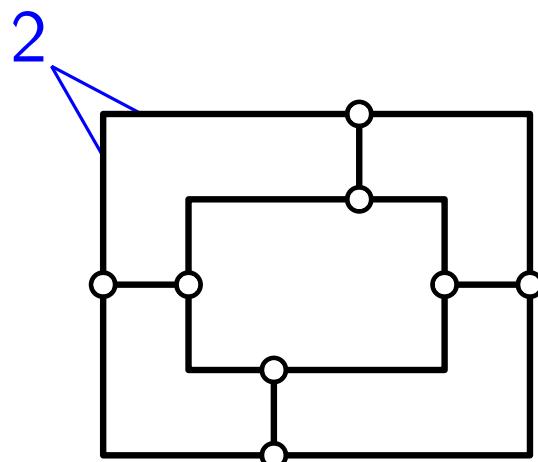
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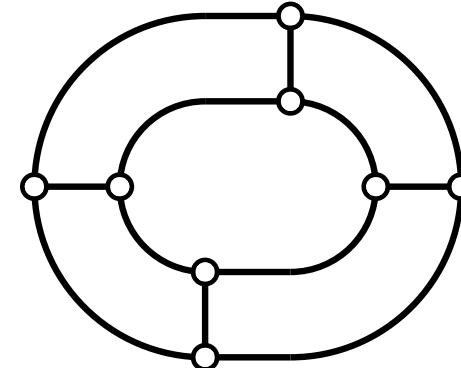
glatt-orthogonal

Kantenkomplexität

Komplexität einer Kante: Anzahl der Segmente



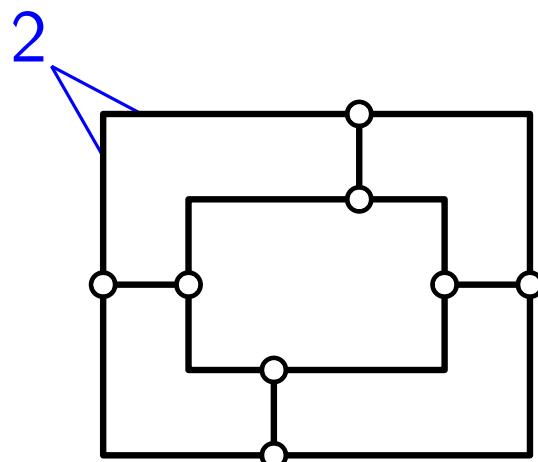
orthogonal



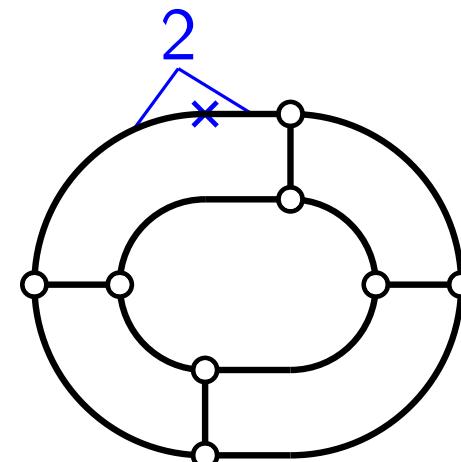
glatt-orthogonal

Kantenkomplexität

Komplexität einer Kante: Anzahl der Segmente



orthogonal

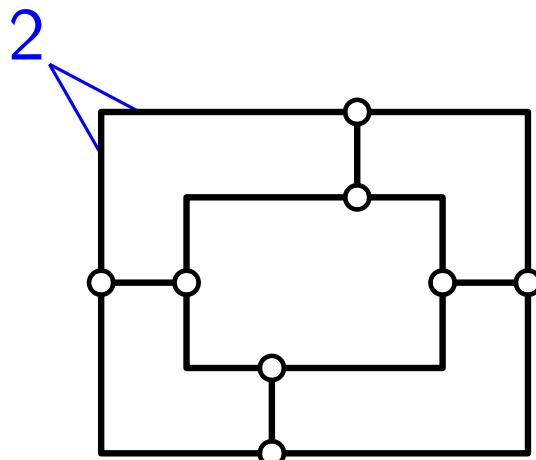


glatt-orthogonal

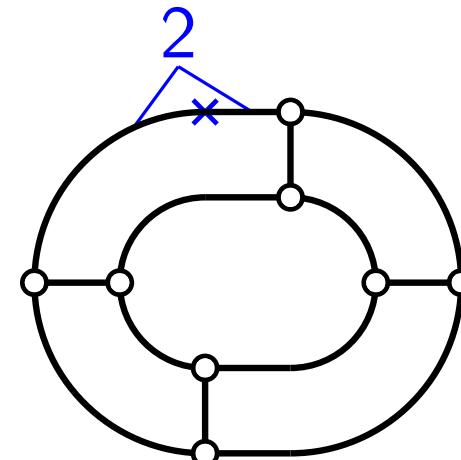
Kantenkomplexität

Komplexität einer Kante: Anzahl der Segmente

Komplexität einer Zeichnung: Größte Komplexität aller Kanten



orthogonal

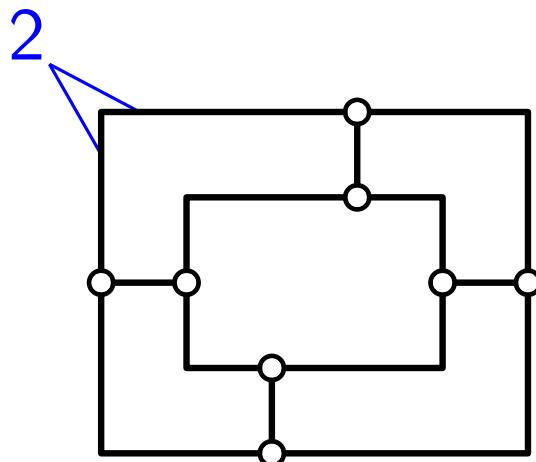
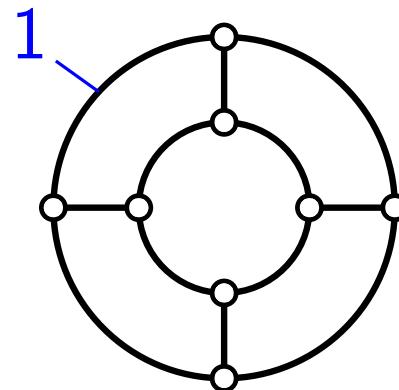
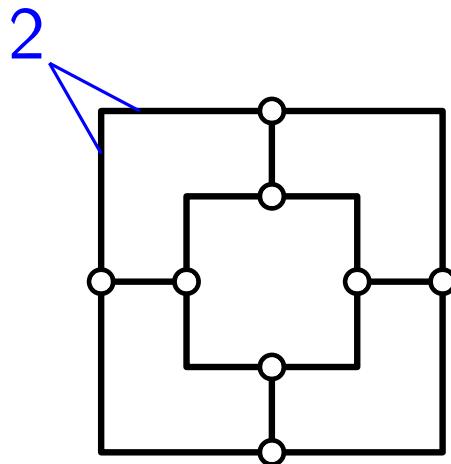


glatt-orthogonal

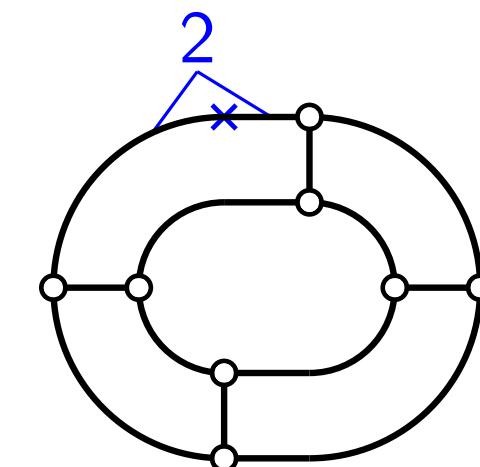
Kantenkomplexität

Komplexität einer Kante: Anzahl der Segmente

Komplexität einer Zeichnung: Größte Komplexität aller Kanten



orthogonal



glatt-orthogonal

Bekannte Resultate

Biedl & Kant [CGTA'98],

Liu et al. [DAM'98]

4-planarer Graph \Rightarrow orth. Komplexität 3, $(n \times n)$ -Gitter

Bekannte Resultate

Biedl & Kant [CGTA'98],

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4-planarer Graph \Rightarrow orth. Komplexität 3, $(n \times n)$ -Gitter

Bekos et al.

[GD'12]

- ➊ Zweifach zusammenhängender 4-planarer Graph \Rightarrow glatt-orth. Komplexität 3

Bekannte Resultate

Biedl & Kant [CGTA'98],

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4-planarer Graph \Rightarrow orth. Komplexität 3, $(n \times n)$ -Gitter

Bekos et al.

[GD'12]

- Zweifach zusammenhängender 4-planarer Graph \Rightarrow glatt-orth. Komplexität 3
- 4-planarer Graph $\not\Rightarrow$ glatt-orth. Komplexität 1

Bekannte Resultate

Biedl & Kant [CGTA'98],

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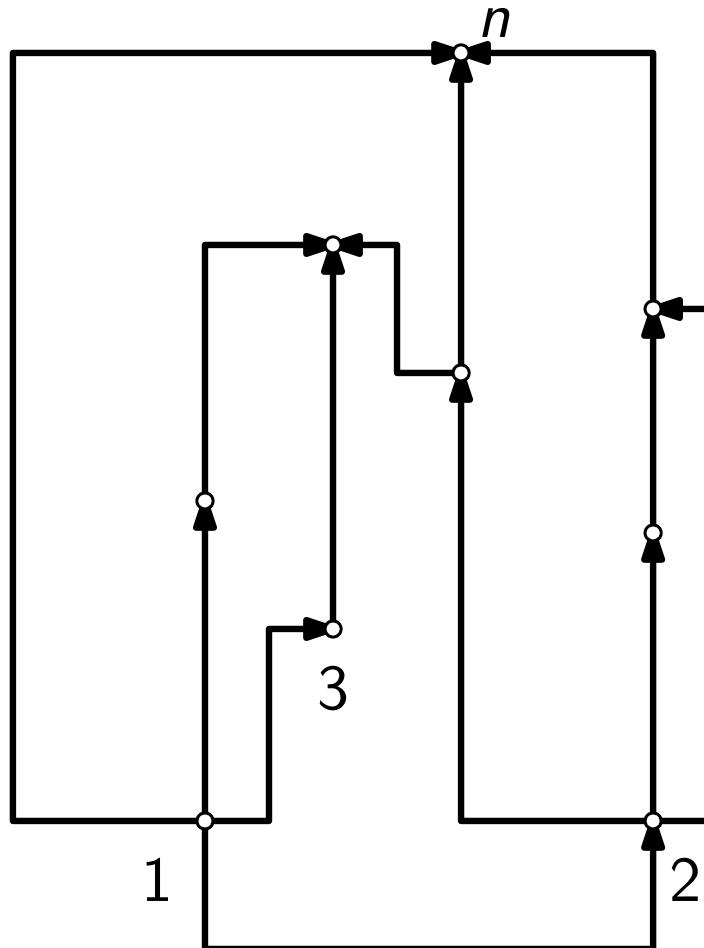
4-planarer Graph \Rightarrow orth. Komplexität 3, $(n \times n)$ -Gitter

Bekos et al.

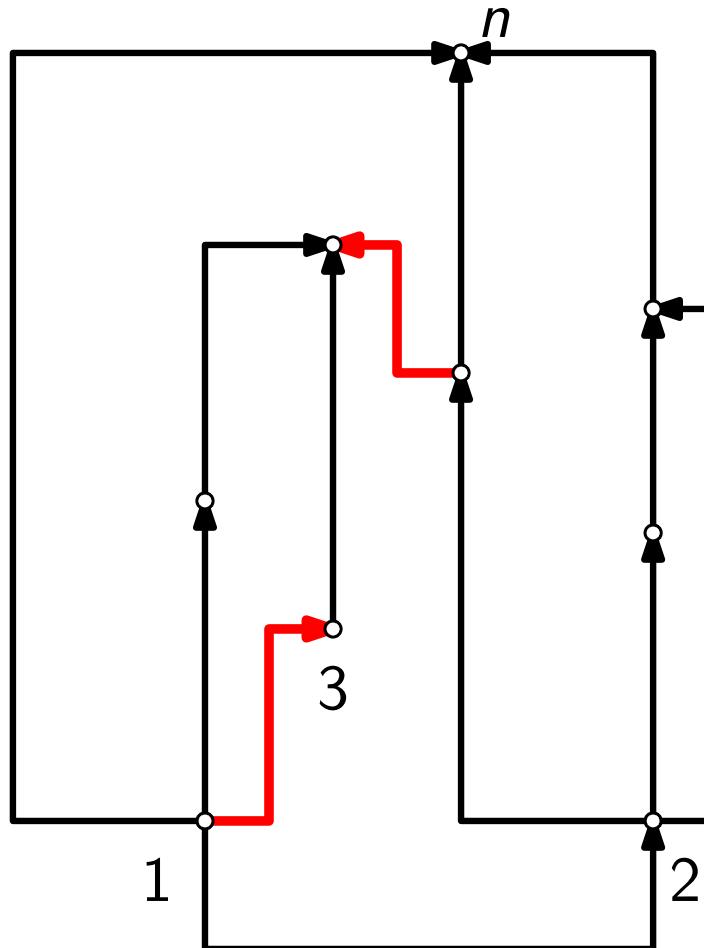
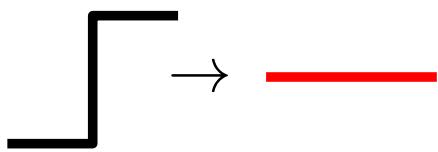
[GD'12]

- Zweifach zusammenhängender 4-planarer Graph \Rightarrow glatt-orth. Komplexität 3
- 4-planarer Graph $\not\Rightarrow$ glatt-orth. Komplexität 1

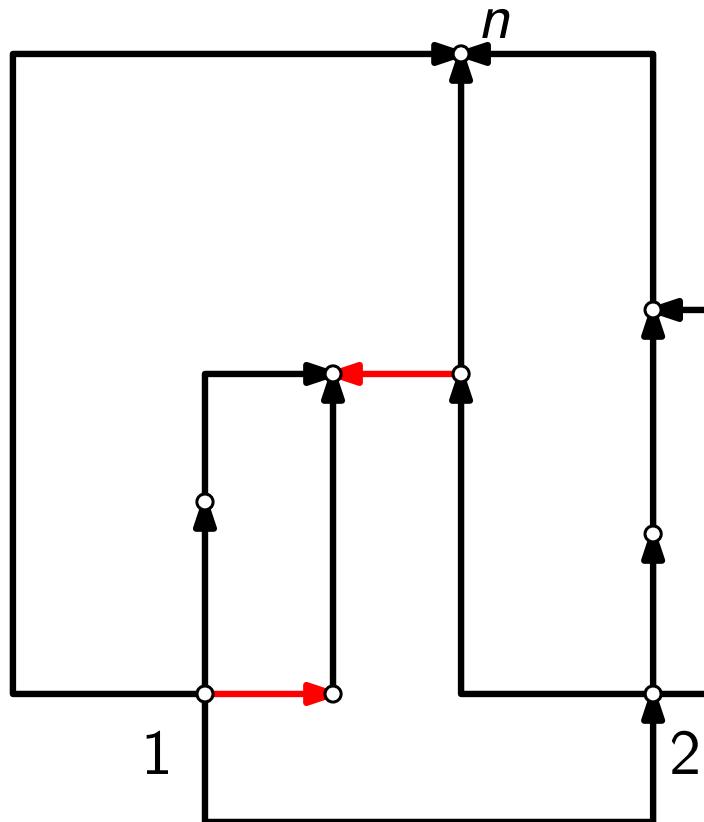
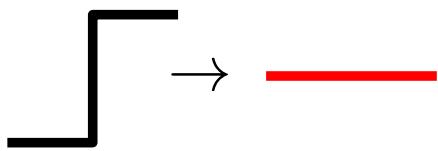
Komplexität-2 Zeichnungen



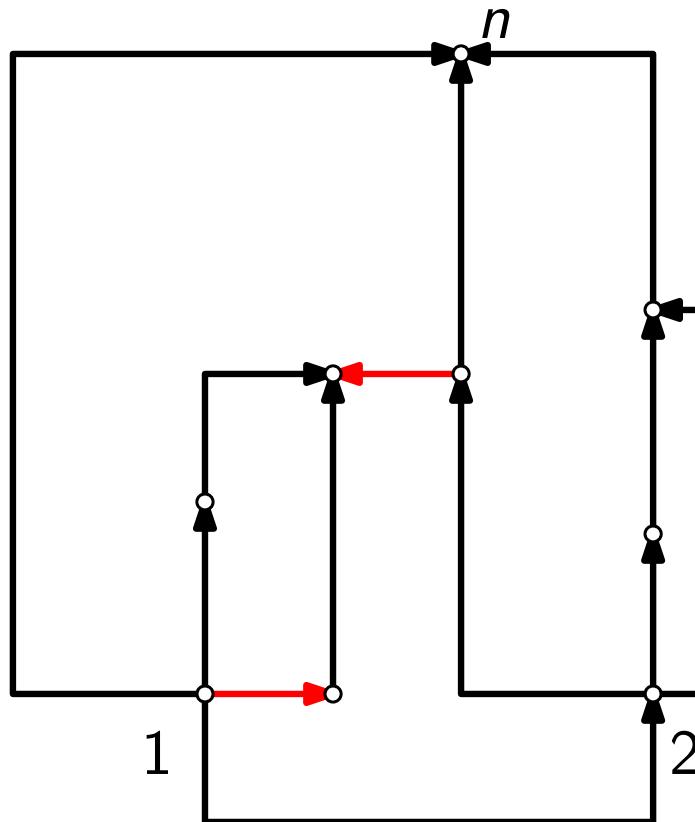
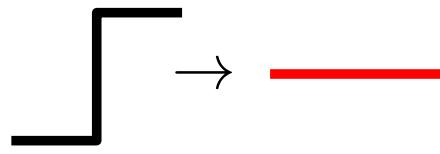
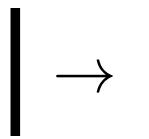
Komplexität-2 Zeichnungen



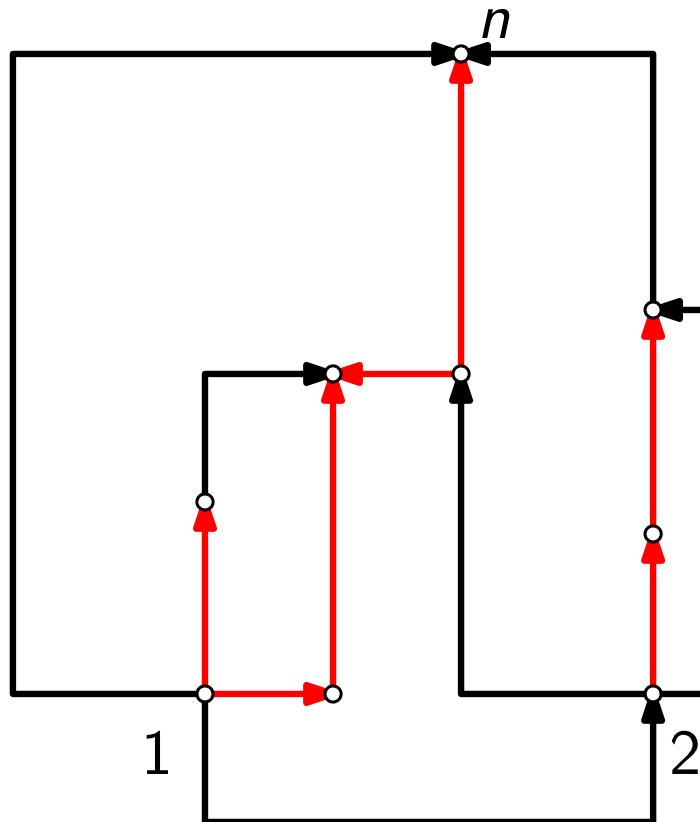
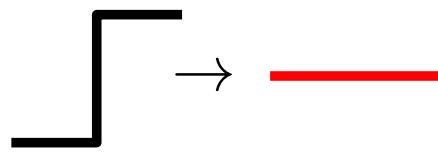
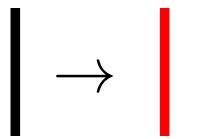
Komplexität-2 Zeichnungen



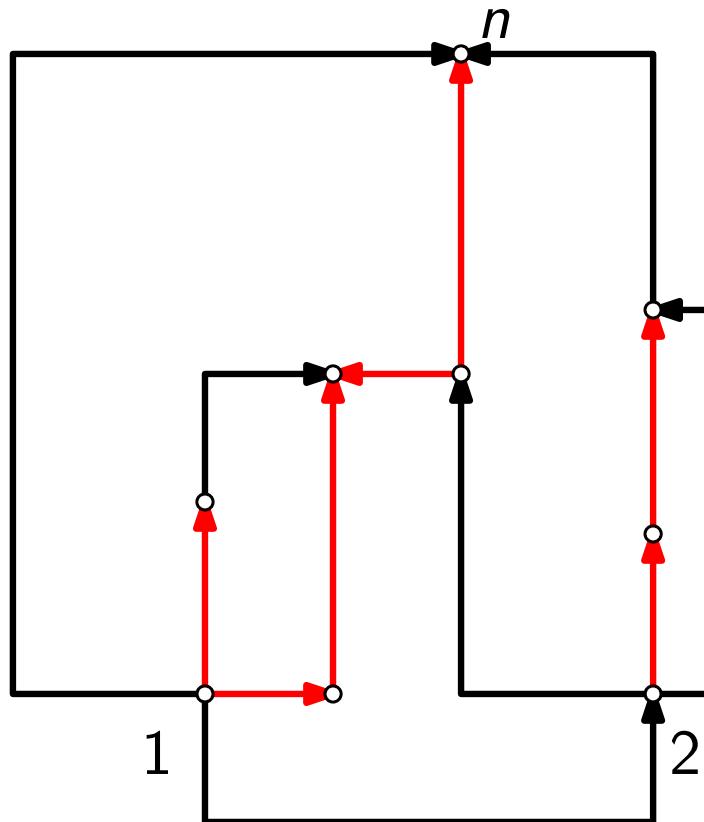
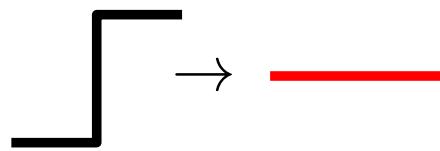
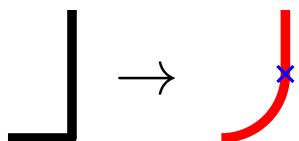
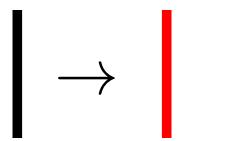
Komplexität-2 Zeichnungen



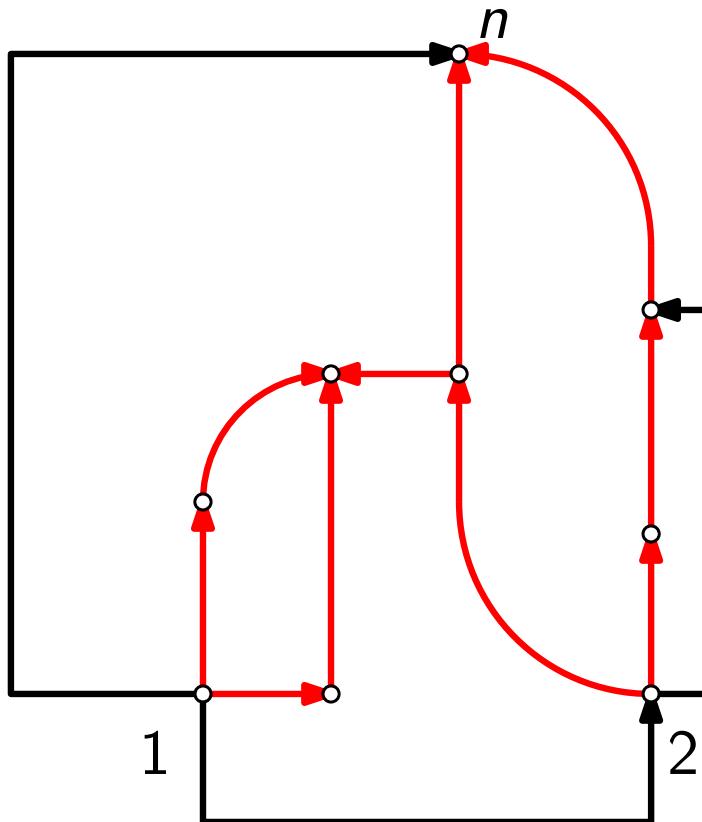
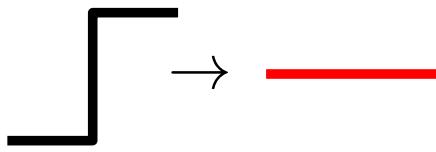
Komplexität-2 Zeichnungen



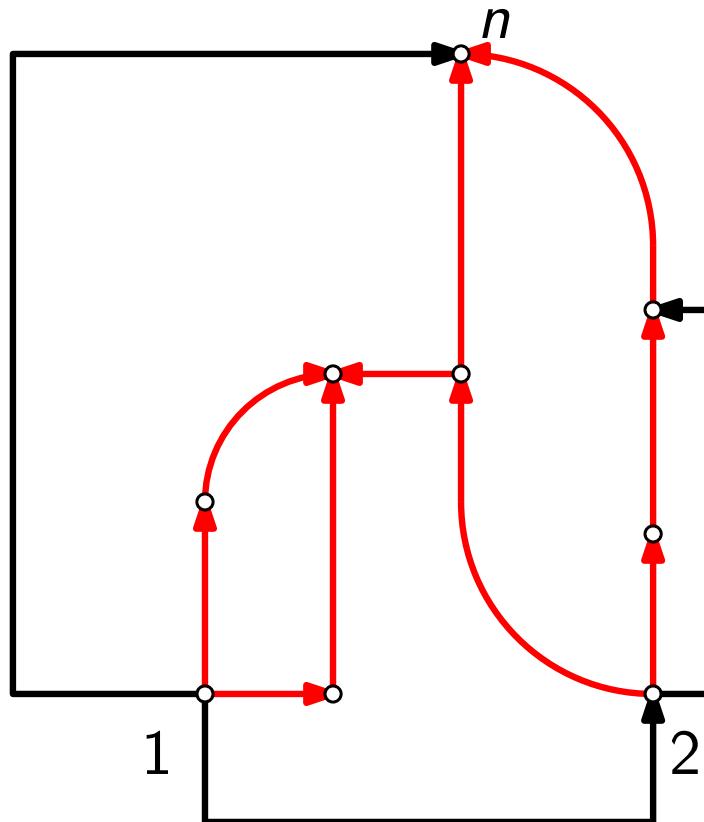
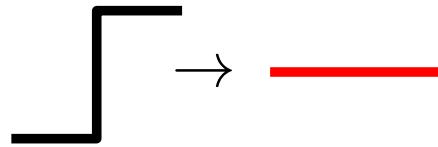
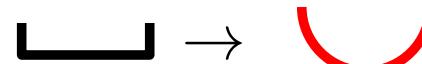
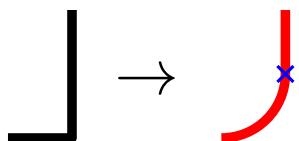
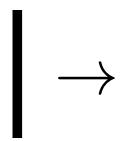
Komplexität-2 Zeichnungen



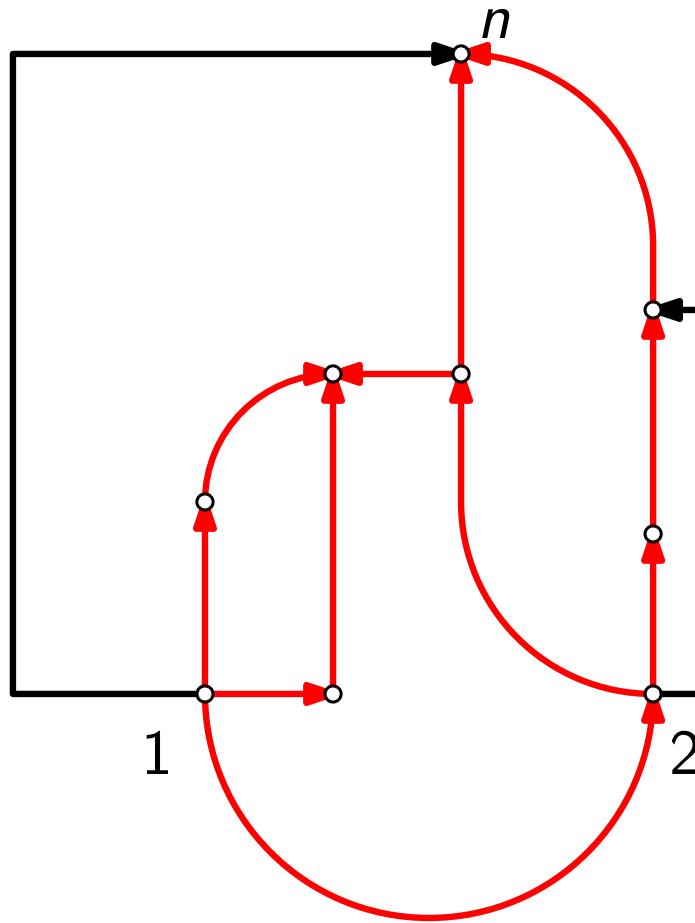
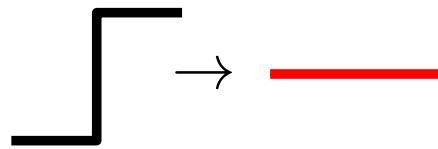
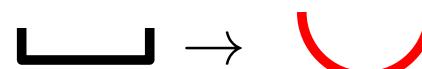
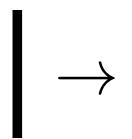
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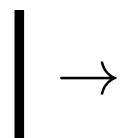
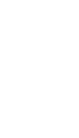
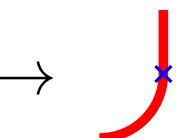
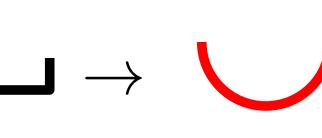
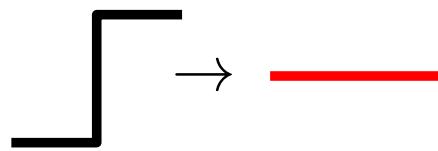
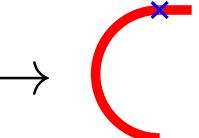
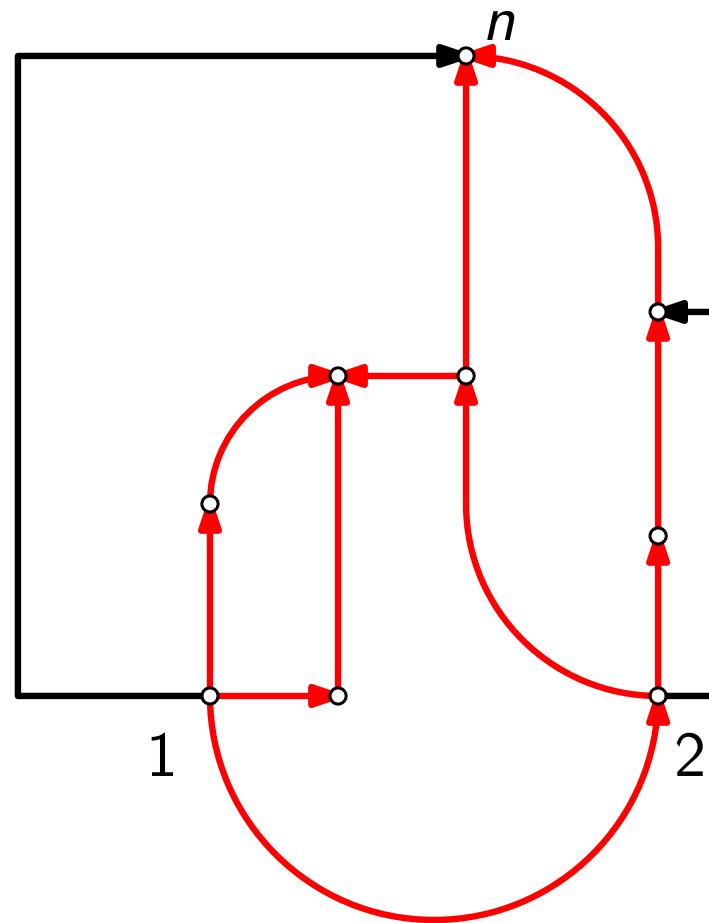
Komplexität-2 Zeichnungen



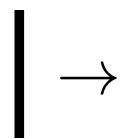
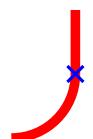
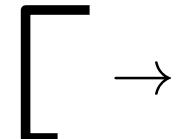
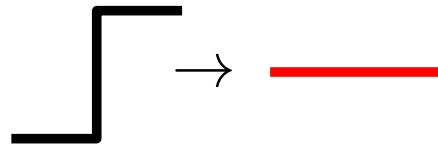
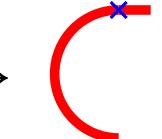
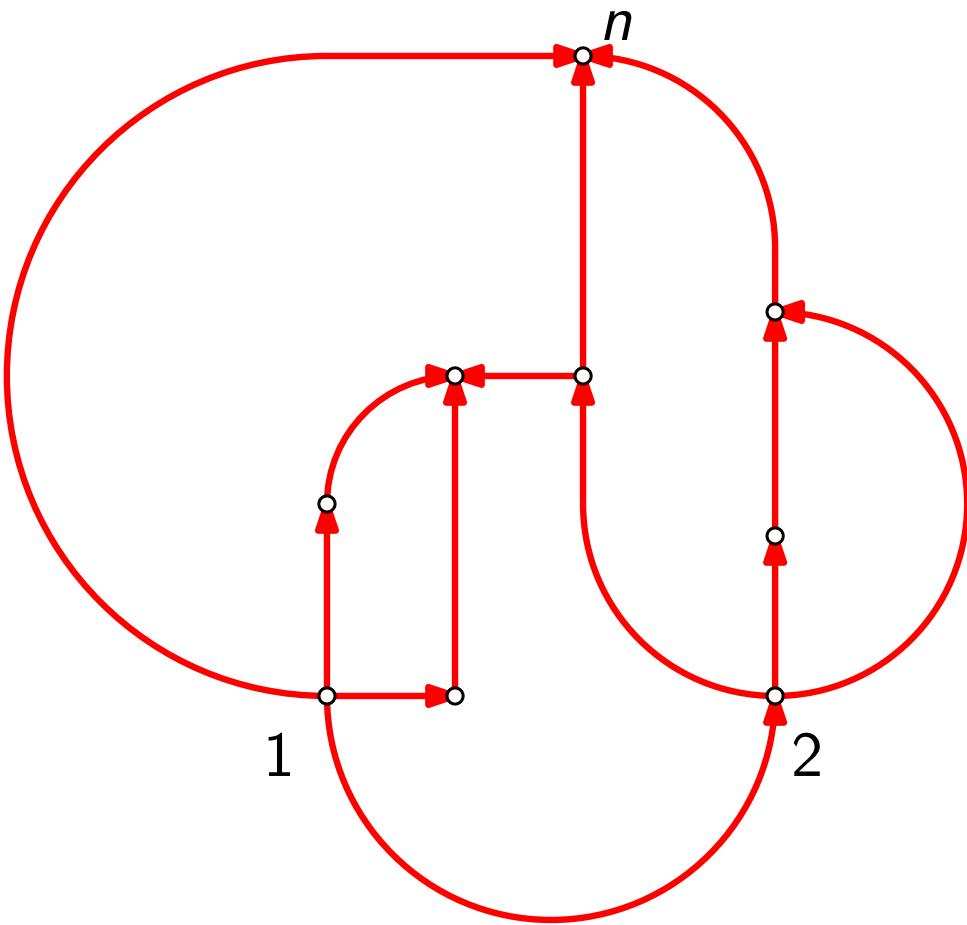
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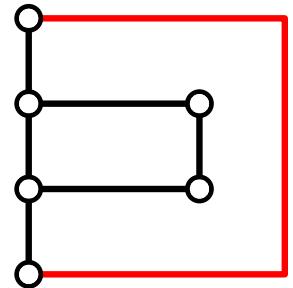
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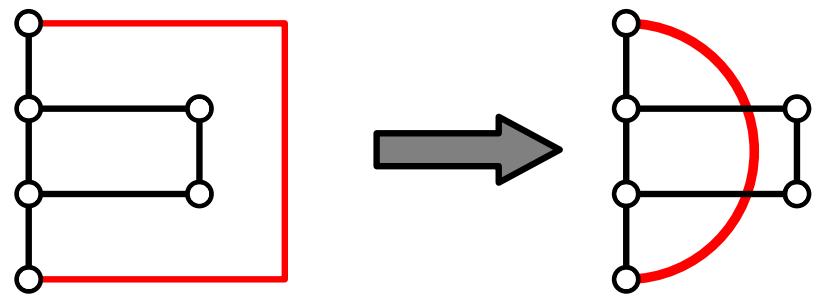
Komplexität-2 Zeichnungen

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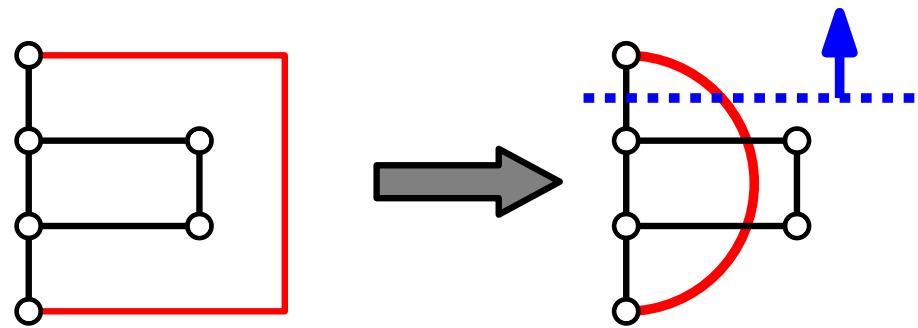
Kreuzungen



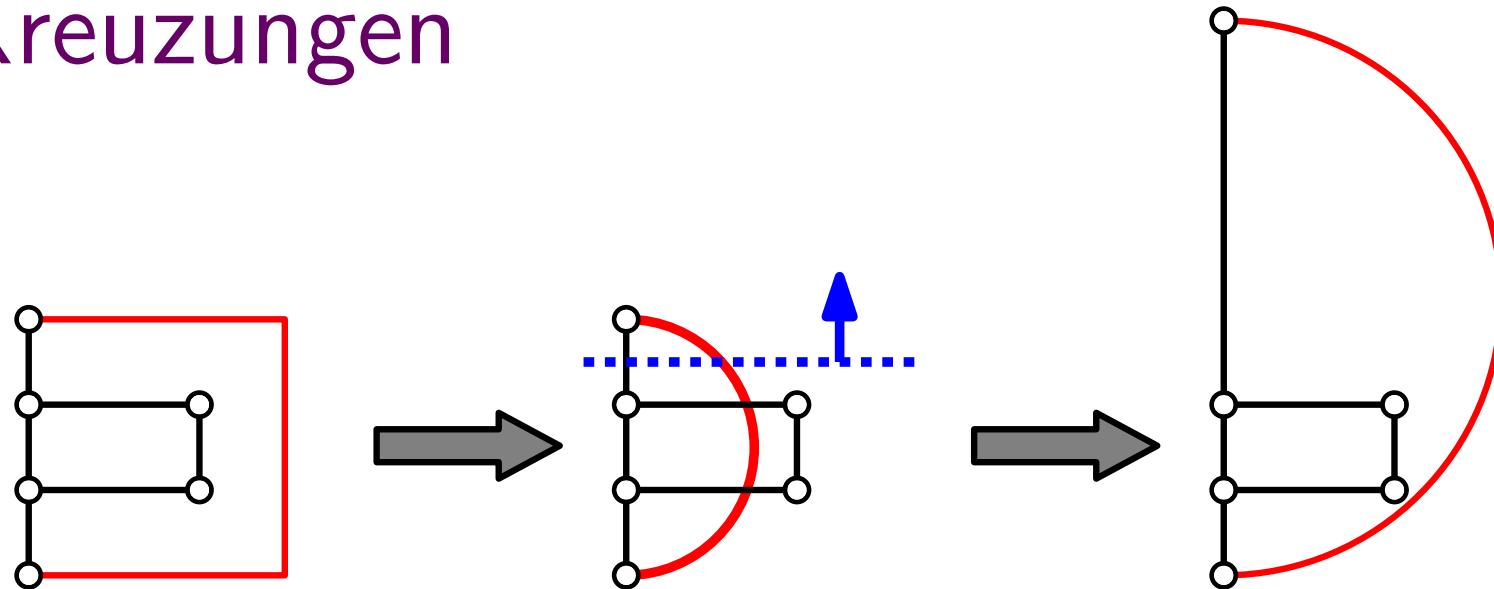
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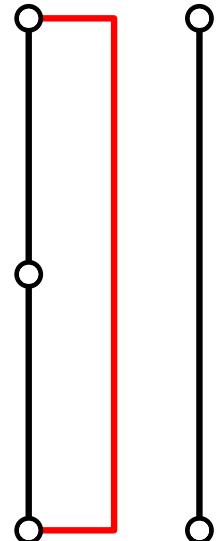
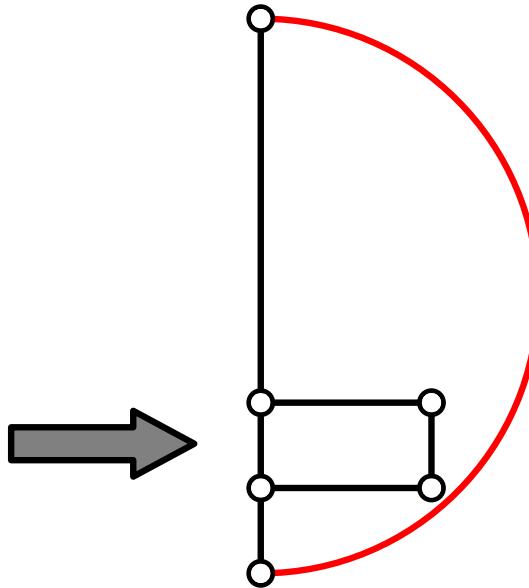
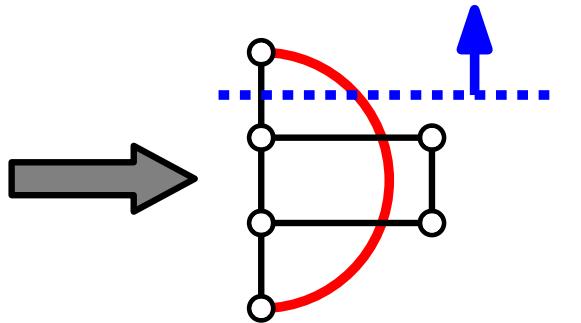
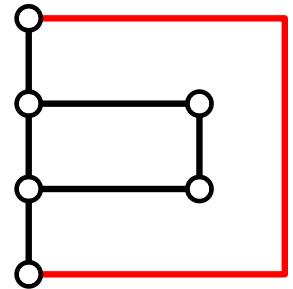
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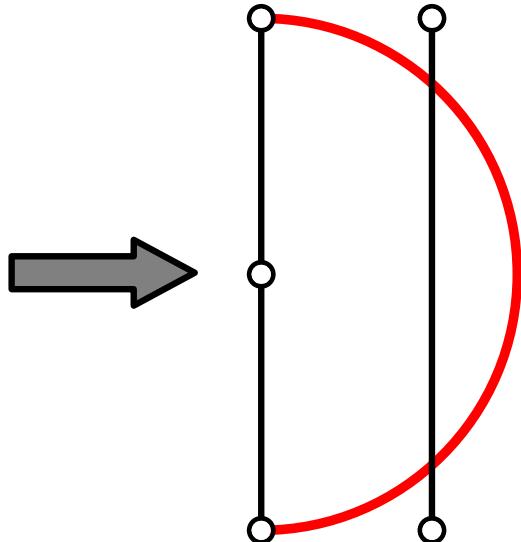
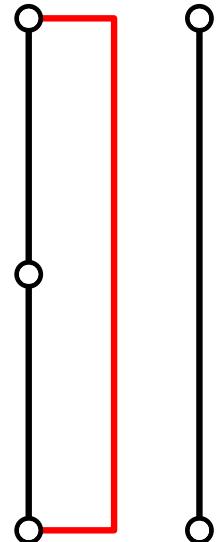
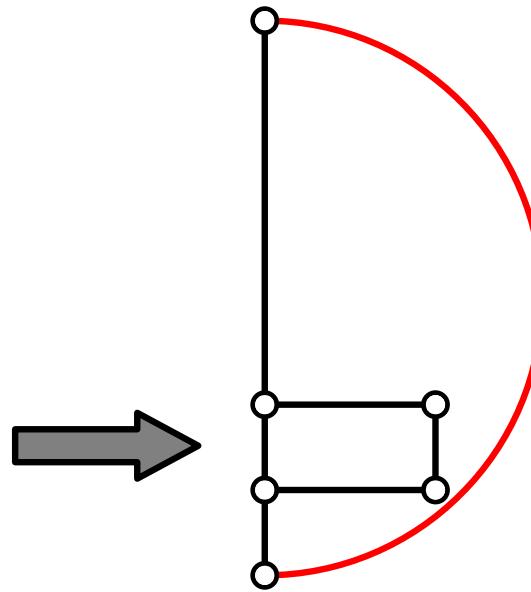
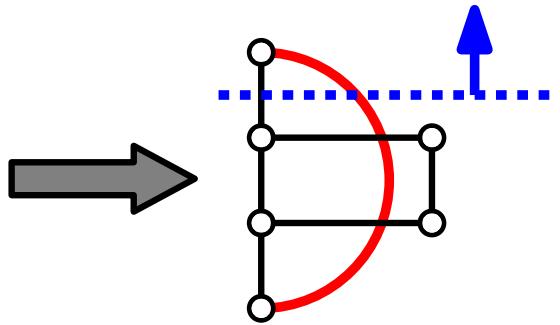
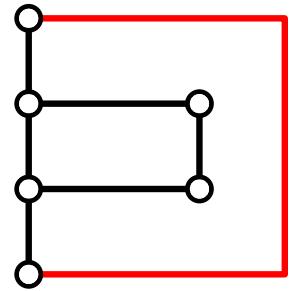
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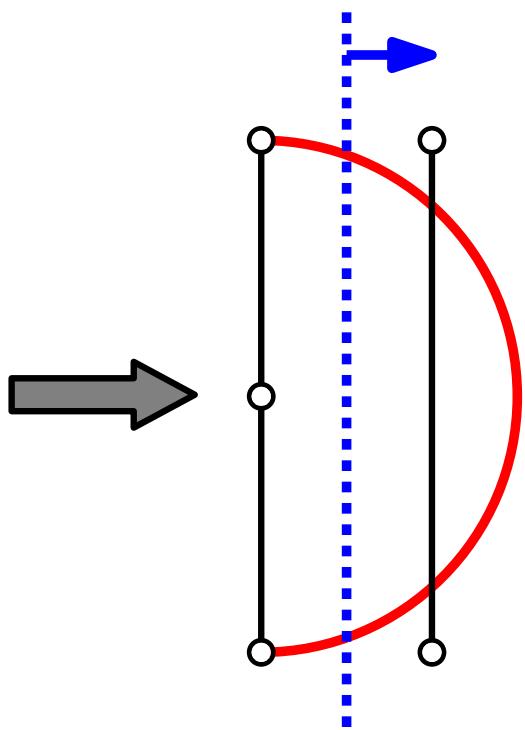
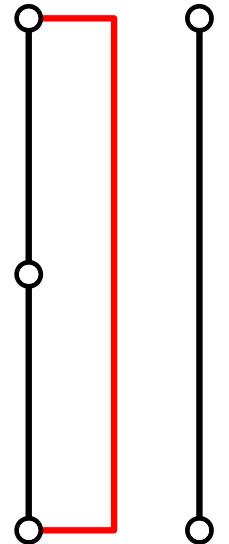
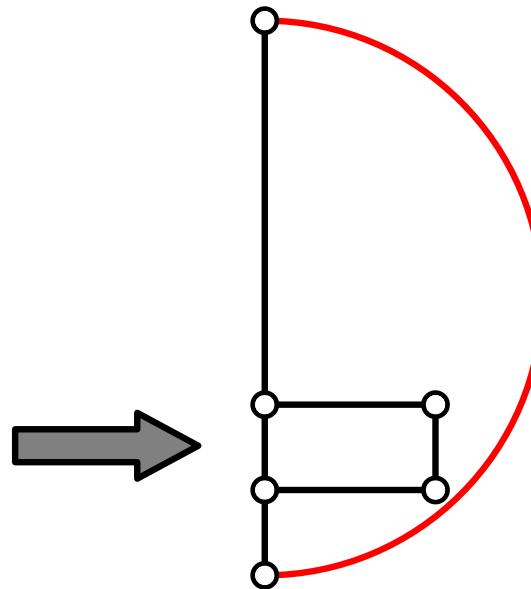
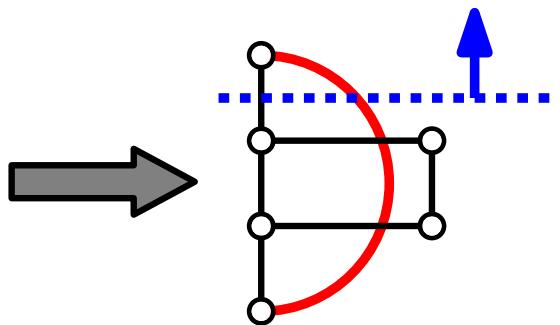
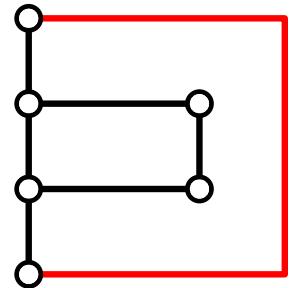
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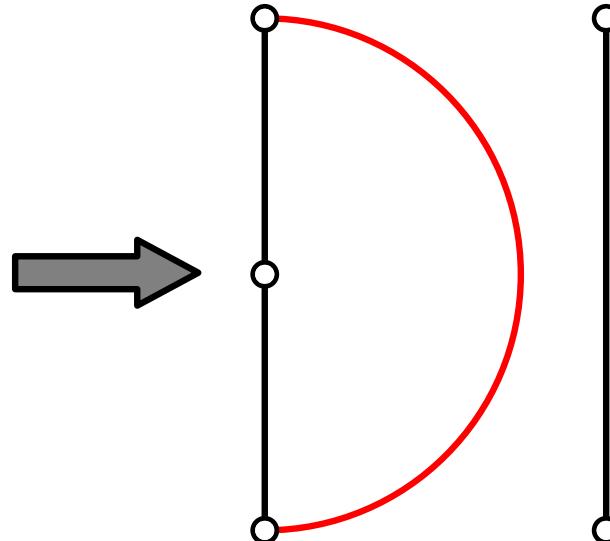
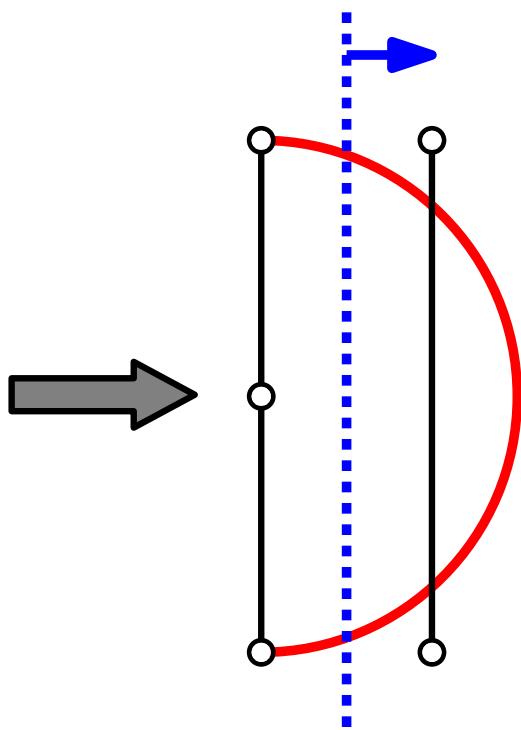
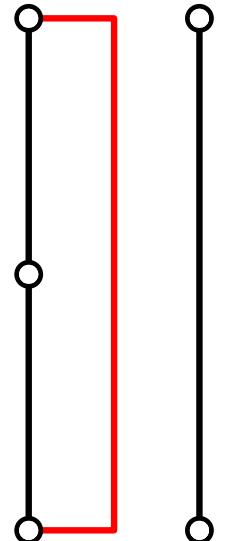
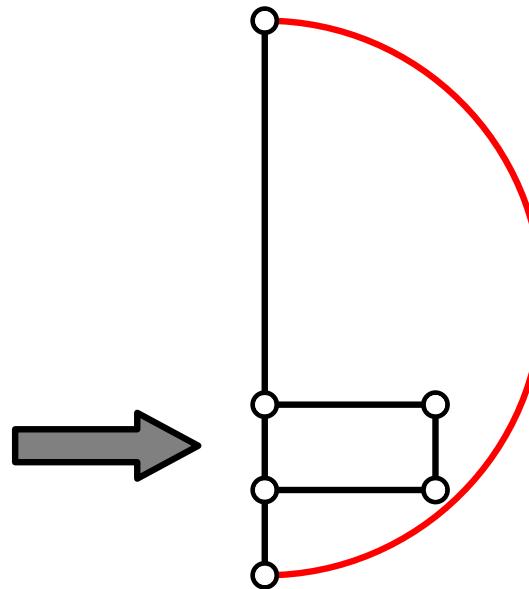
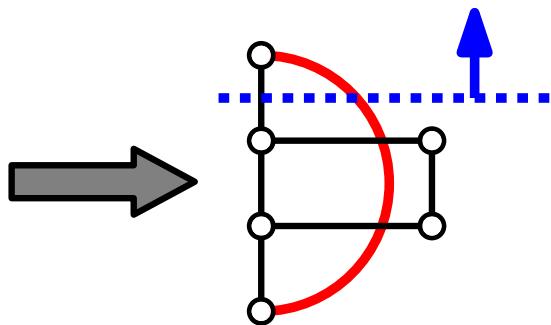
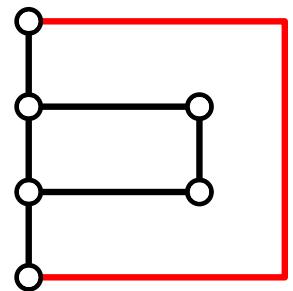
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Kreuzungen



Kreuzungen

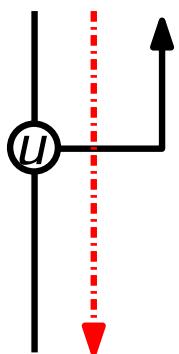


Schnitte

Def.

Schnitte

Def. ● y -monotone Kurve



Schnitte

- Def.
- y -monotone Kurve
 - horizontale, vertikale und Kreissegmente



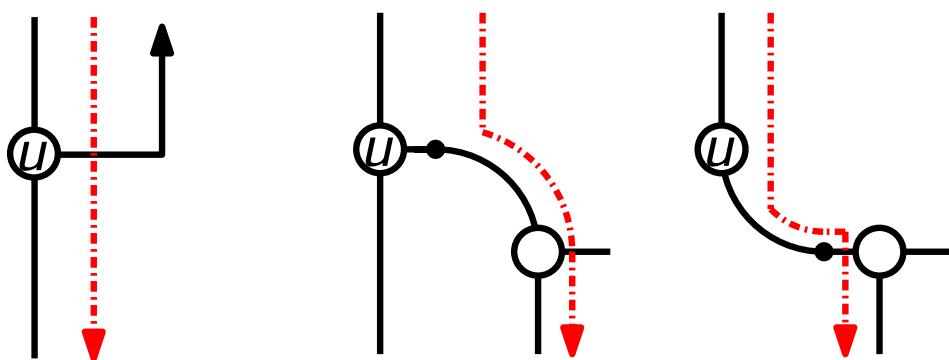
Schnitte

- Def.
- y -monotone Kurve
 - horizontale, vertikale und Kreissegmente
 - Teilt Zeichnung in linken und rechten Teil



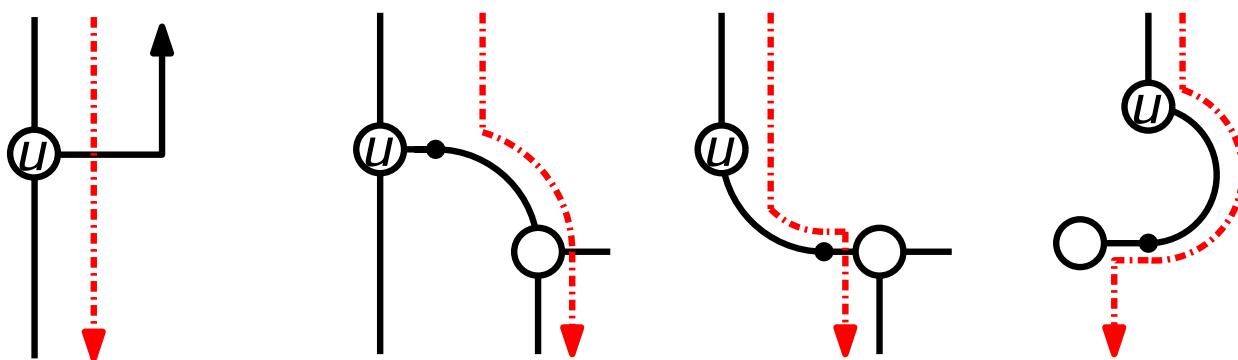
Schnitte

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 - horizontale, vertikale und Kreissegmente
 - Teilt Zeichnung in linken und rechten Teil
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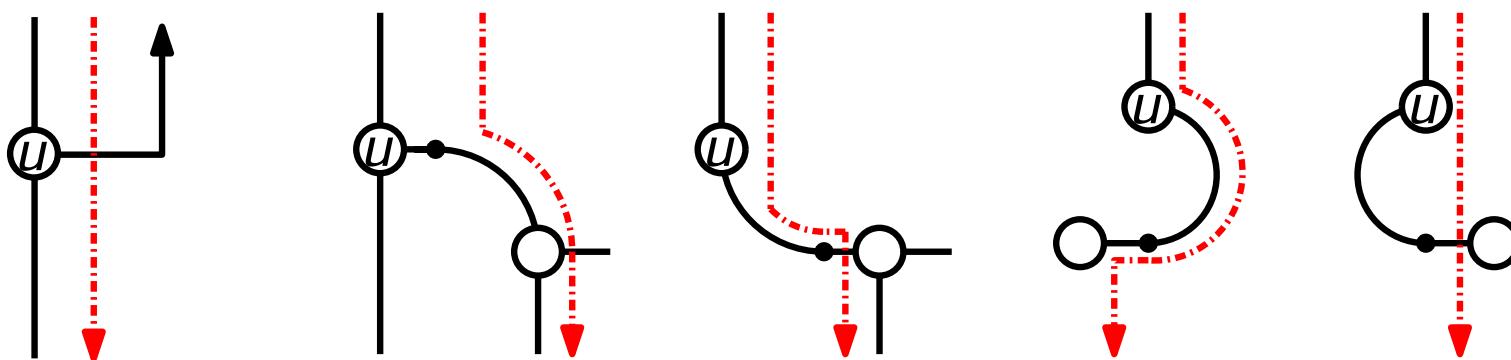
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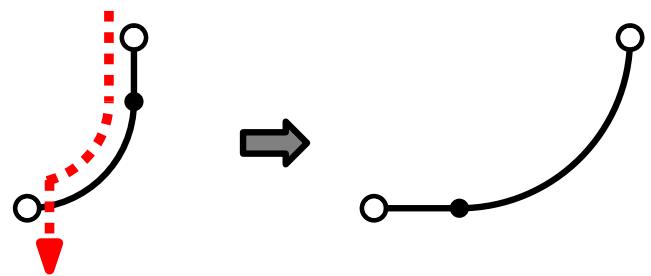
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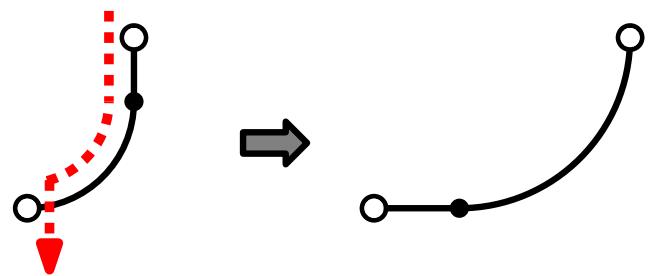
Maintain invariants

L-Form

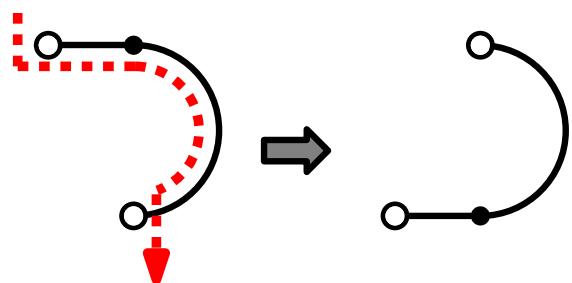


Maintain invariants

L-Form

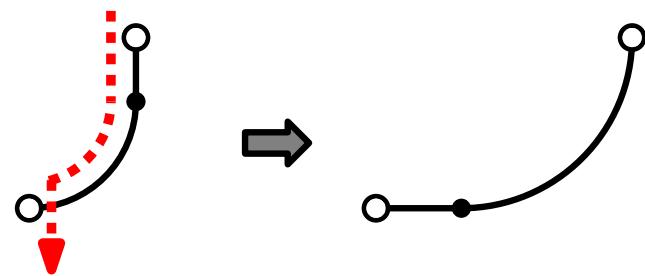


C-Form

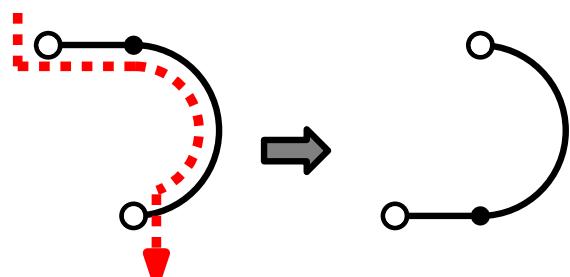


Maintain invariants

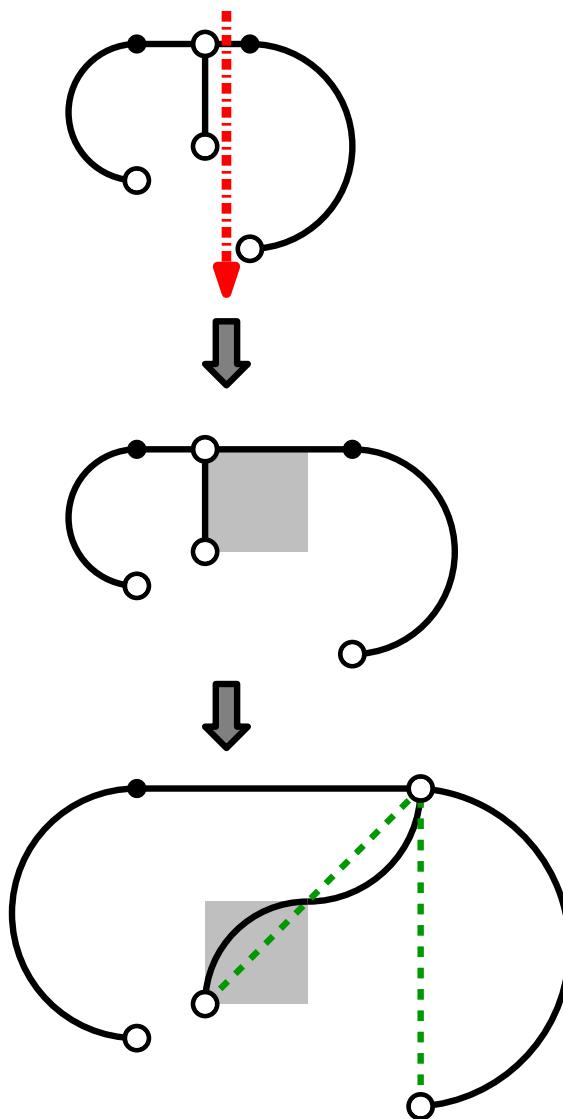
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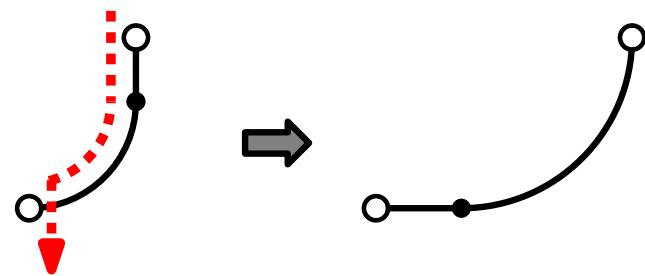


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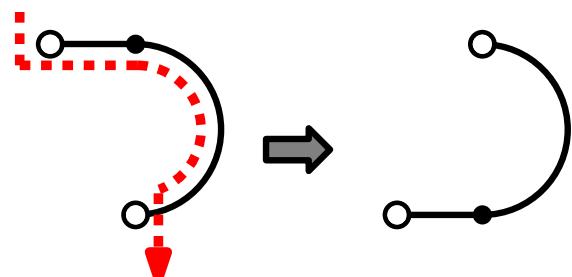


Maintain invariants

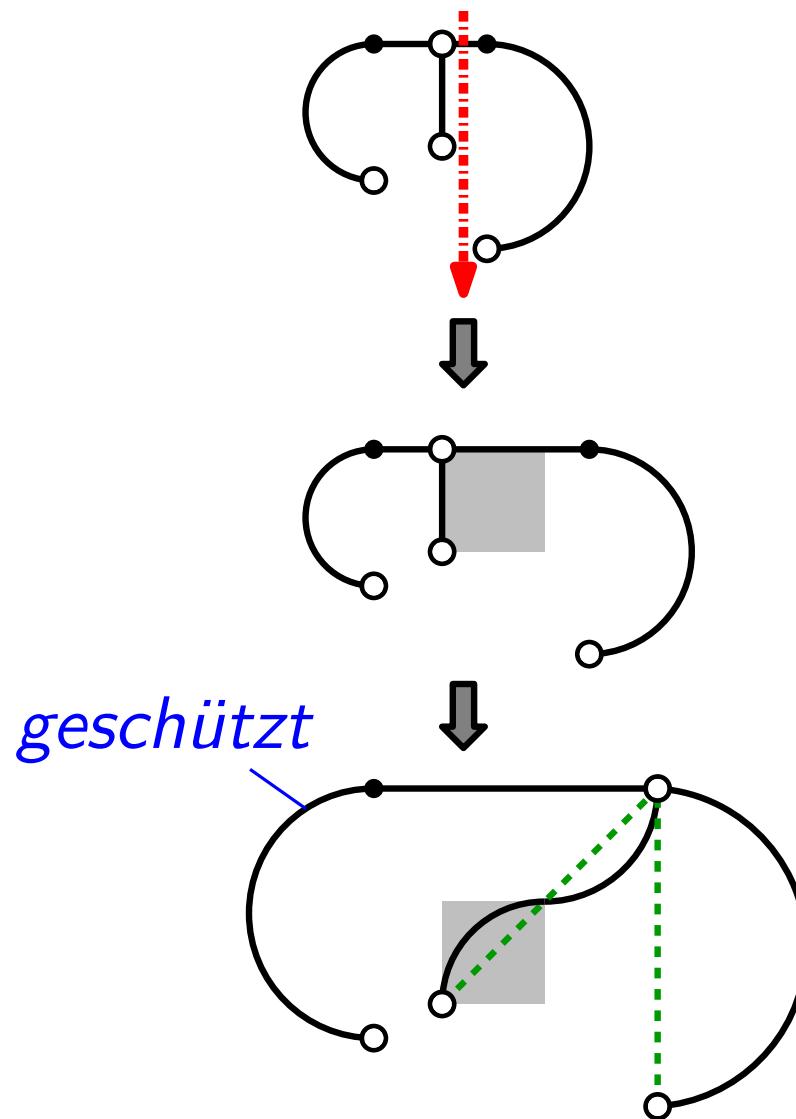
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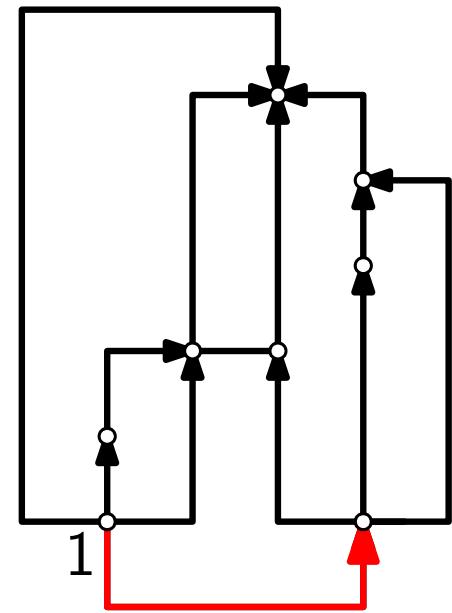
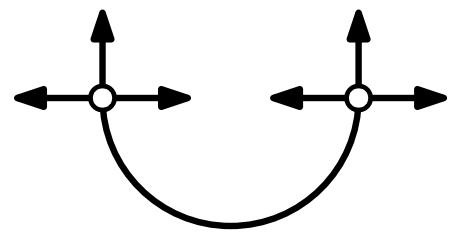
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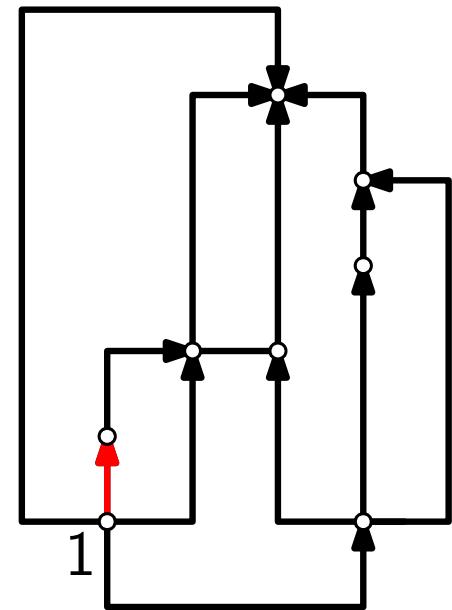
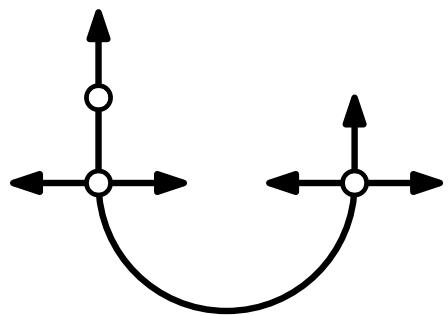
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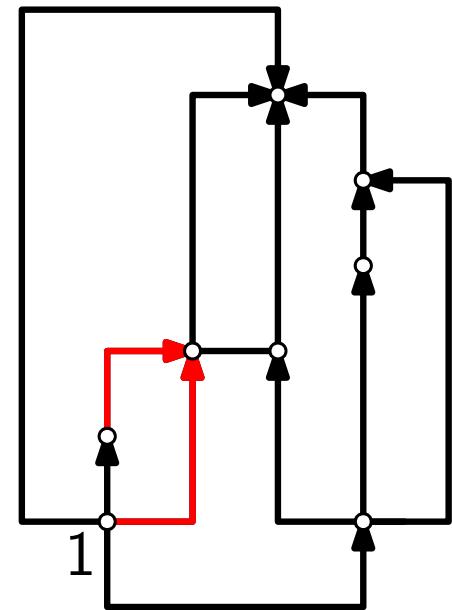
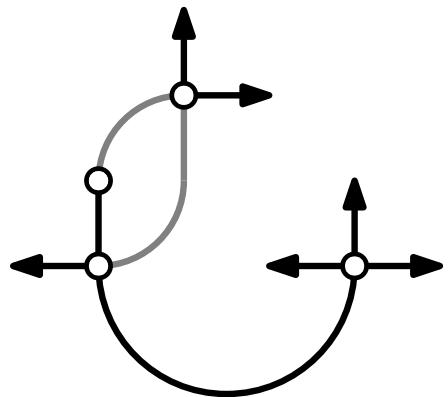
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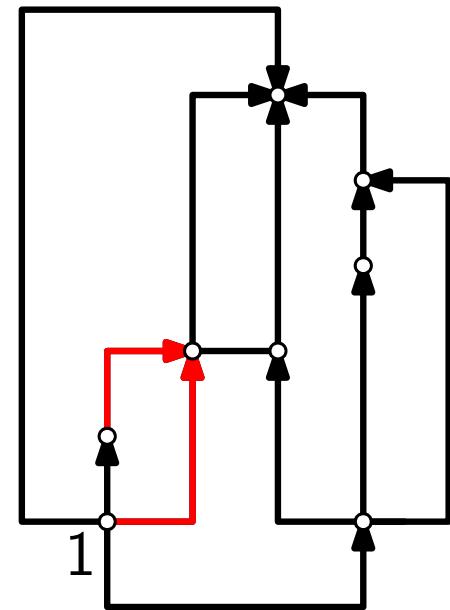
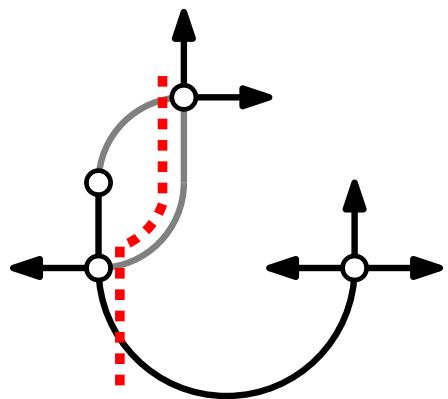
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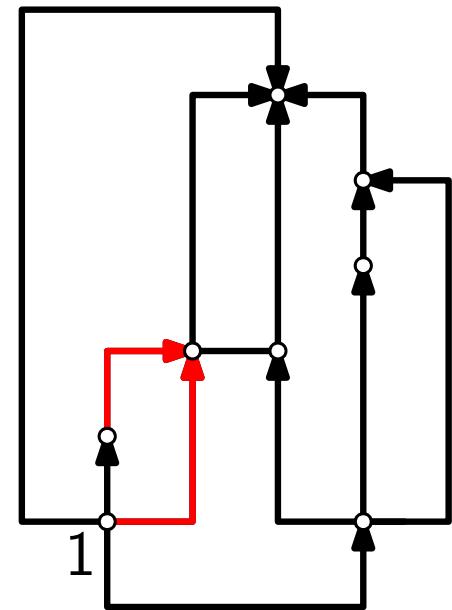
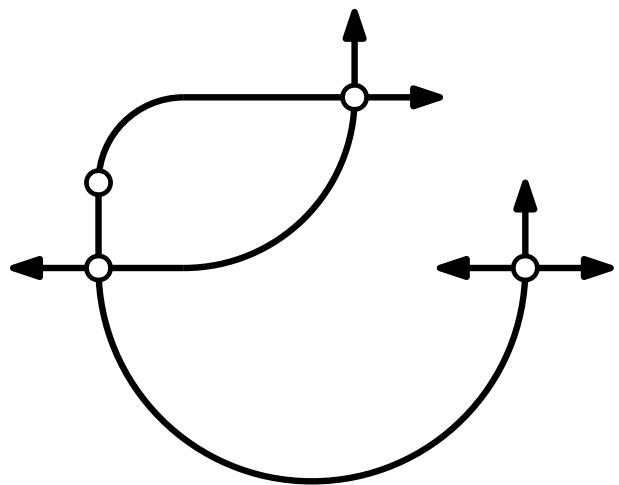
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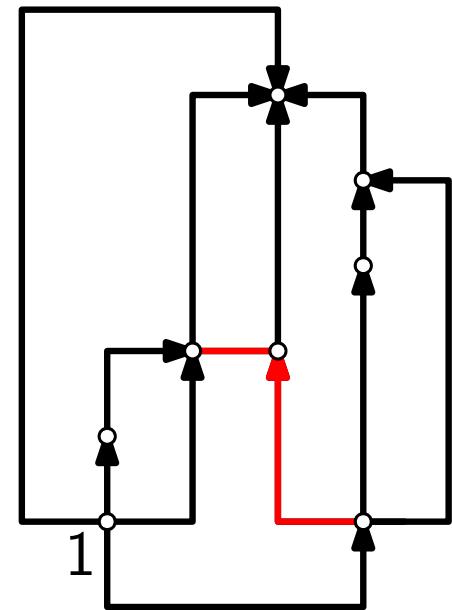
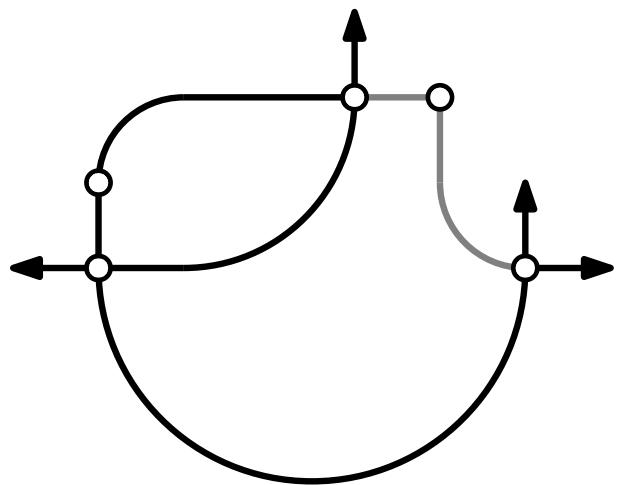
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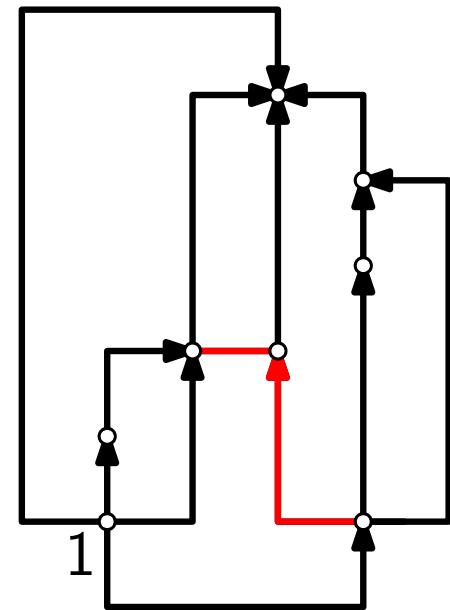
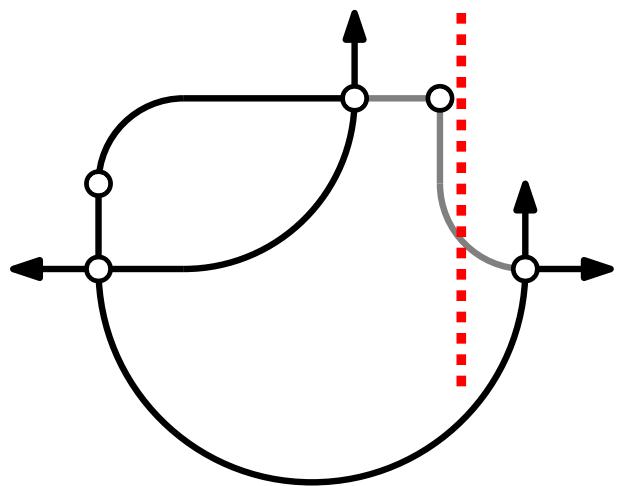
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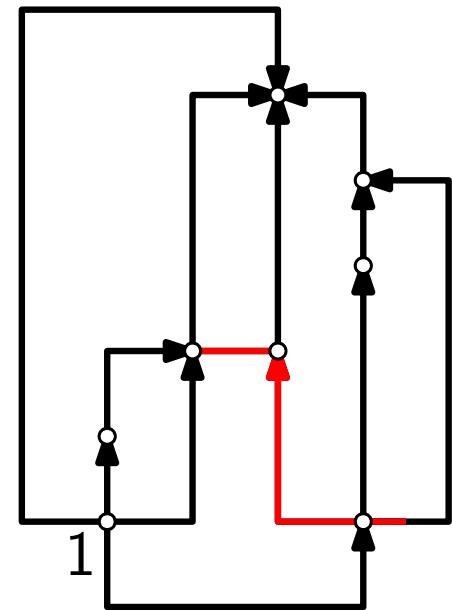
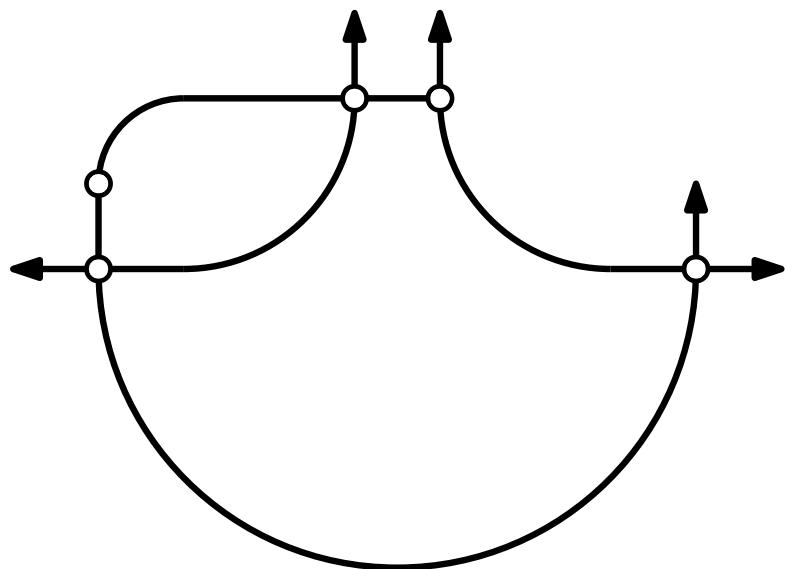
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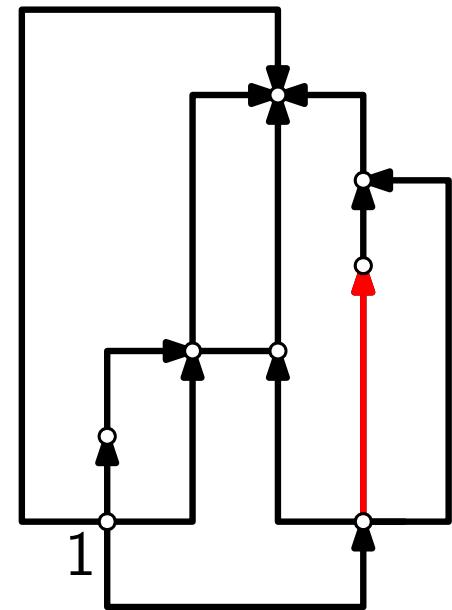
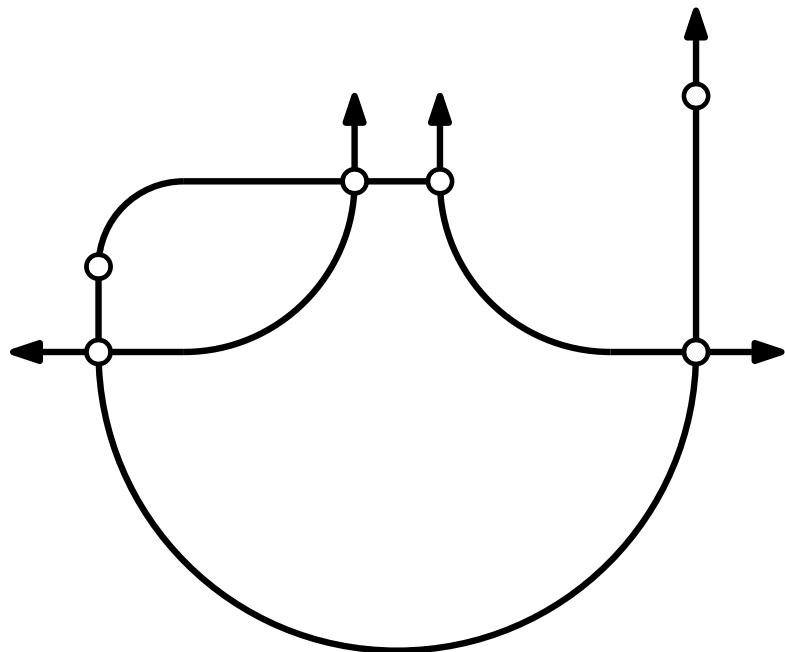
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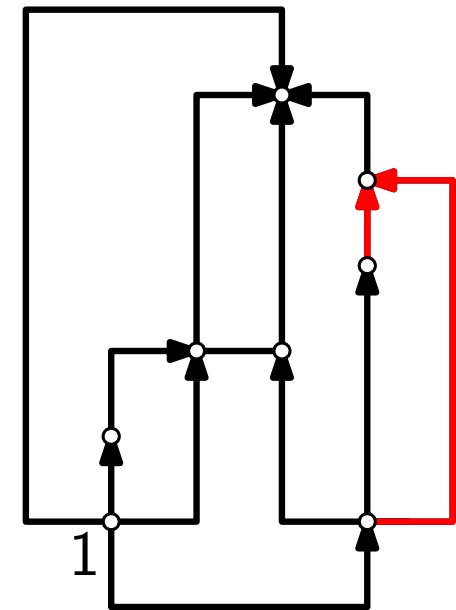
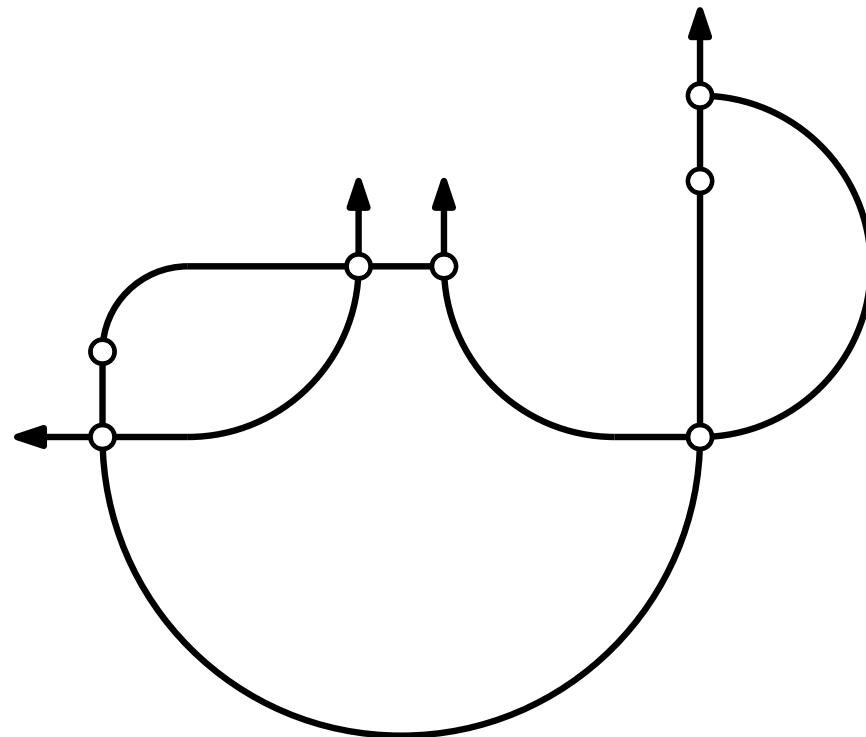
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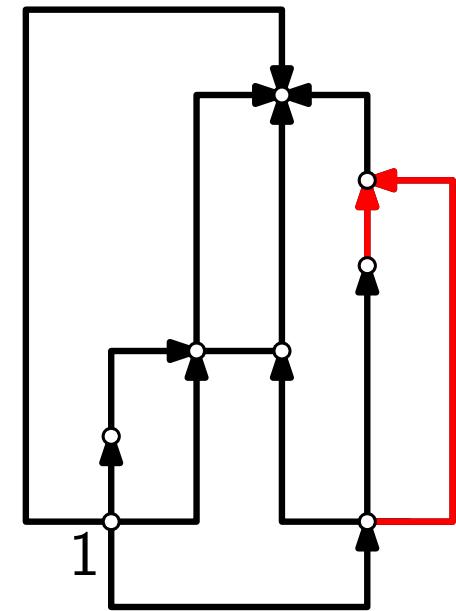
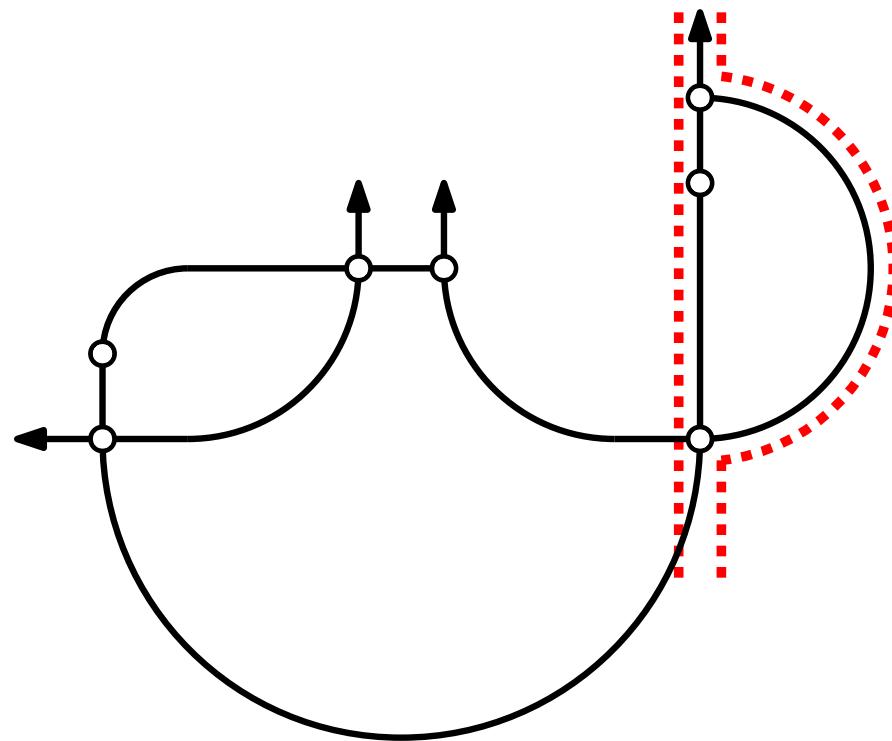
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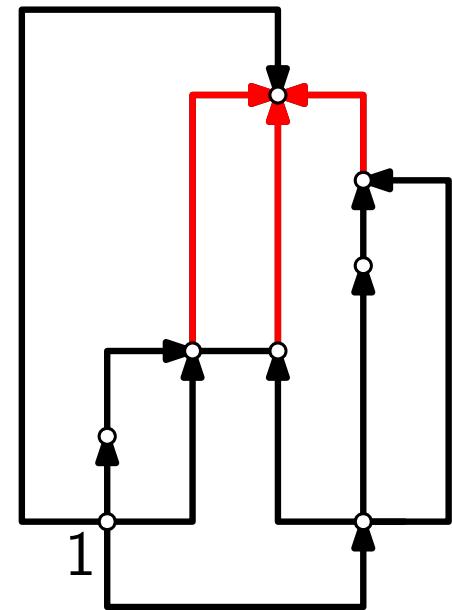
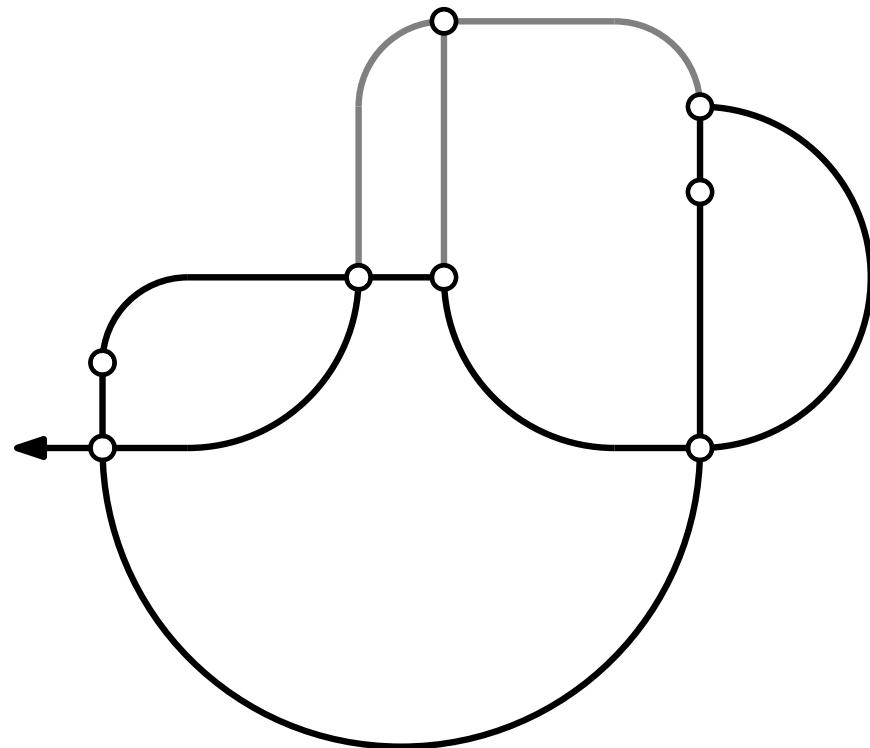
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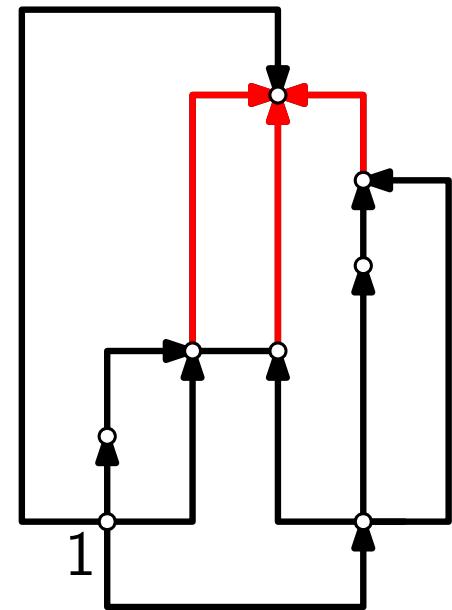
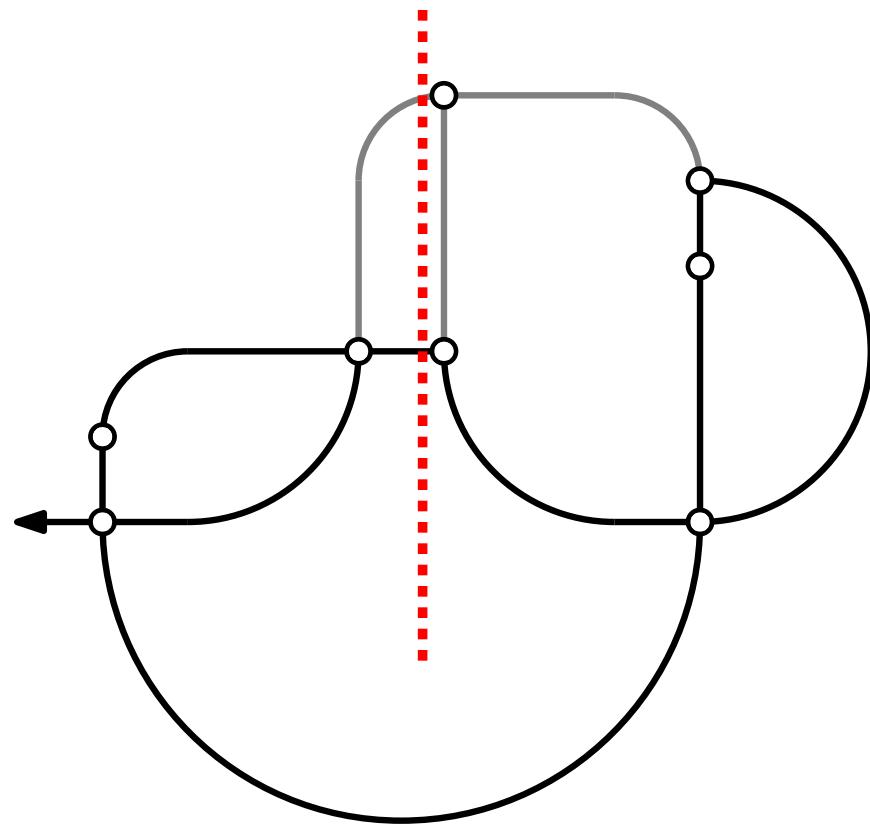
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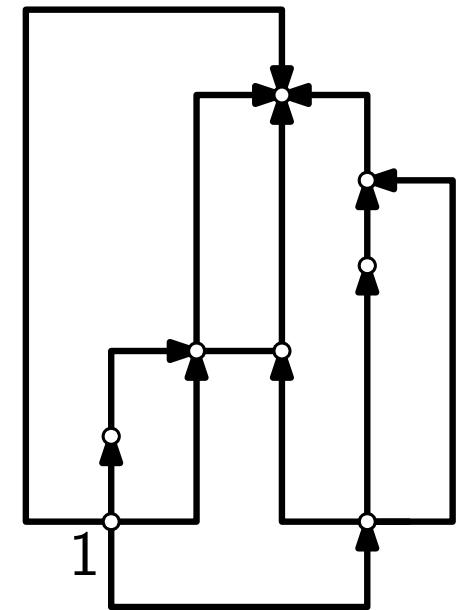
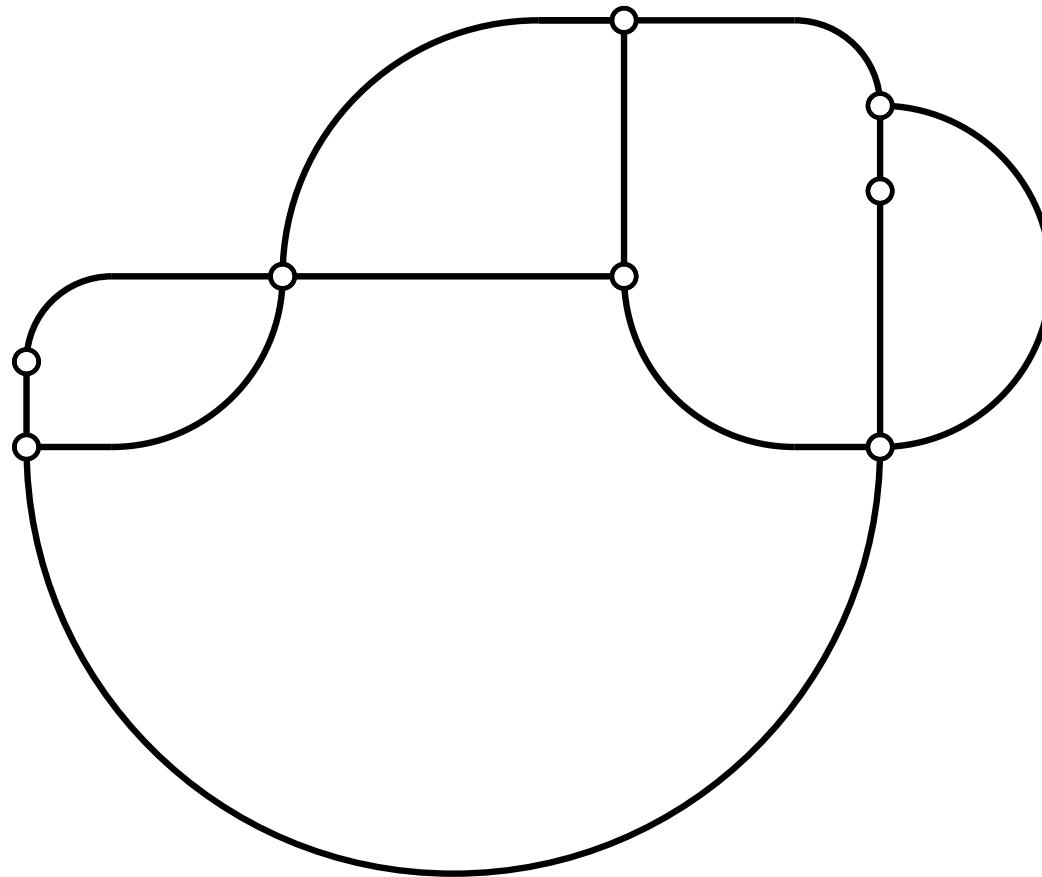
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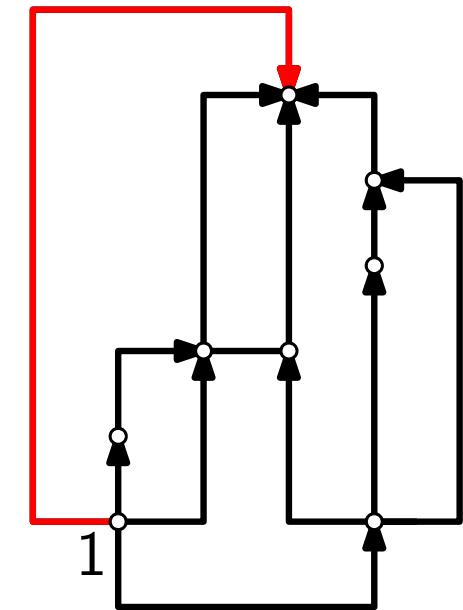
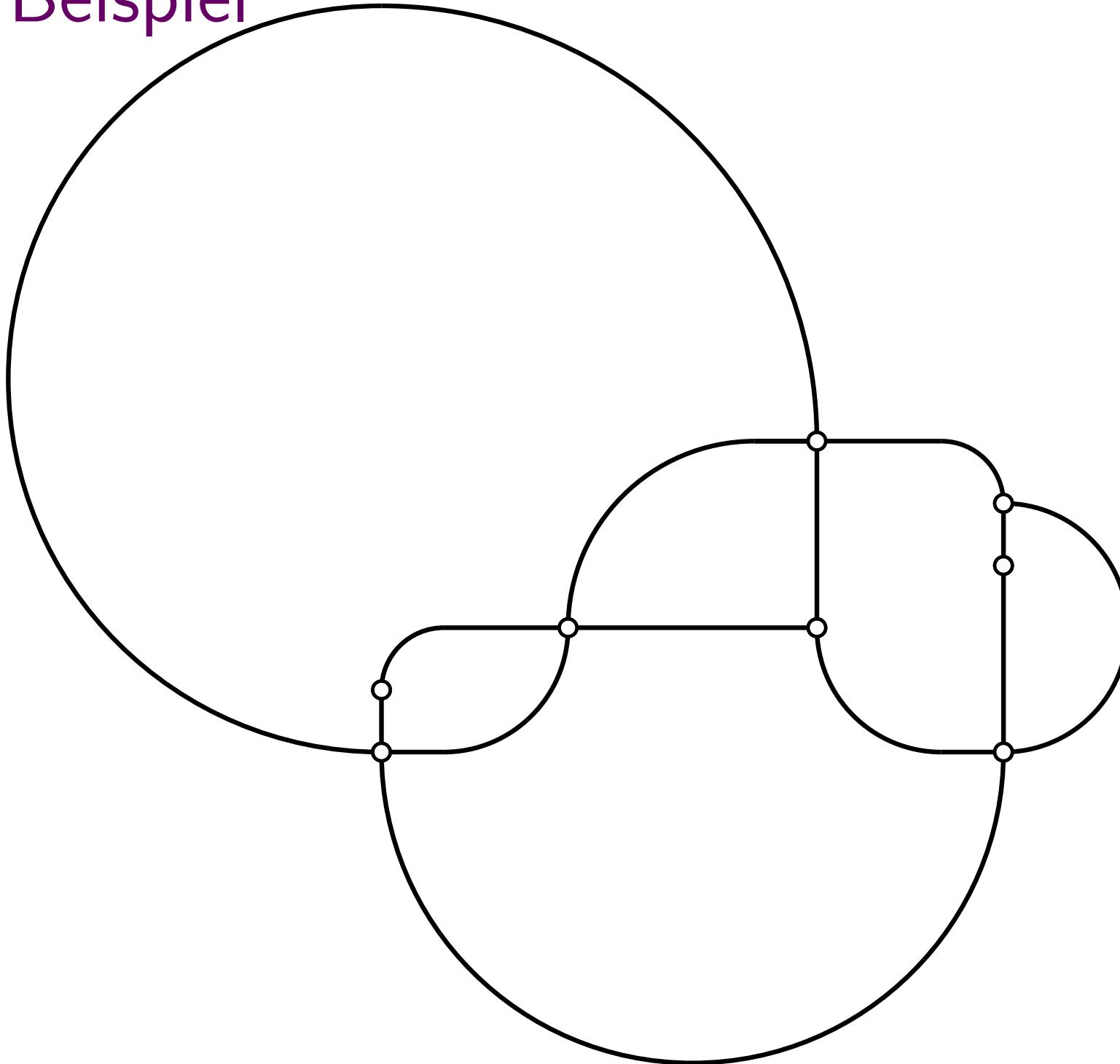
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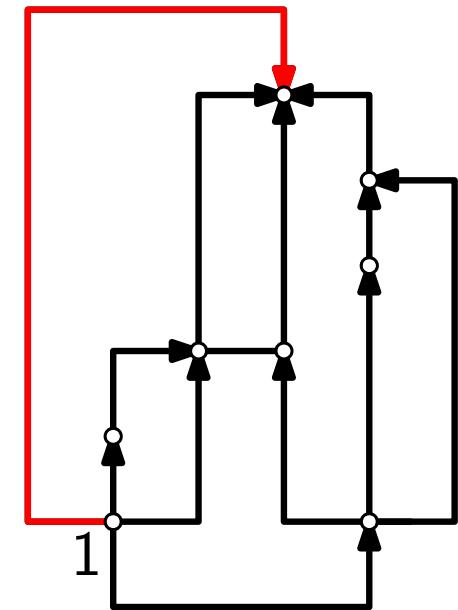
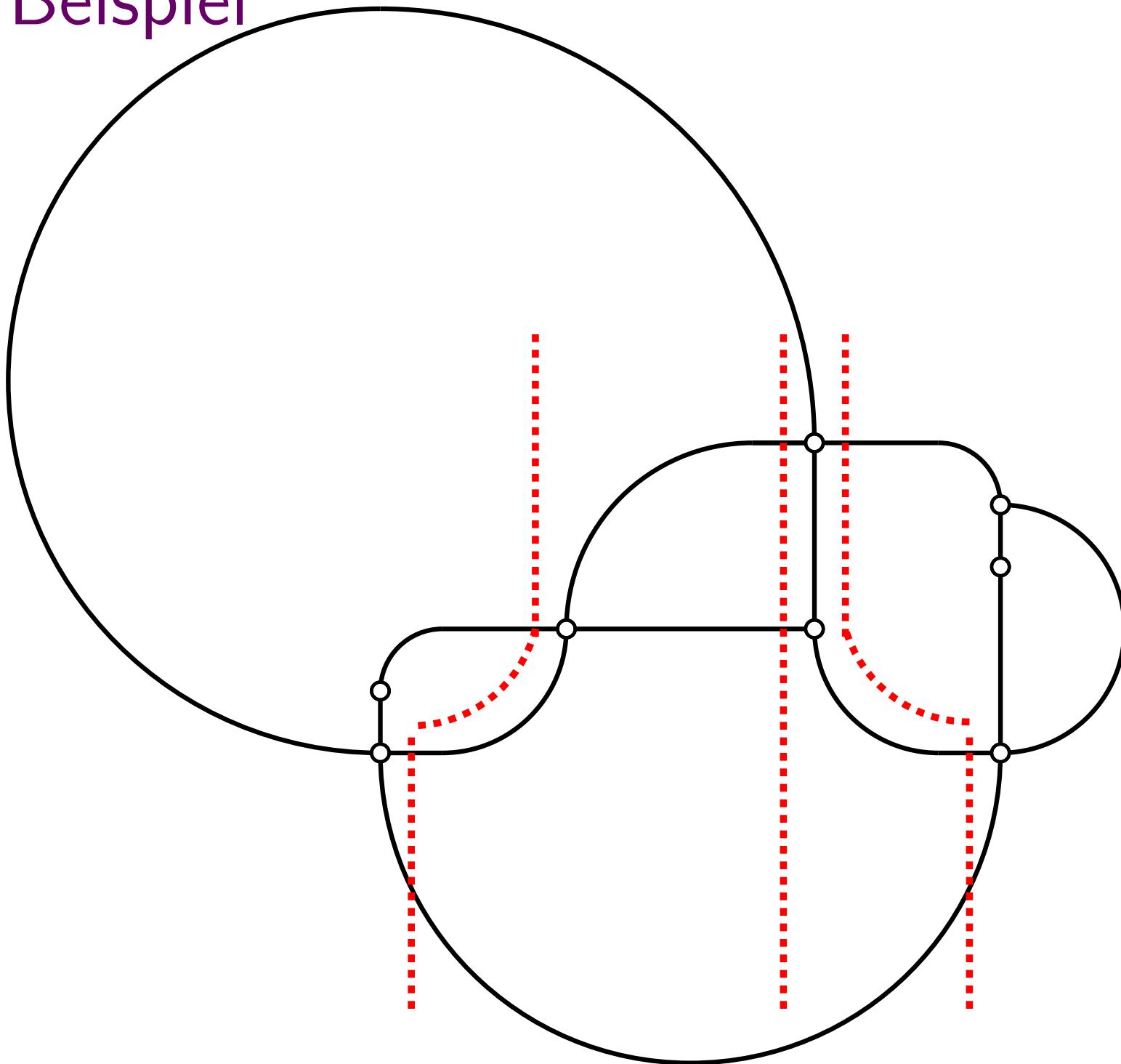
Beispiel



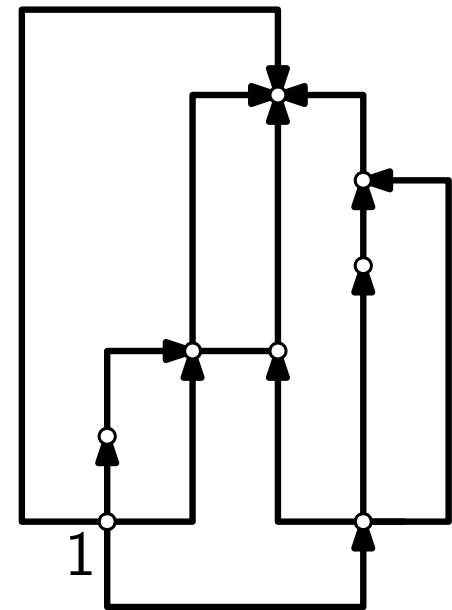
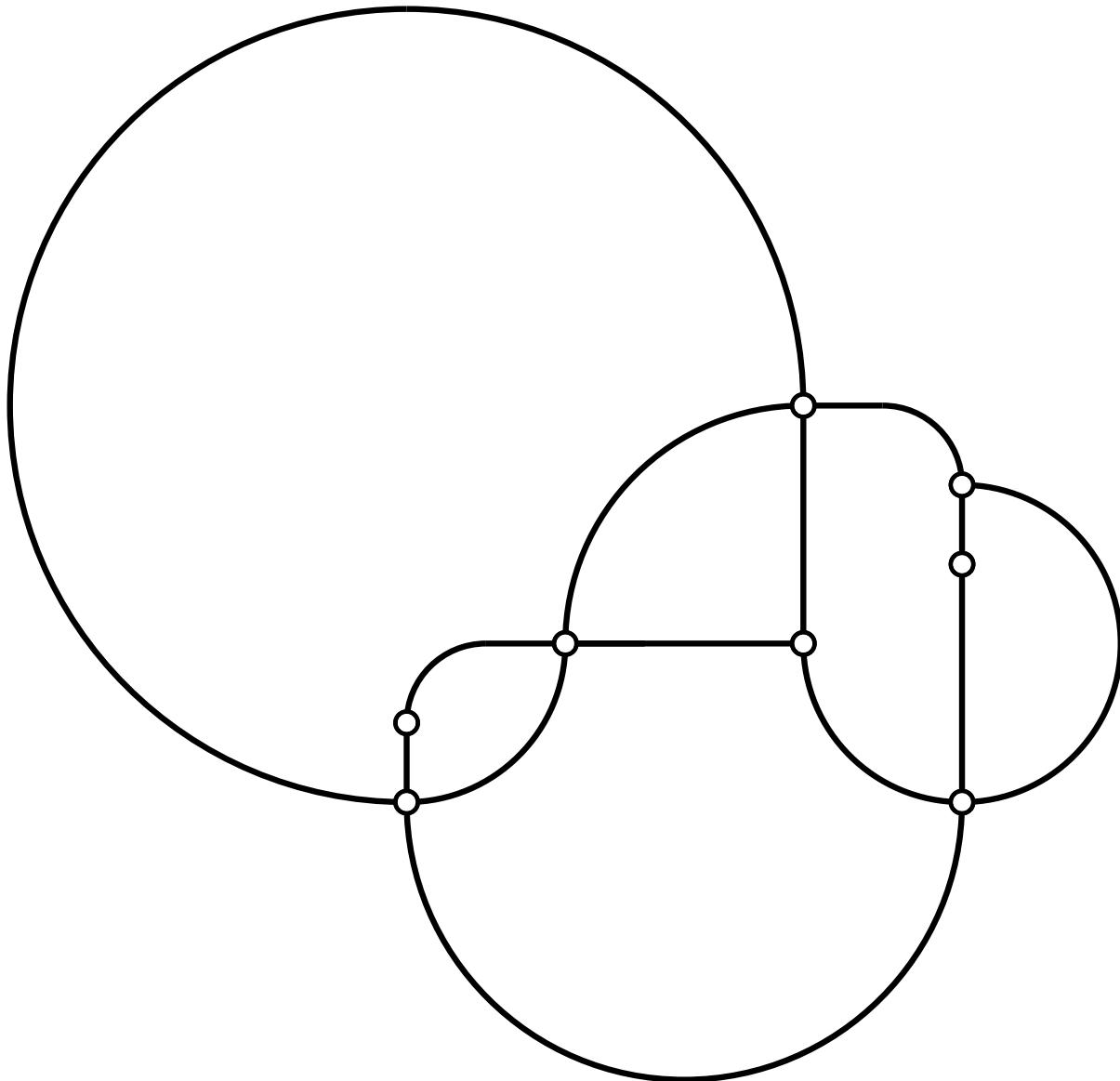
Beispiel



Beispiel



Beispiel



Glatt-orthogonale Zeichungen – Ergebnisse

Zweifach zusammenhängender 4-planarer Graph \Rightarrow
glatt-orth. Komplexität 3

Glatt-orthogonale Zeichungen – Ergebnisse

~~Zweifach zusammenhängender~~ 4-planarer Graph \Rightarrow
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- zweifach zusammenhängend 4-äußenplanar
 - dreifach zusammenhängend 3-planar
 - Hamiltonsch 3-planar
- \Rightarrow glatt-orth. Komplexität 1

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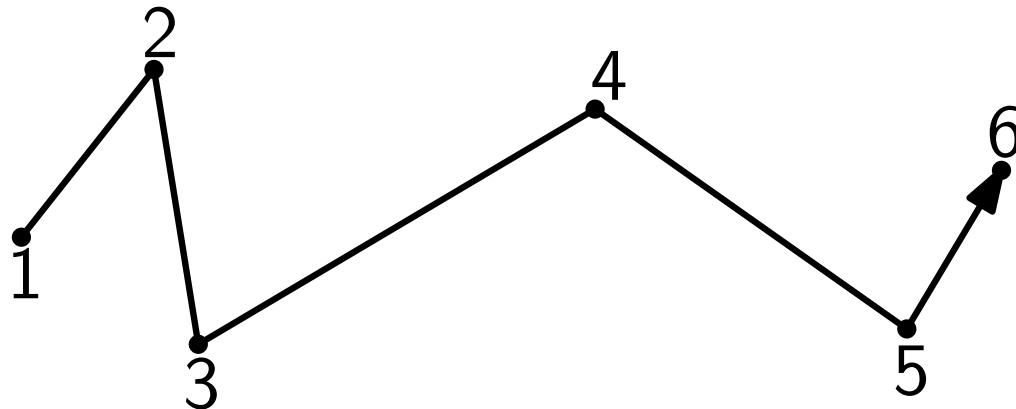
Monotone Zeichnungen von Bäumen

Monotone Zeichnungen

Monotoner Pfad: \exists Richtung d , so dass
Knoten-Reihenfolge in d = Reihenfolge entlang des Pfades.

Monotone Zeichnungen

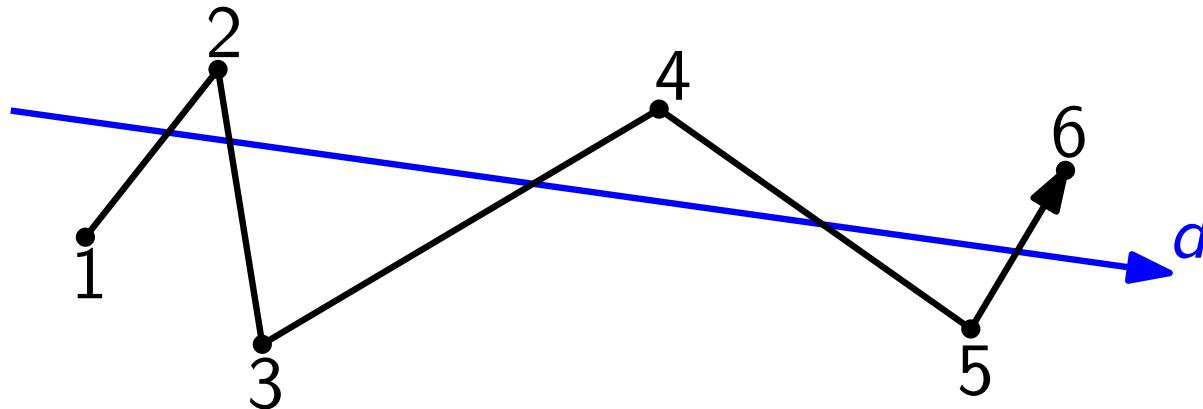
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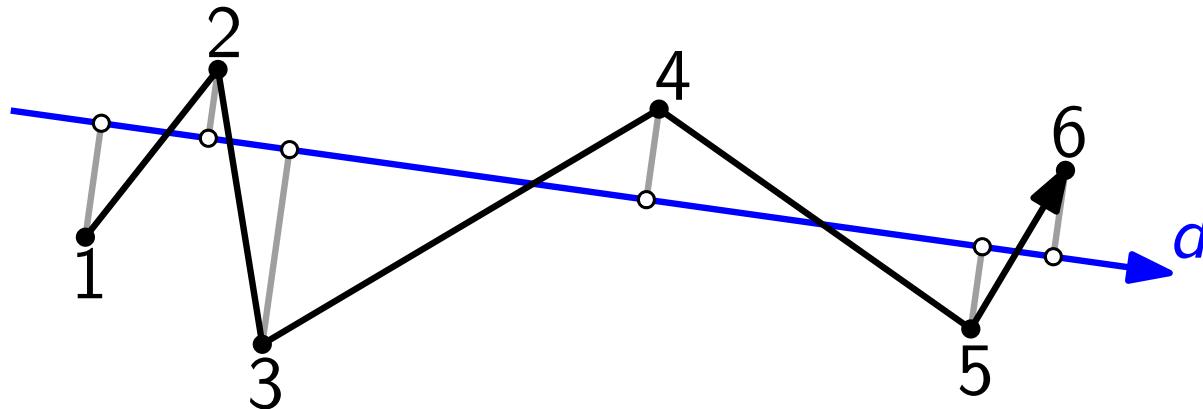
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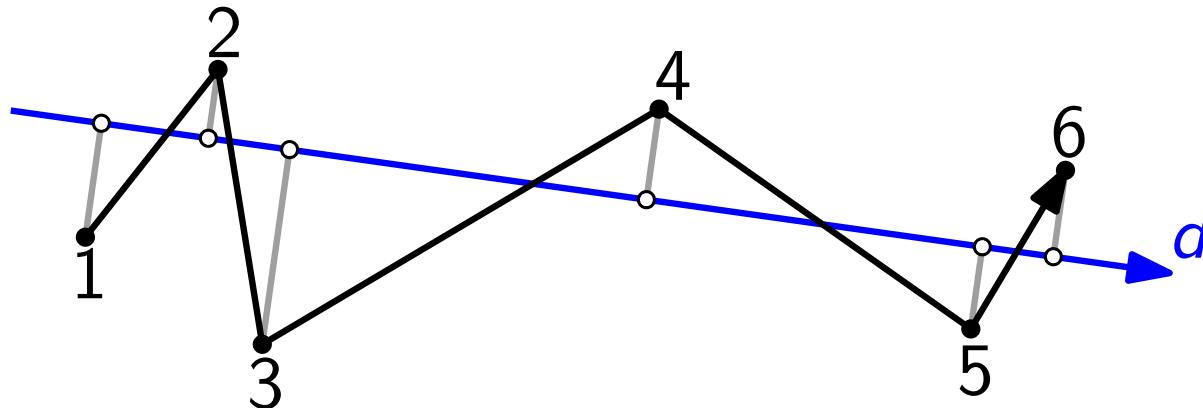
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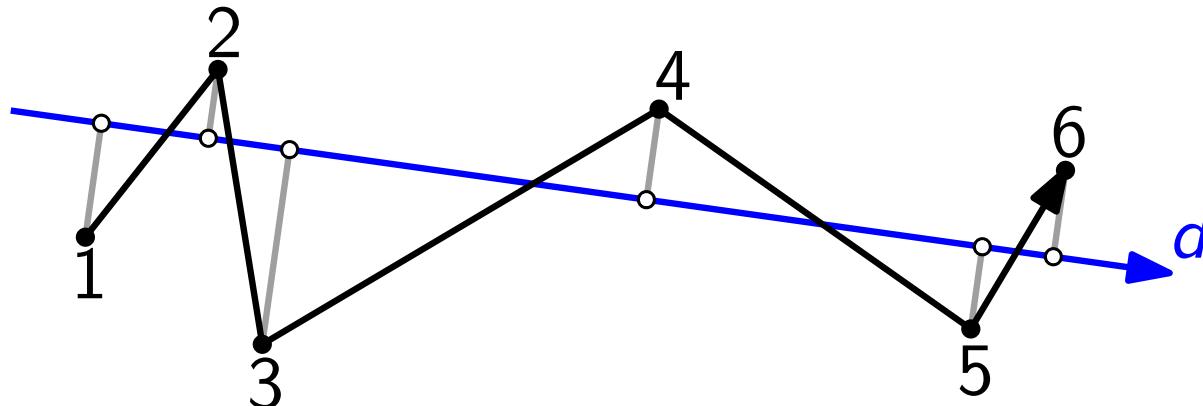


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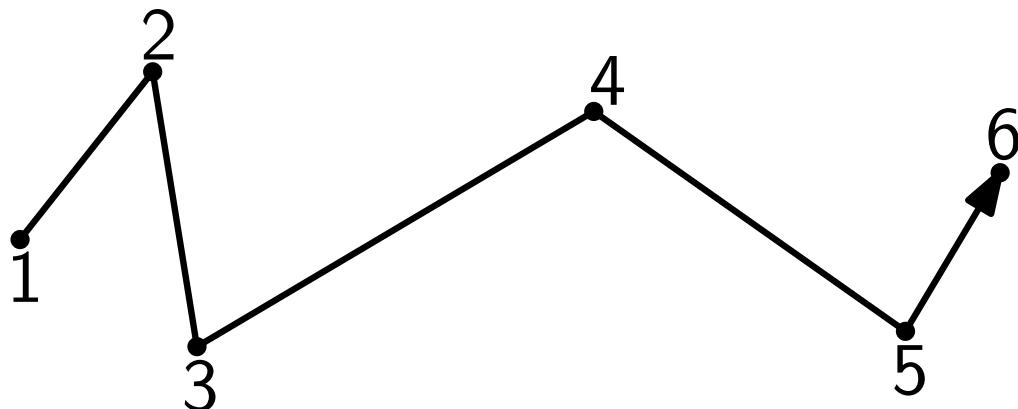
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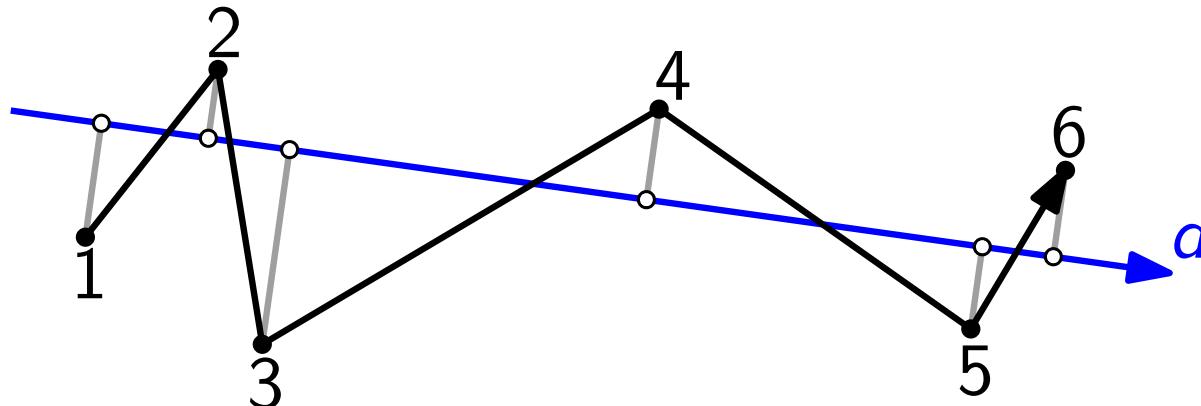
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Streng monotoner $u-v$ Pfad: $d = \overrightarrow{uv}$.



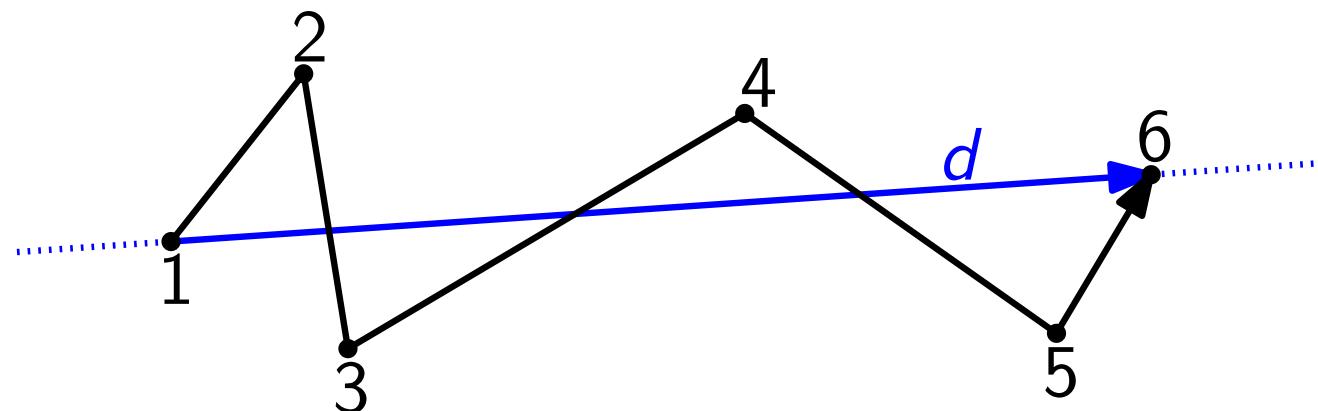
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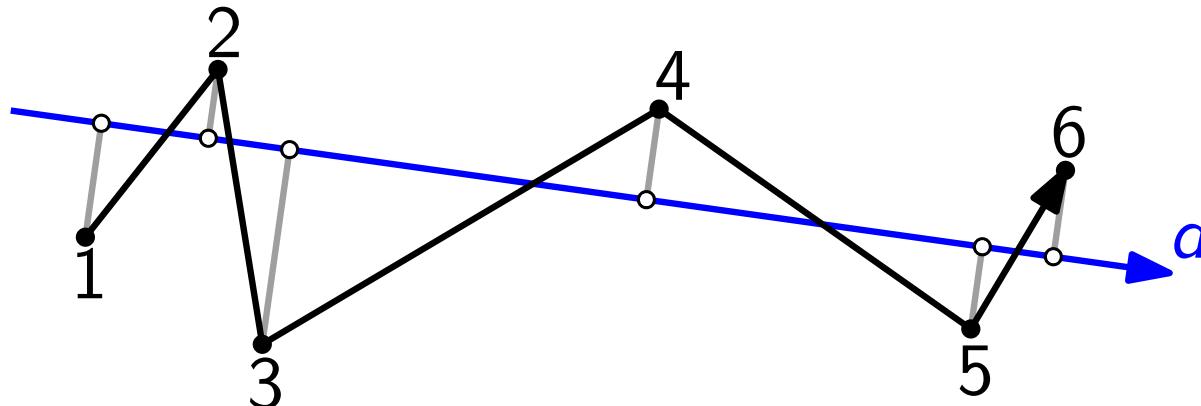
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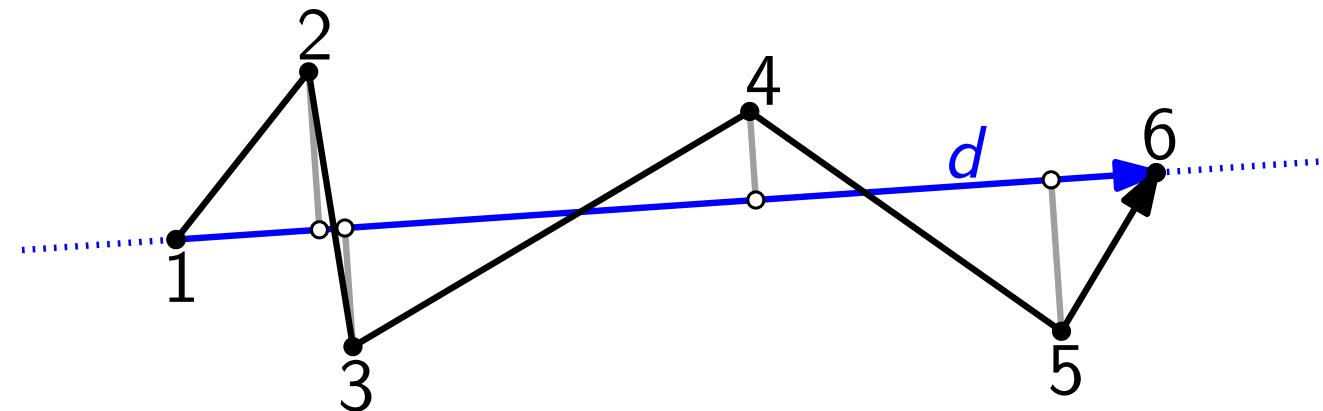
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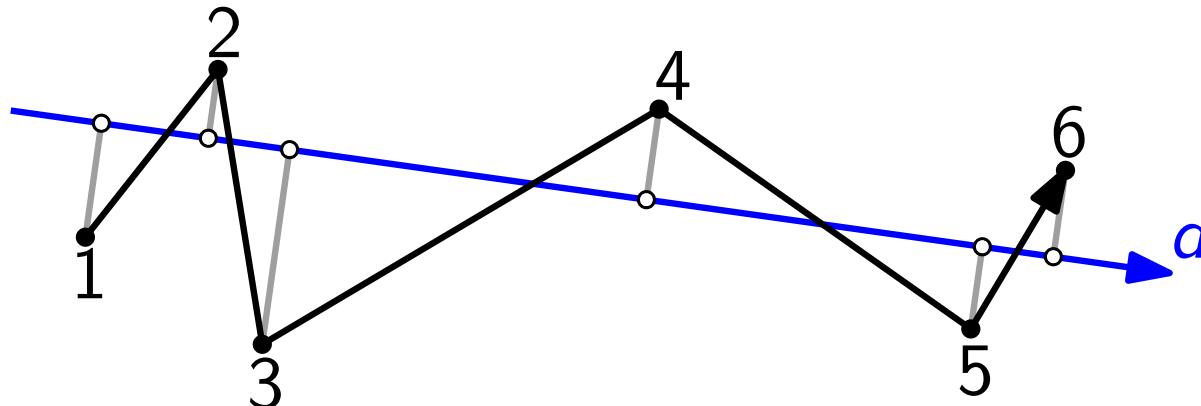
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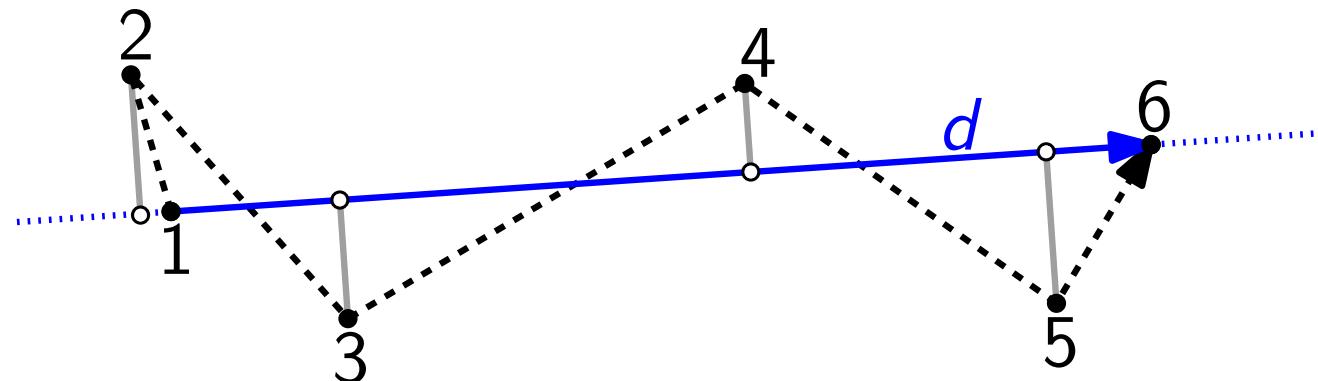
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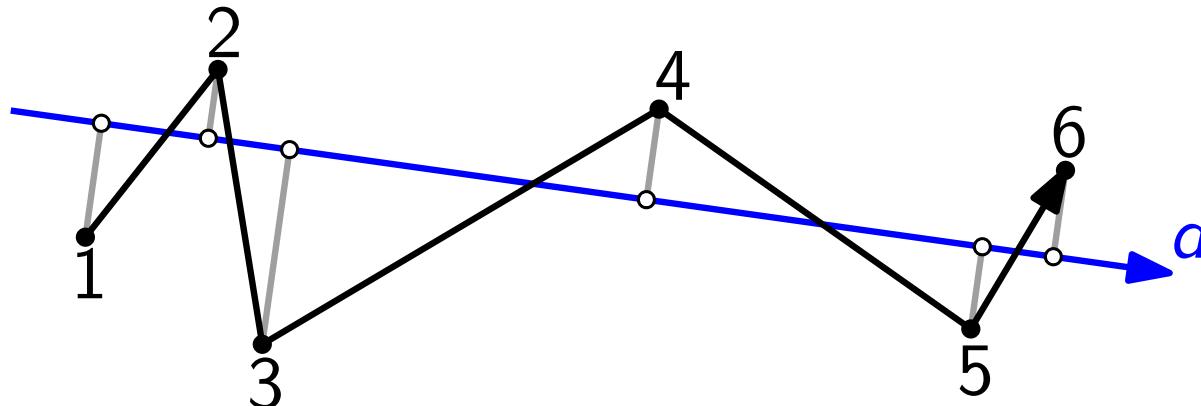
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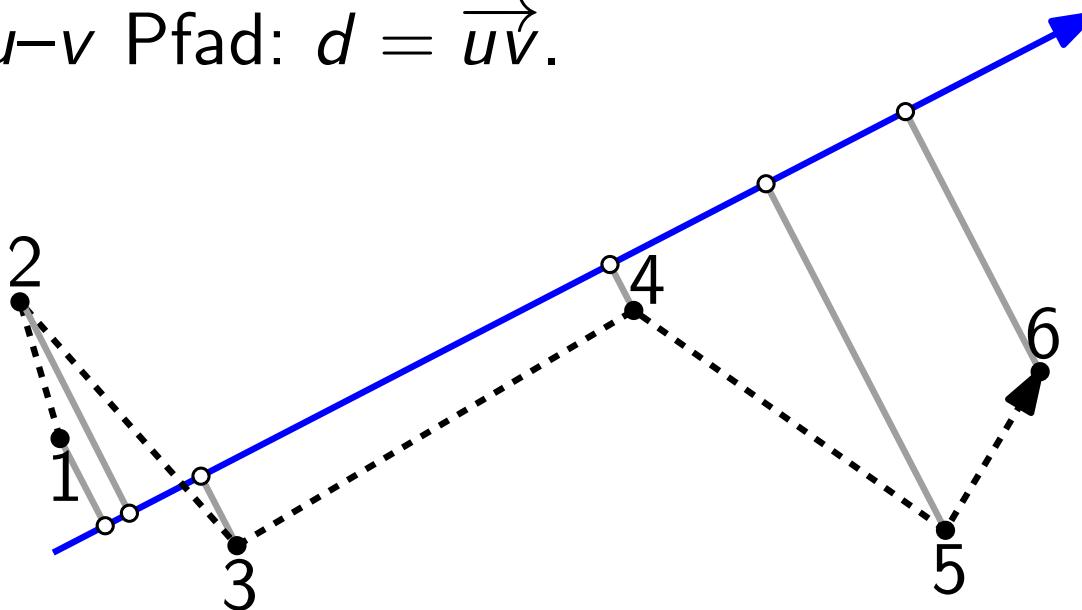
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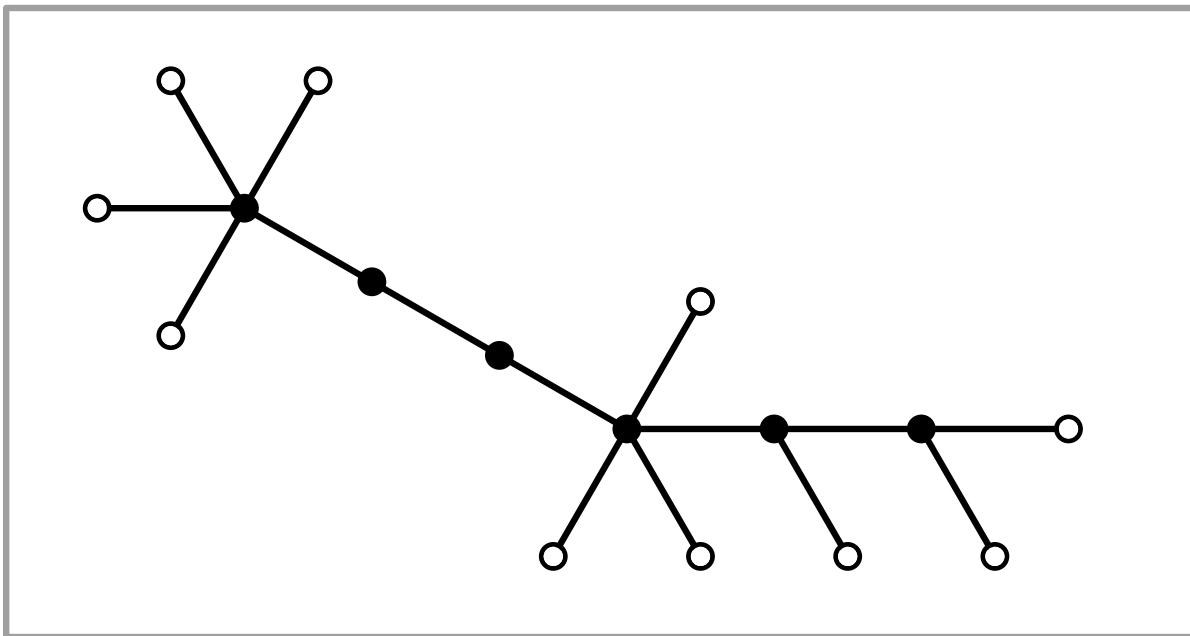


Monotone Zeichnungen

Konvexe Zeichnung: Jede Facette ist konvex.

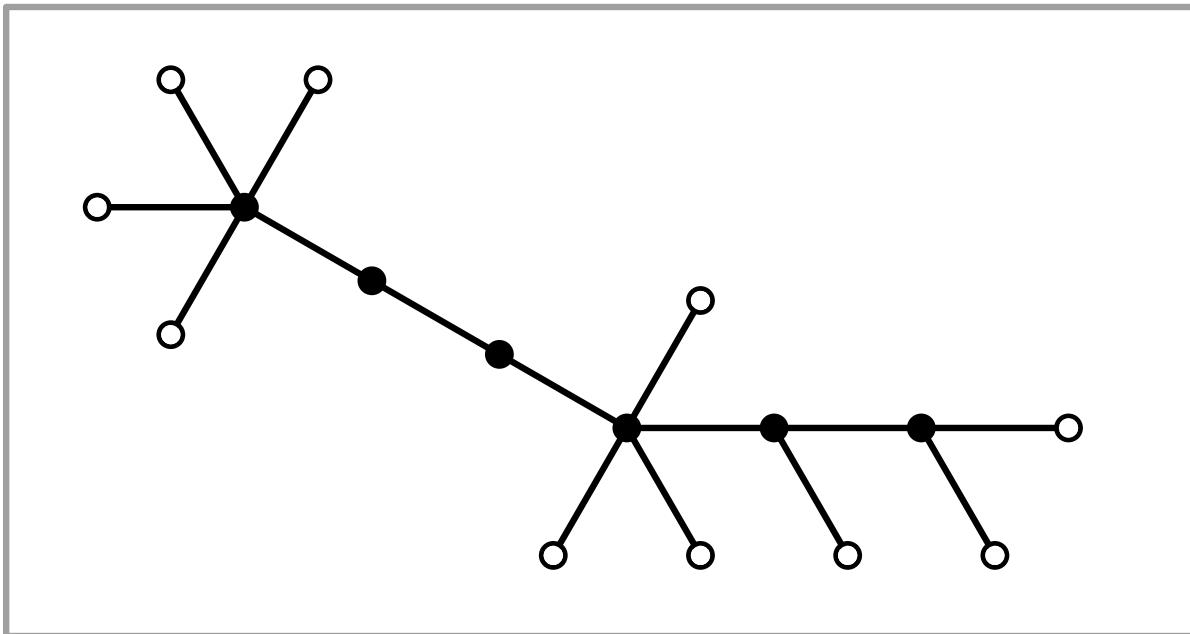
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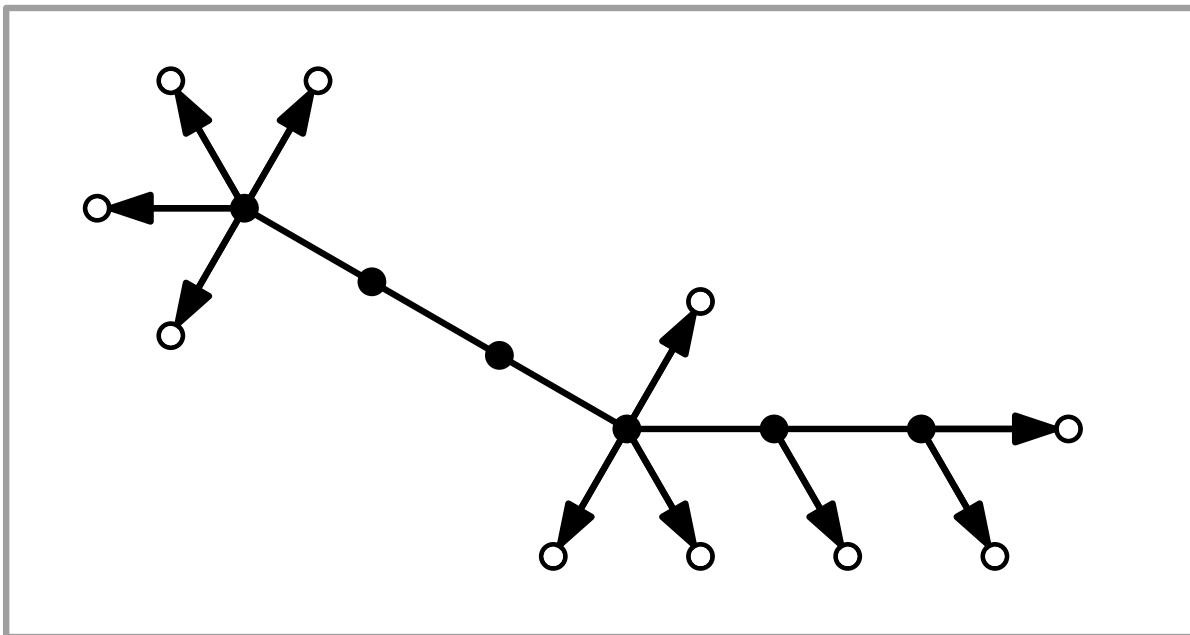
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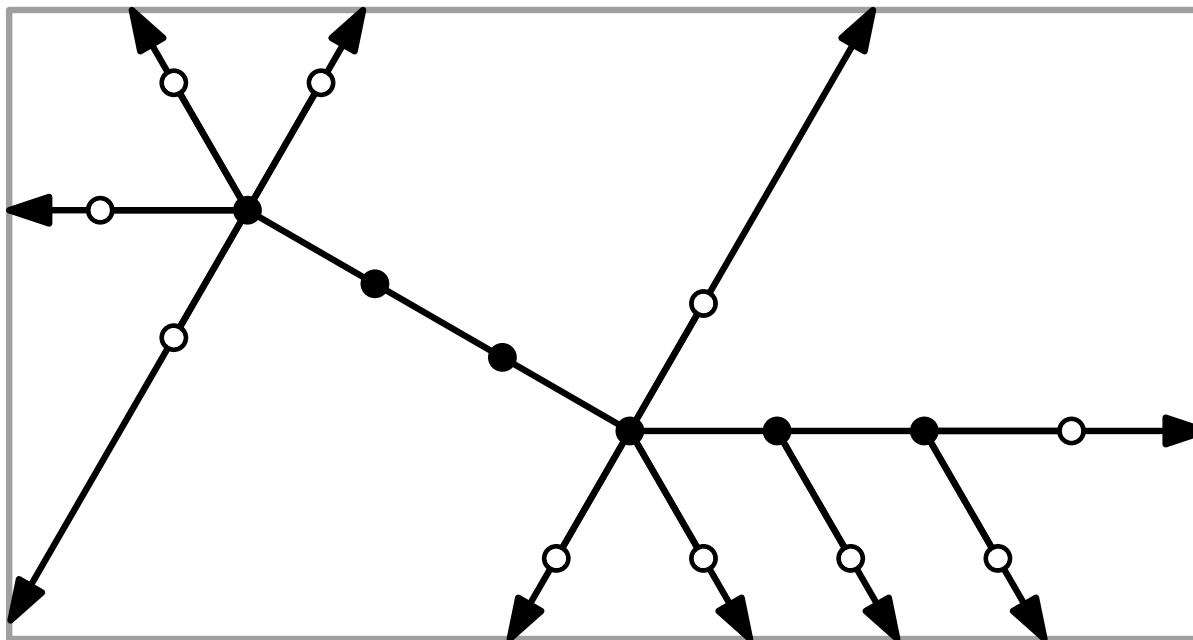
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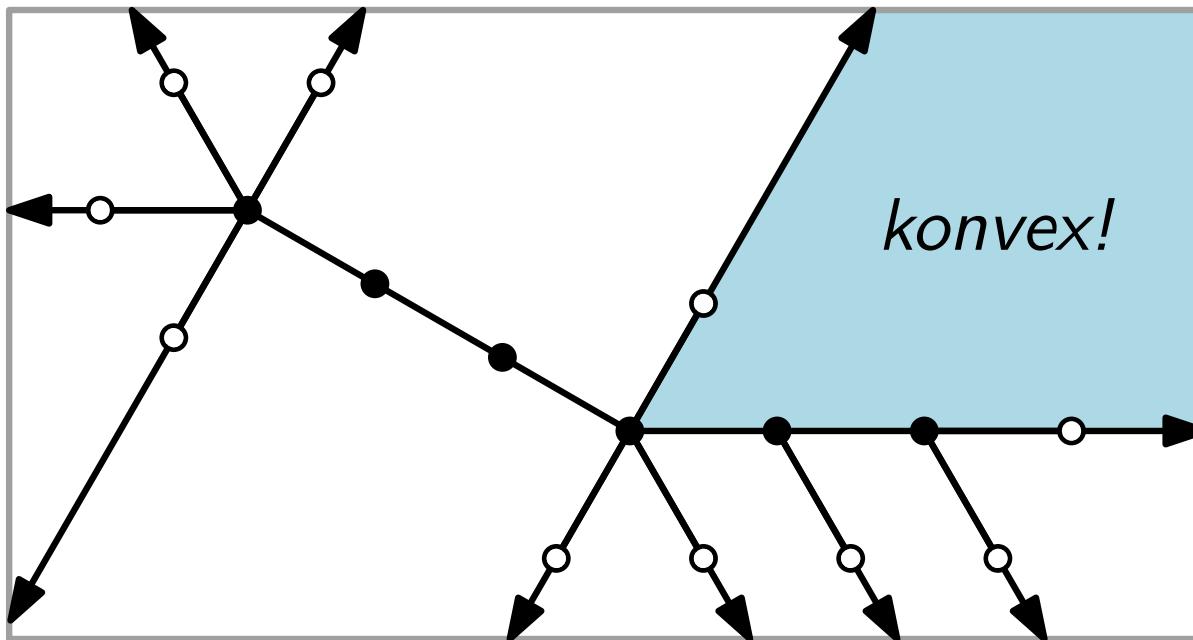
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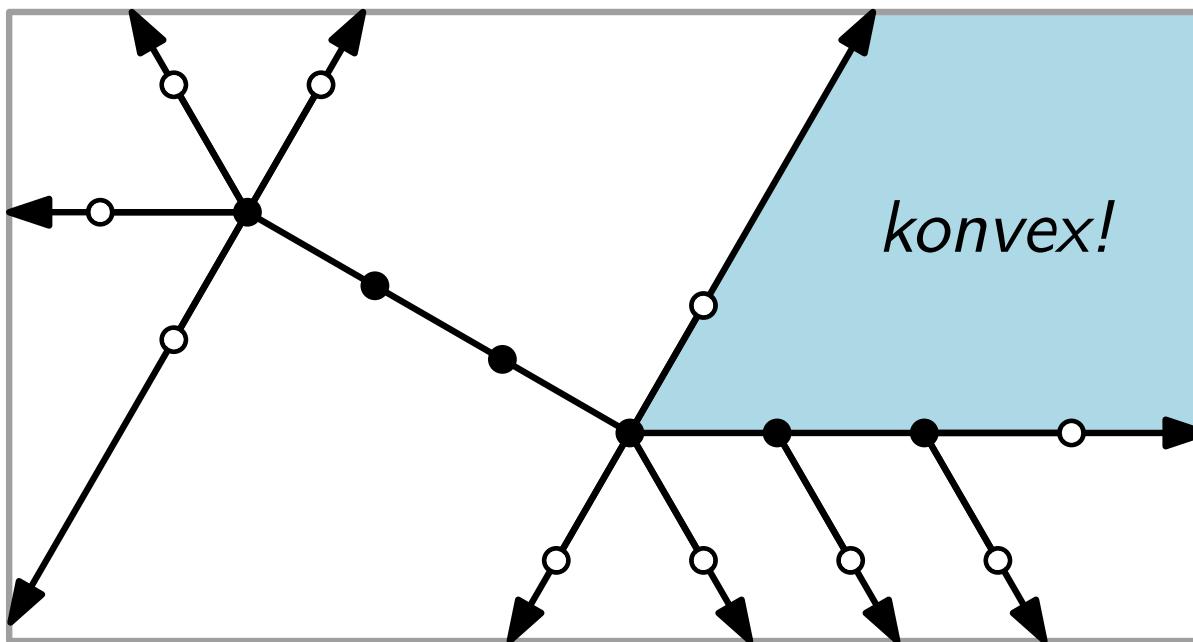
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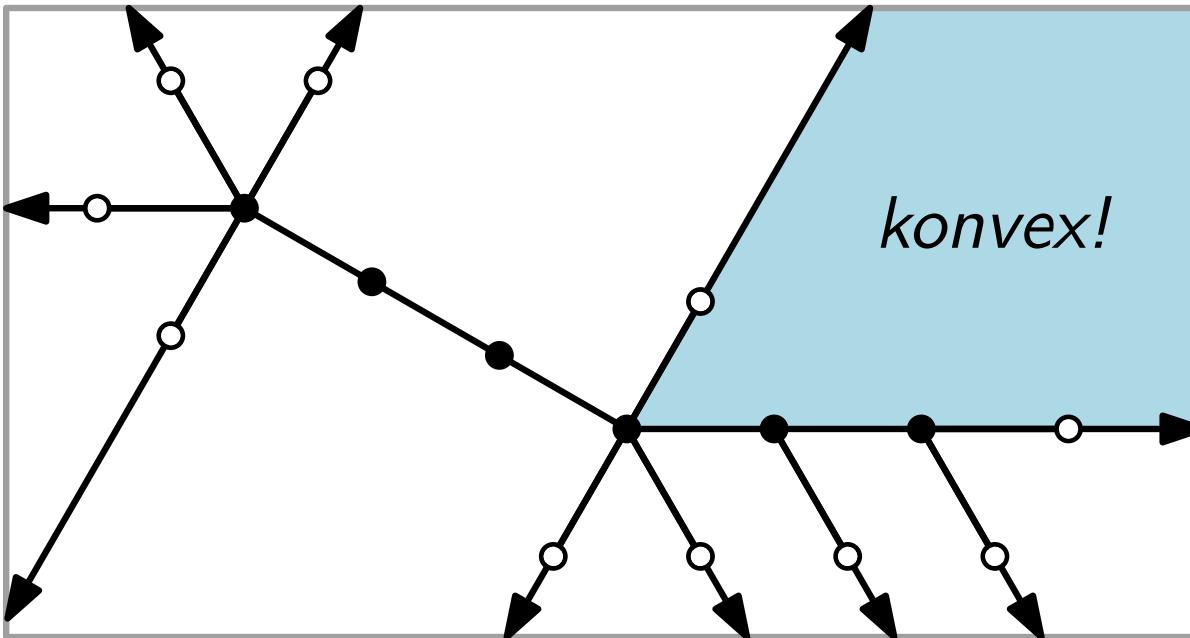
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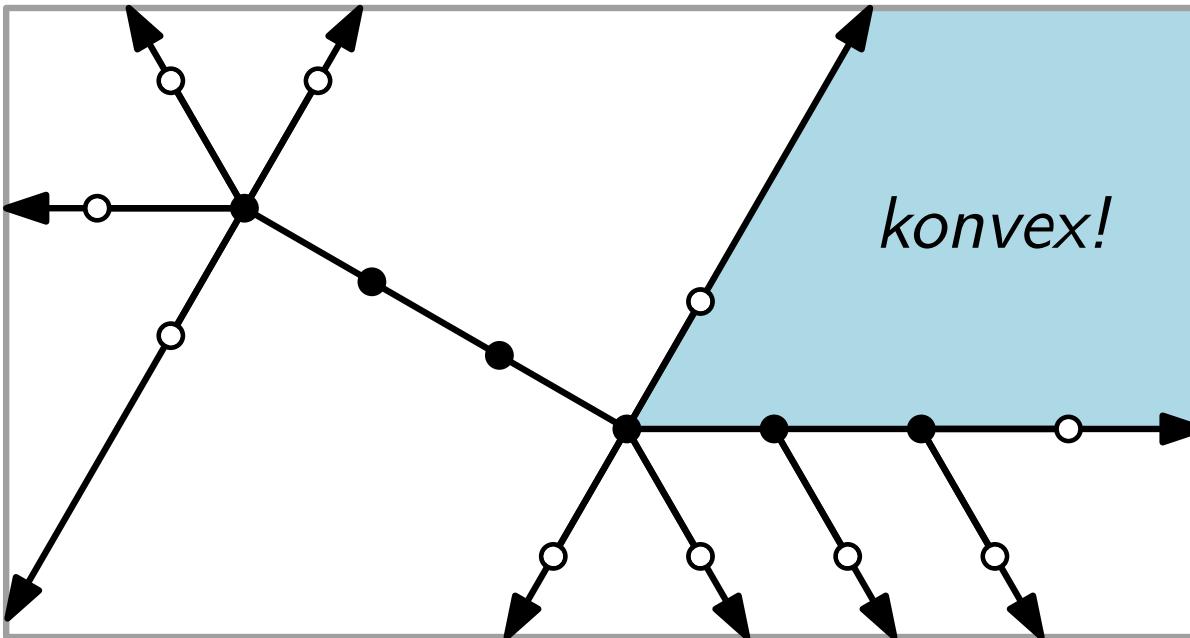


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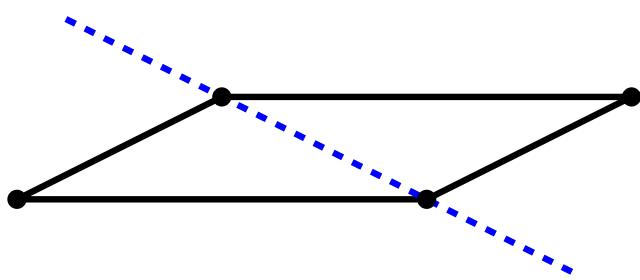


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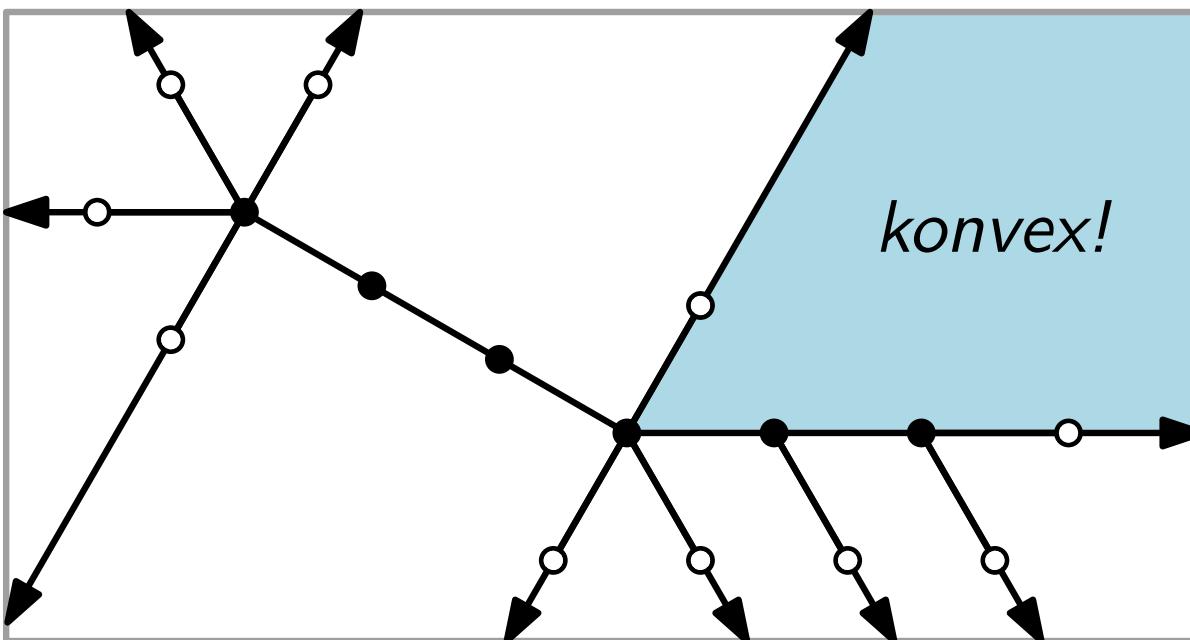


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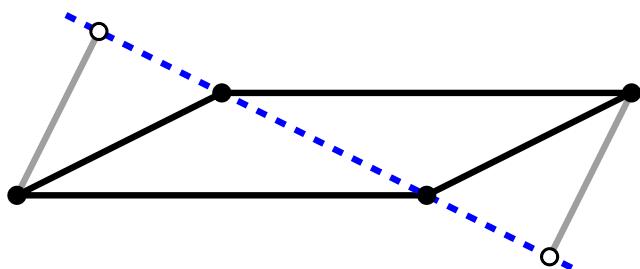


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Monotone Zeichnungen – Bekannte Resultate

Angelini et al.

[JGAA'12]

- Baum \Rightarrow monotone Zeichnung, $O(n^{1.6}) \times O(n^{1.6})$ Gitter

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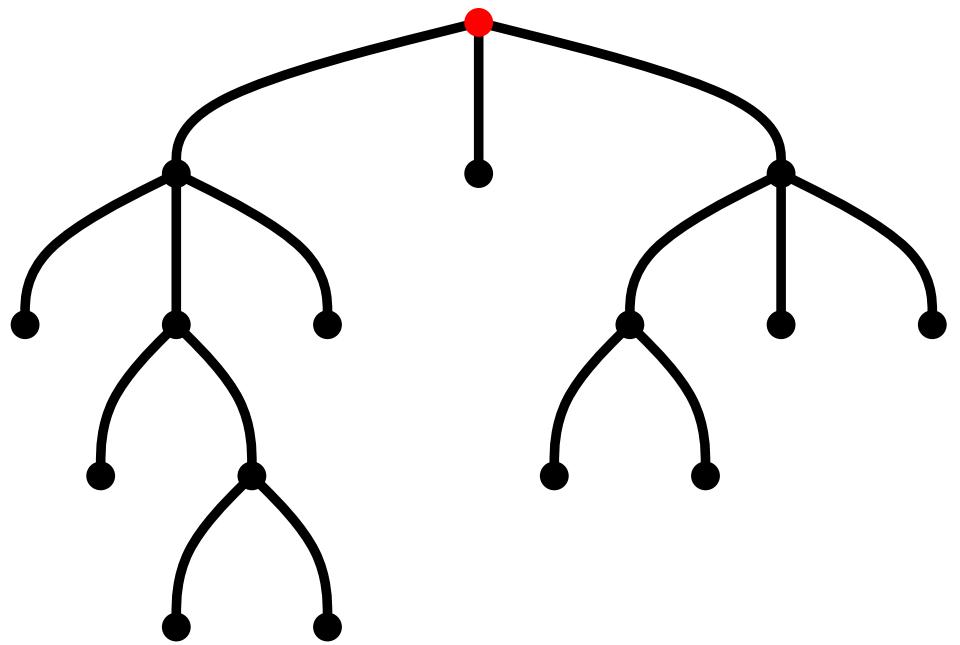
Planarer Graph \Rightarrow monotone Zeichnung, $O(n) \times O(n^2)$ Gitter

Carlson & Eppstein

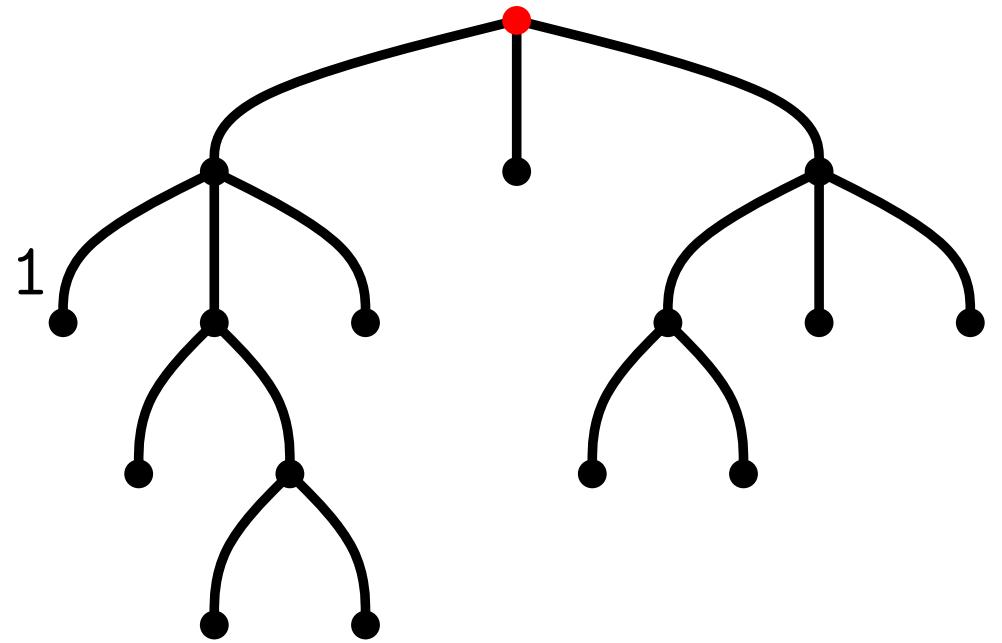
[GD'06]

Baum \Rightarrow konvexe Zeichnung, *optimaler Winkelauflösung*

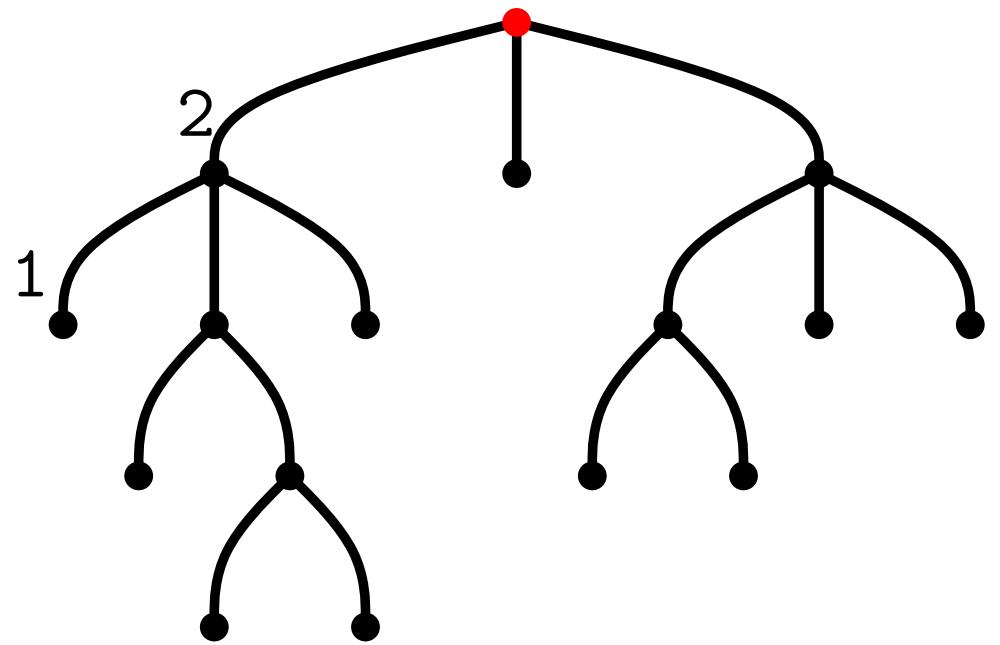
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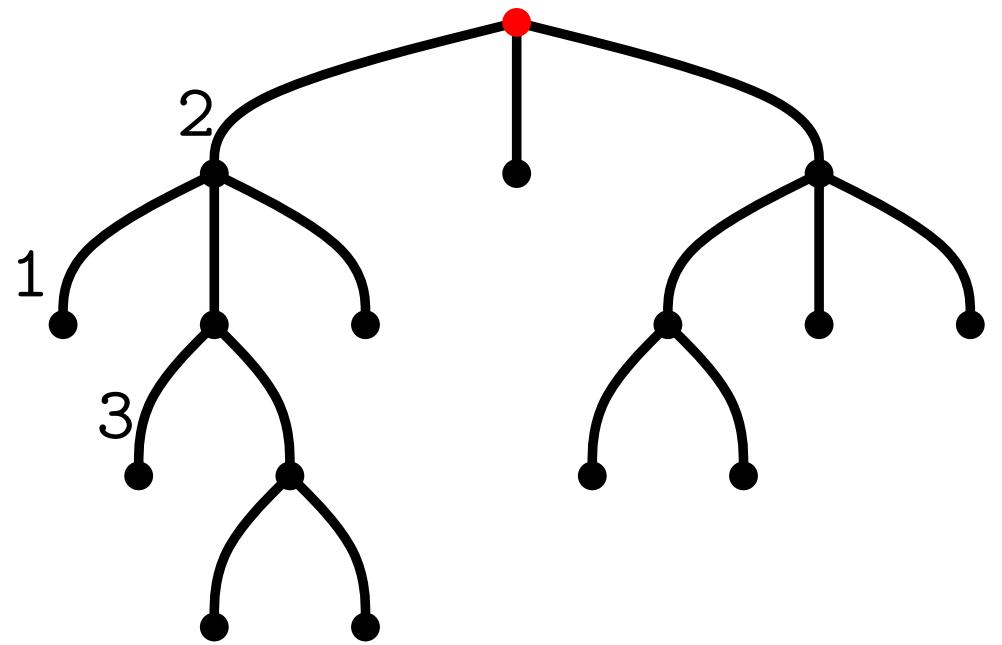
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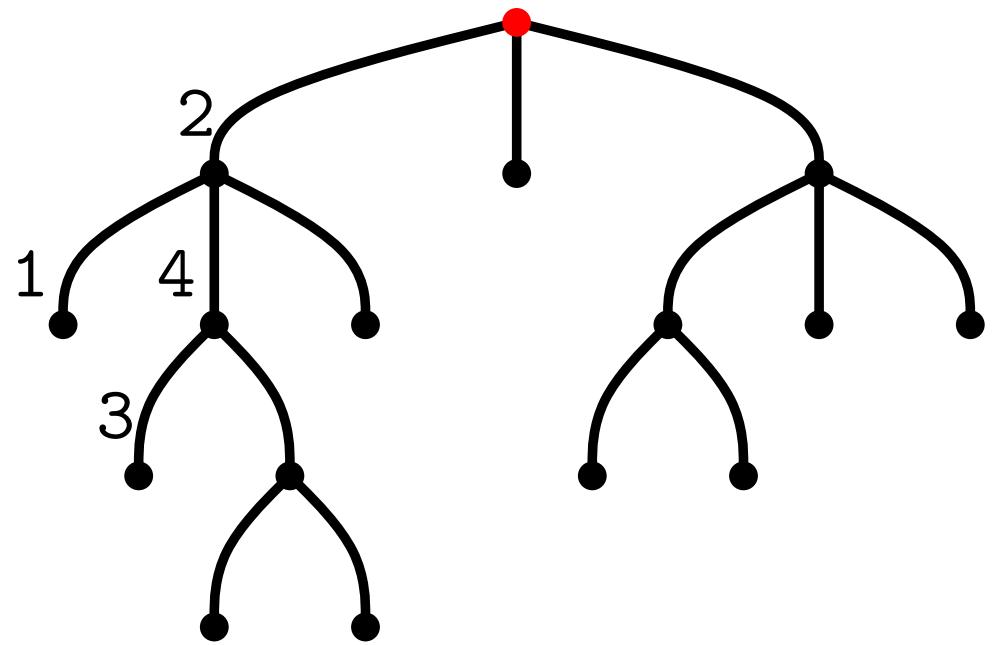
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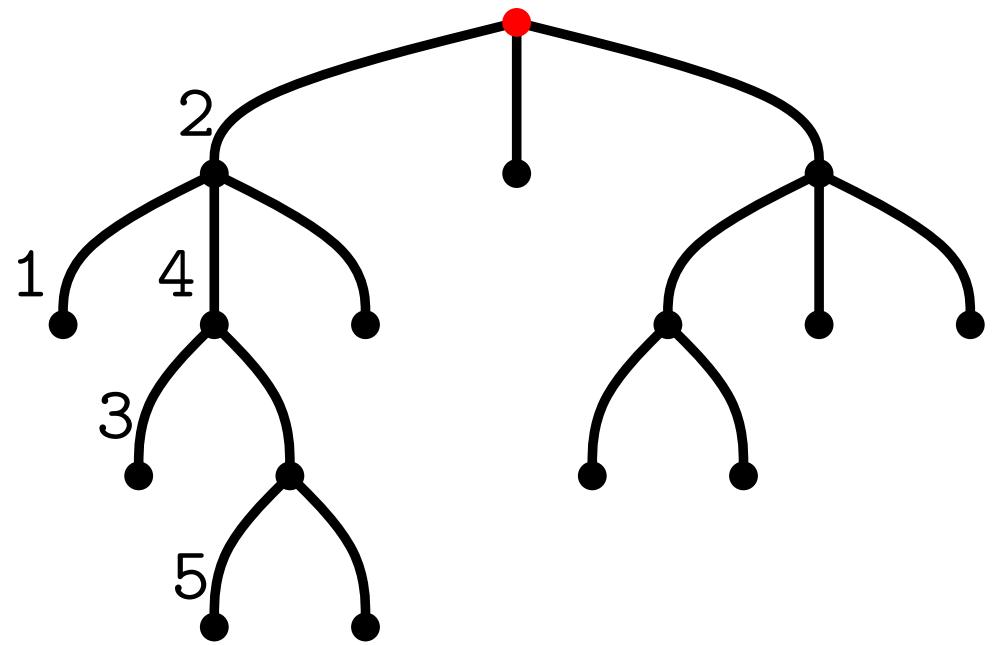
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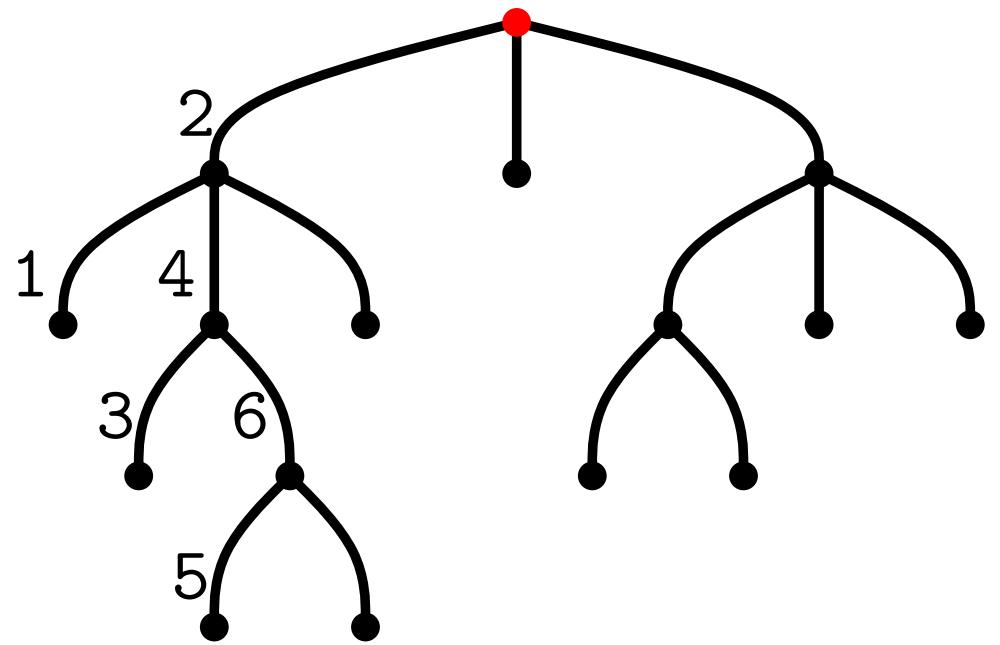
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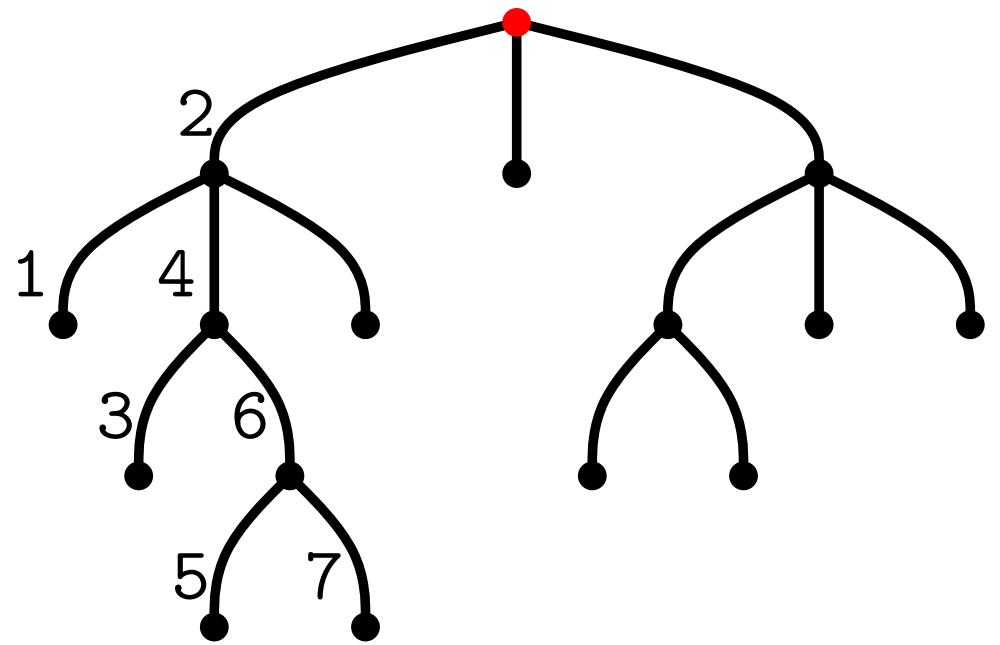
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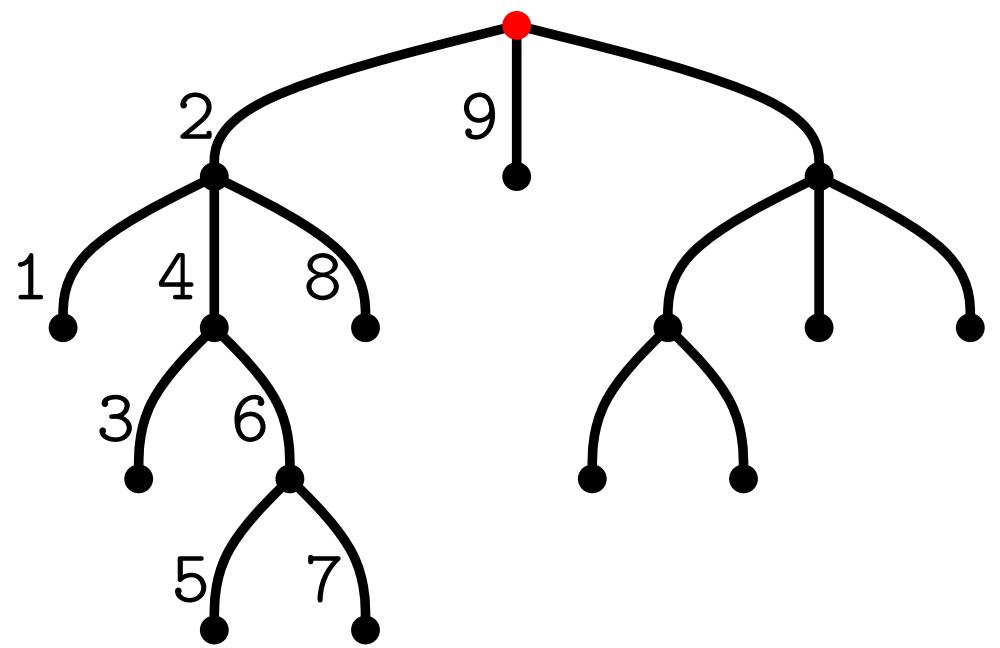
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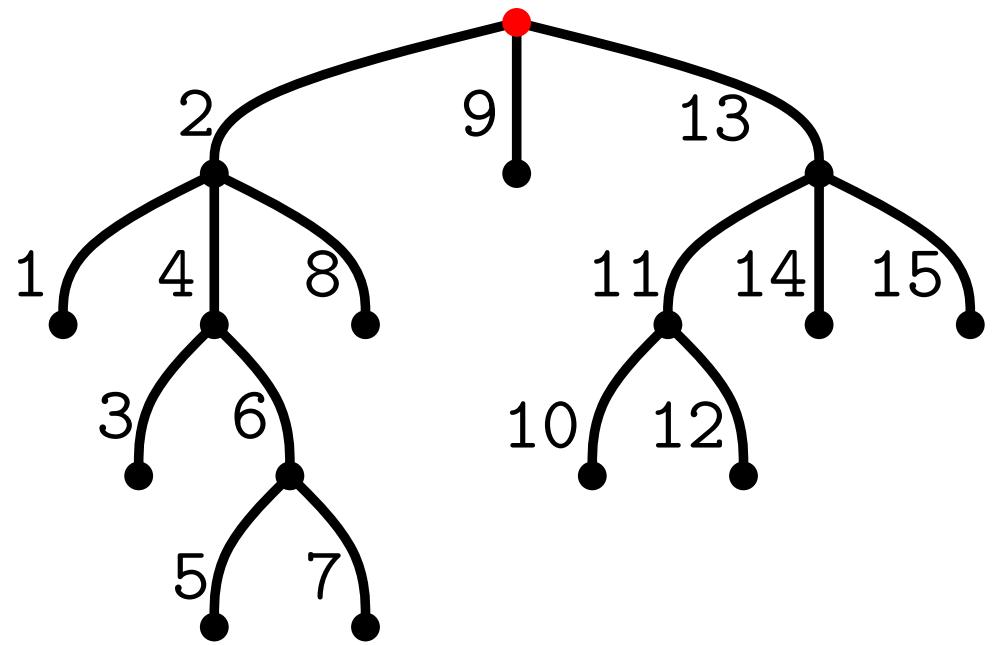
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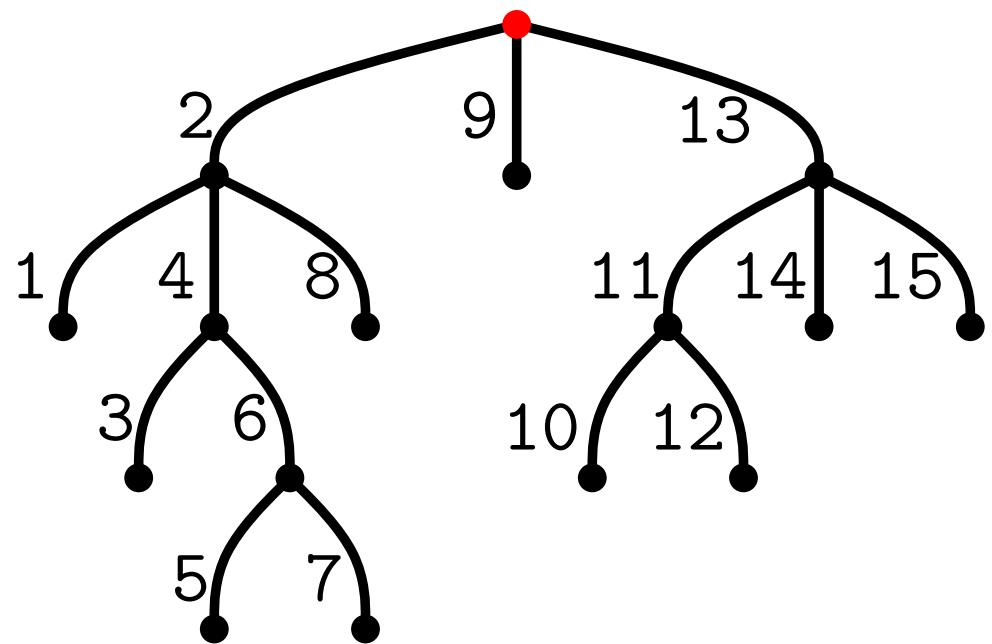
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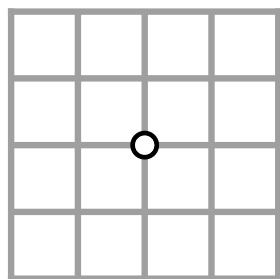
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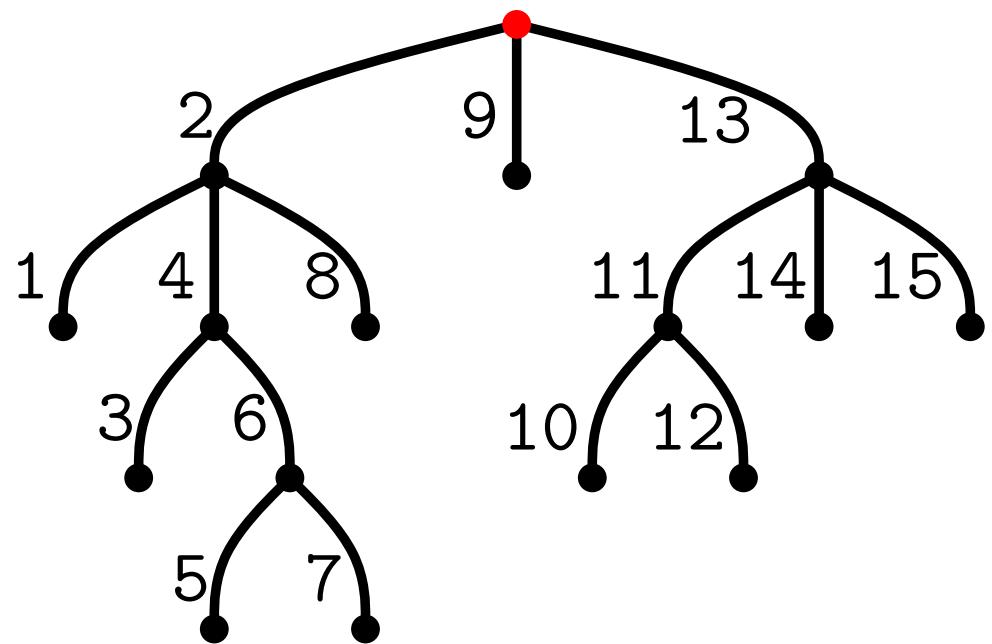
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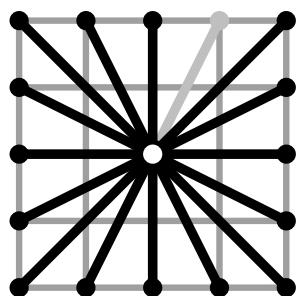
Schritt II: Wähle Vektoren



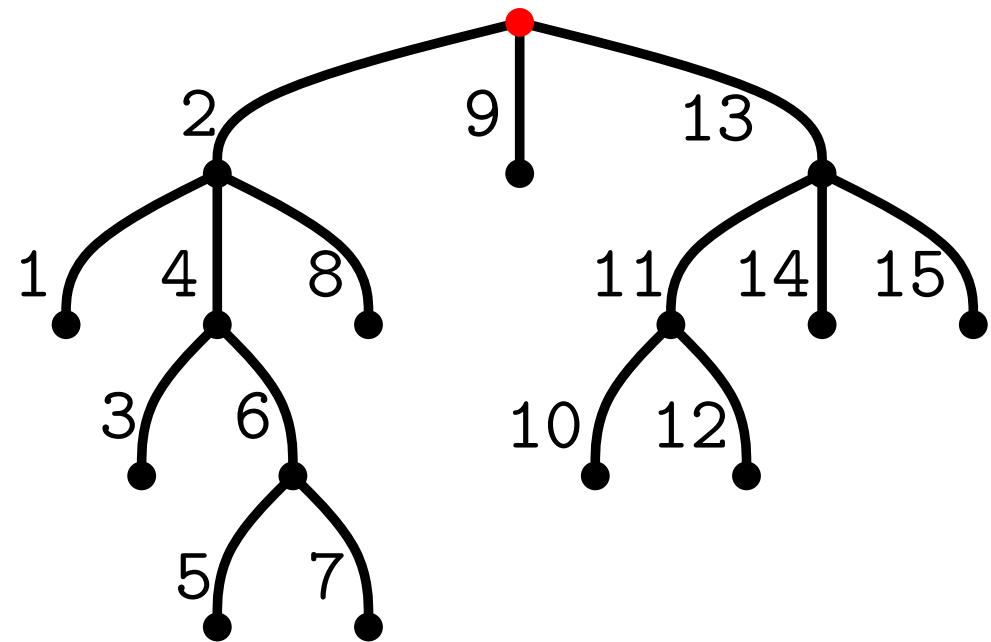
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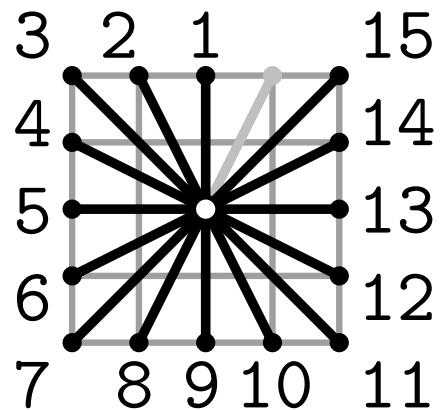
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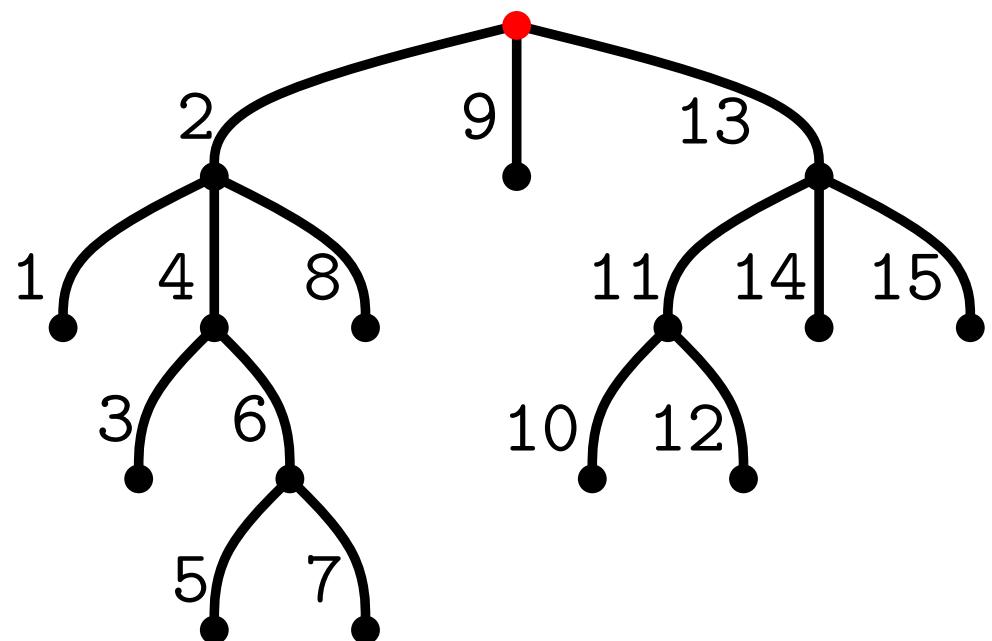
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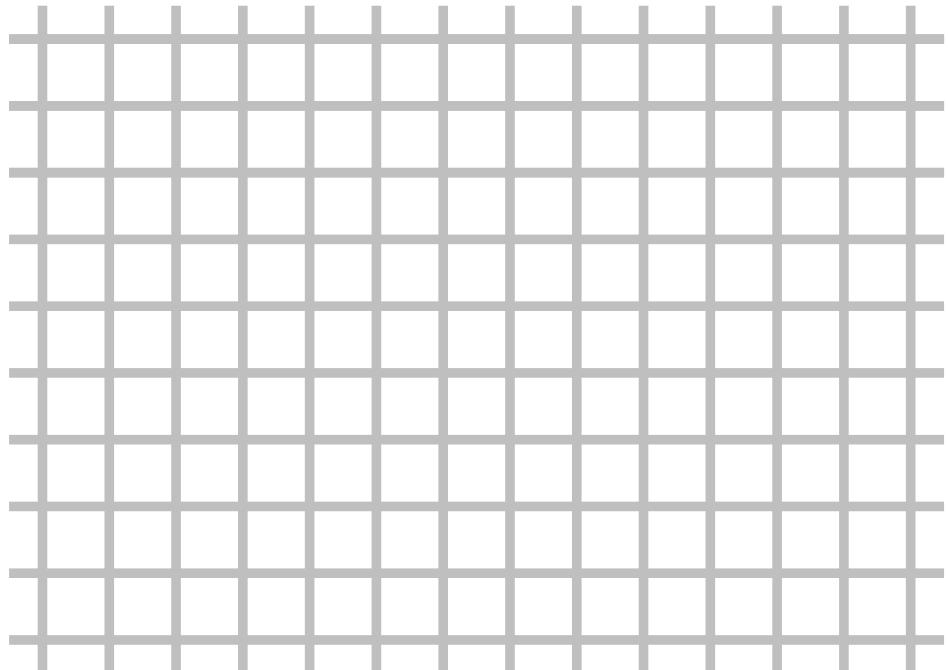
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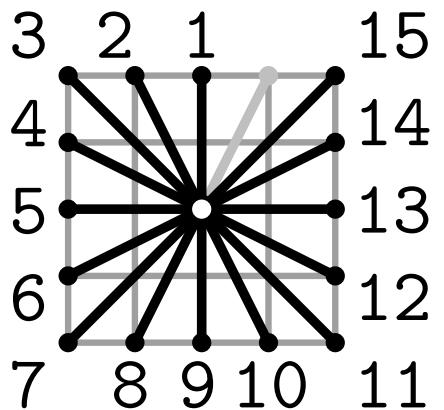
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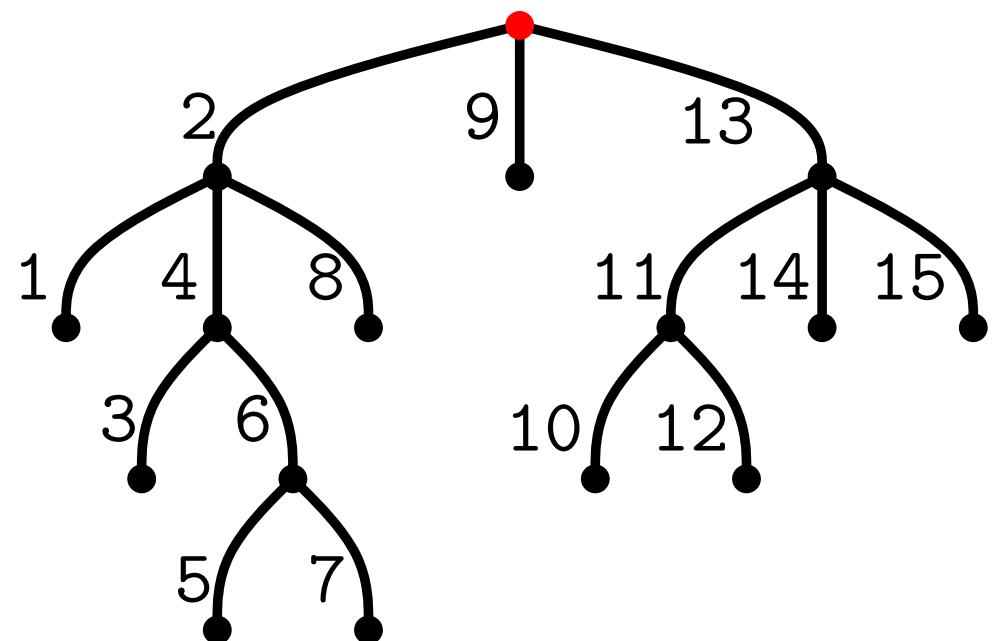
Schritt III: Zeichne Baum



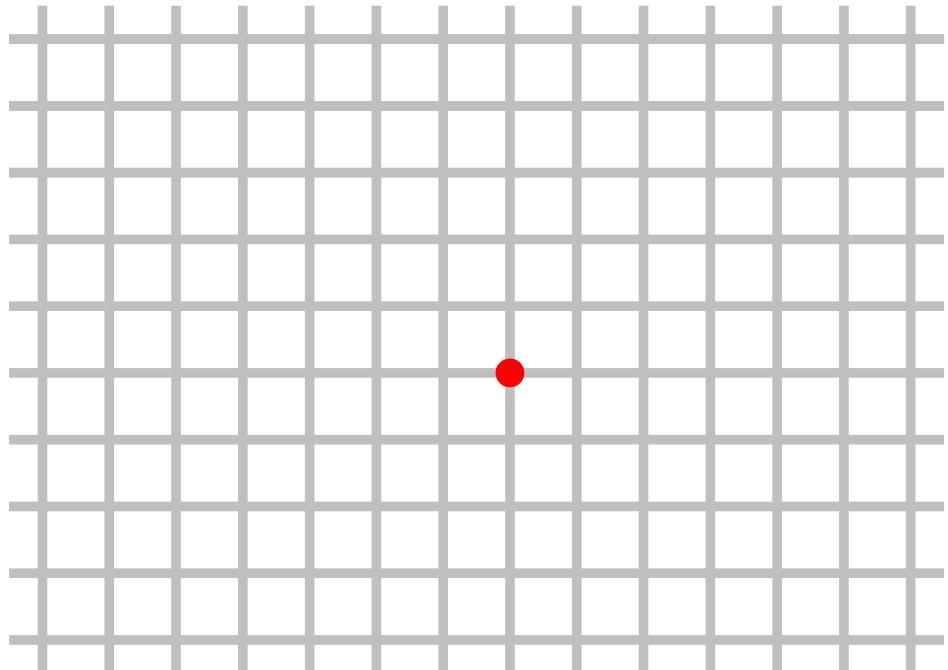
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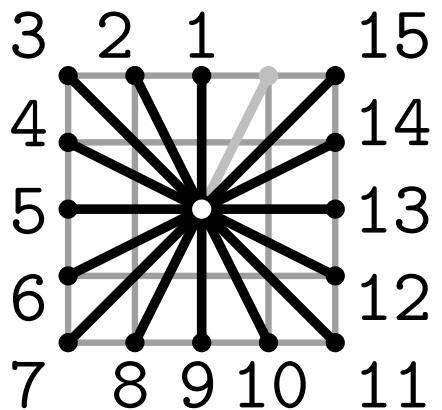
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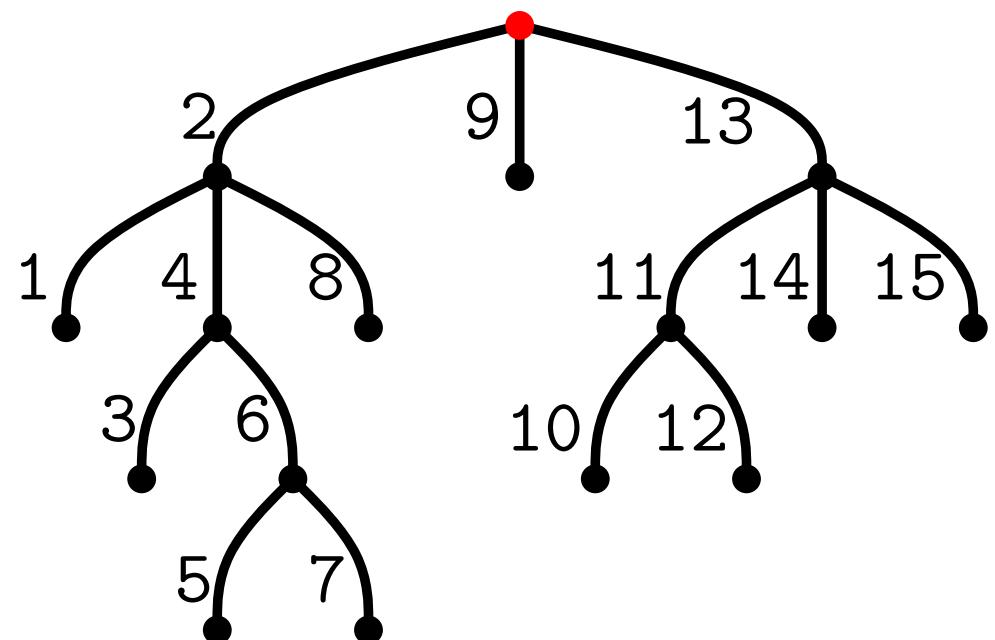
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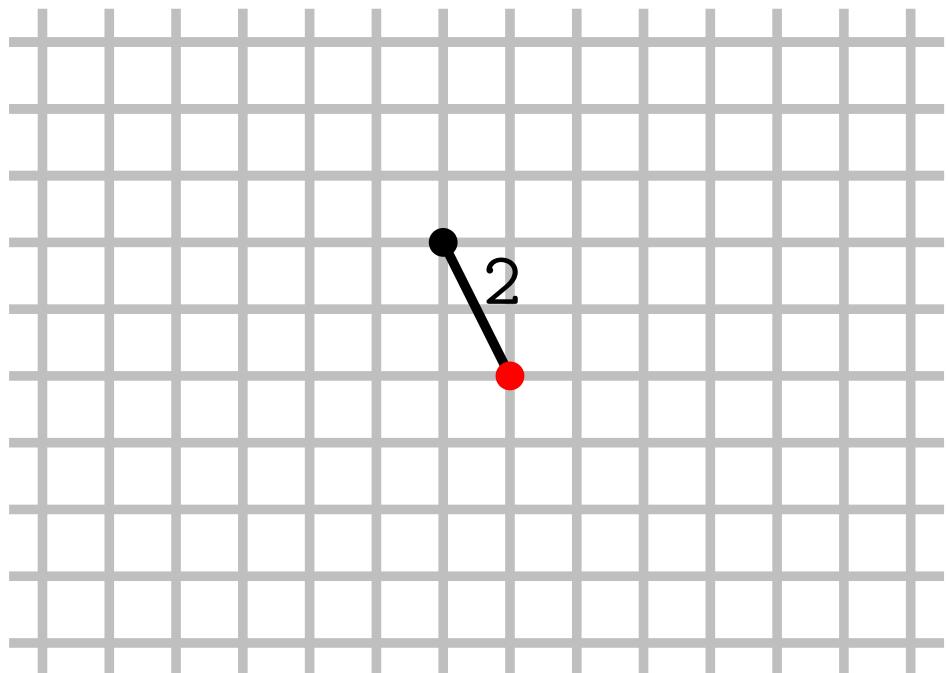
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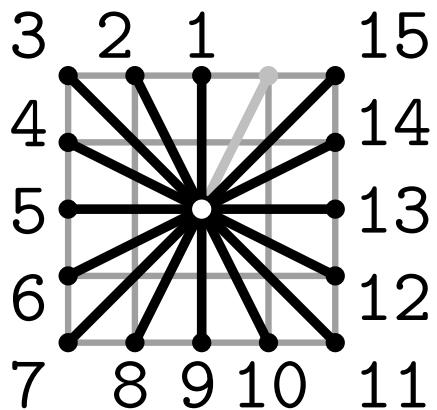
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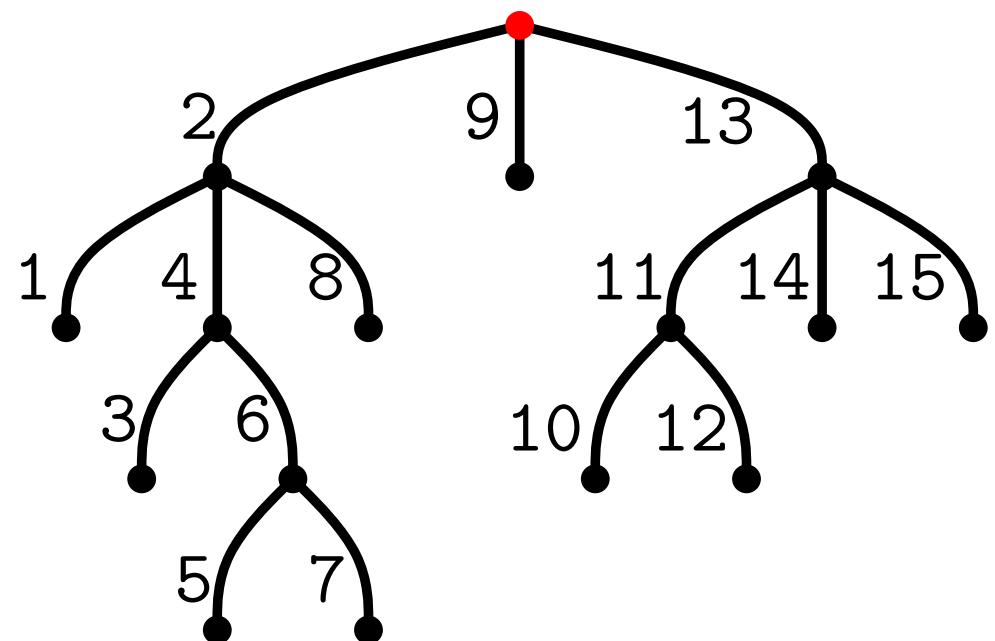
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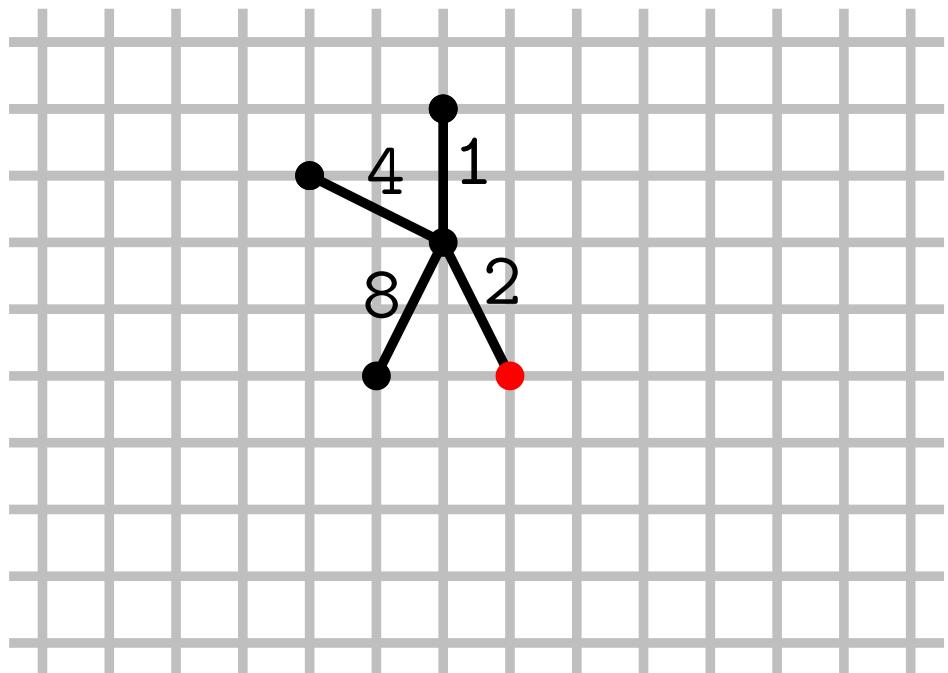
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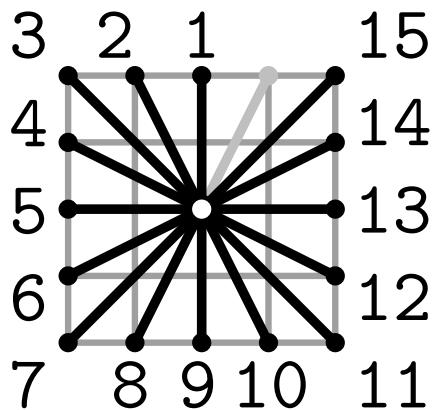
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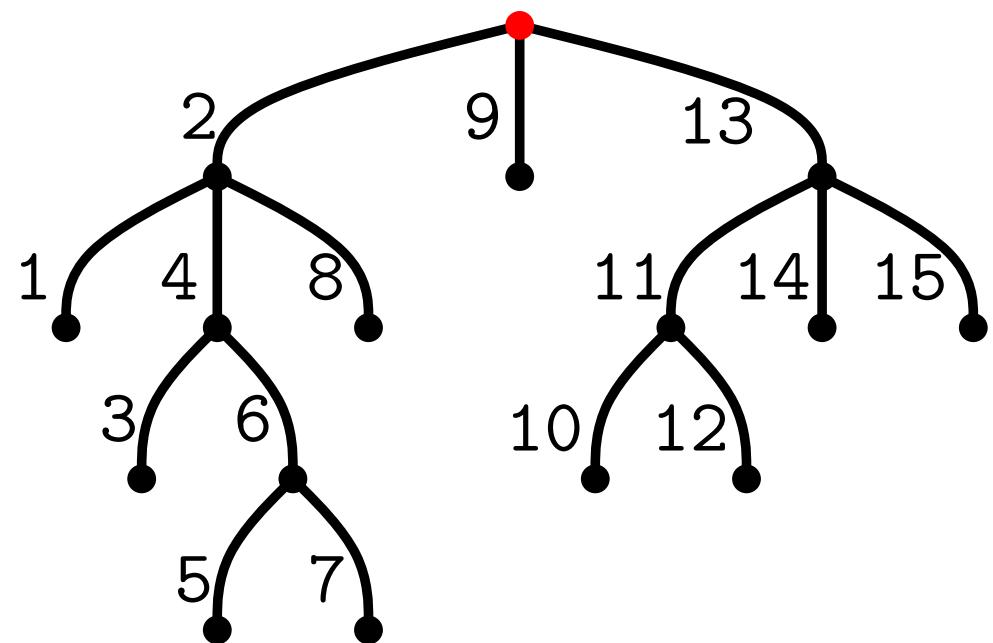
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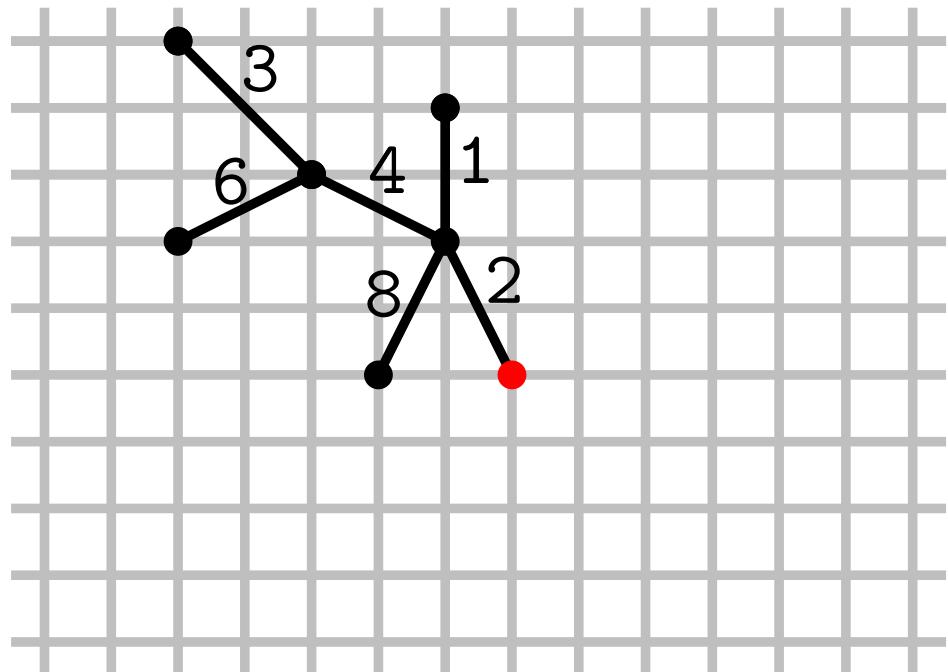
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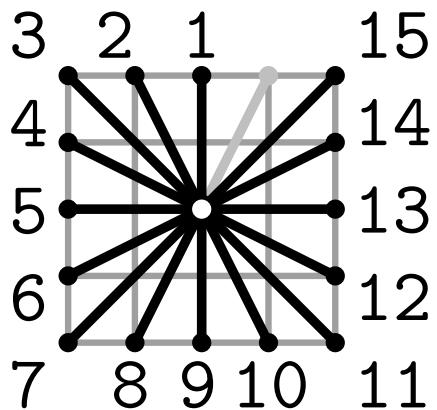
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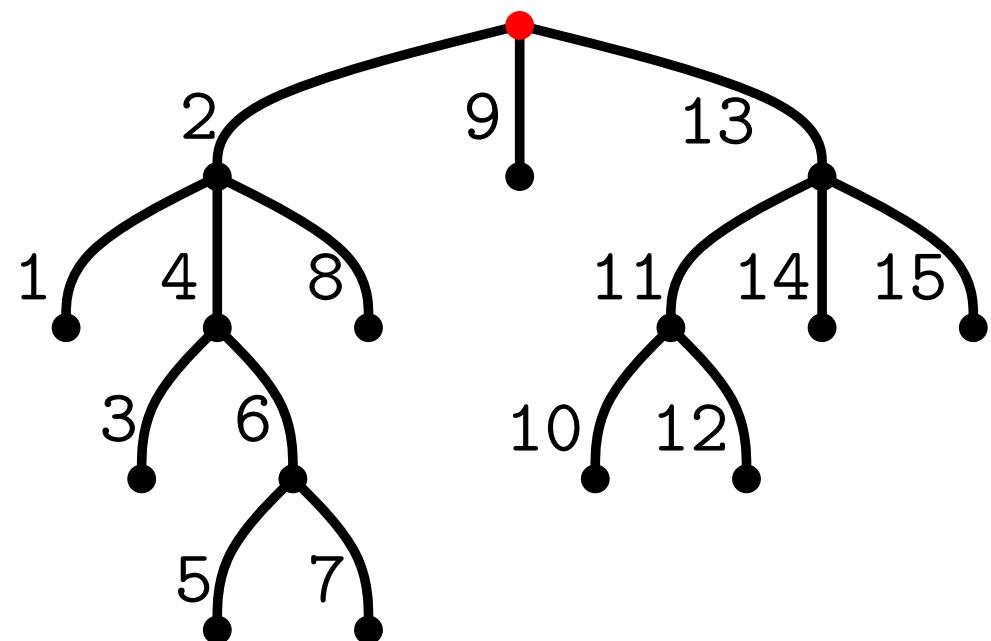
Schritt III: Zeichne Baum



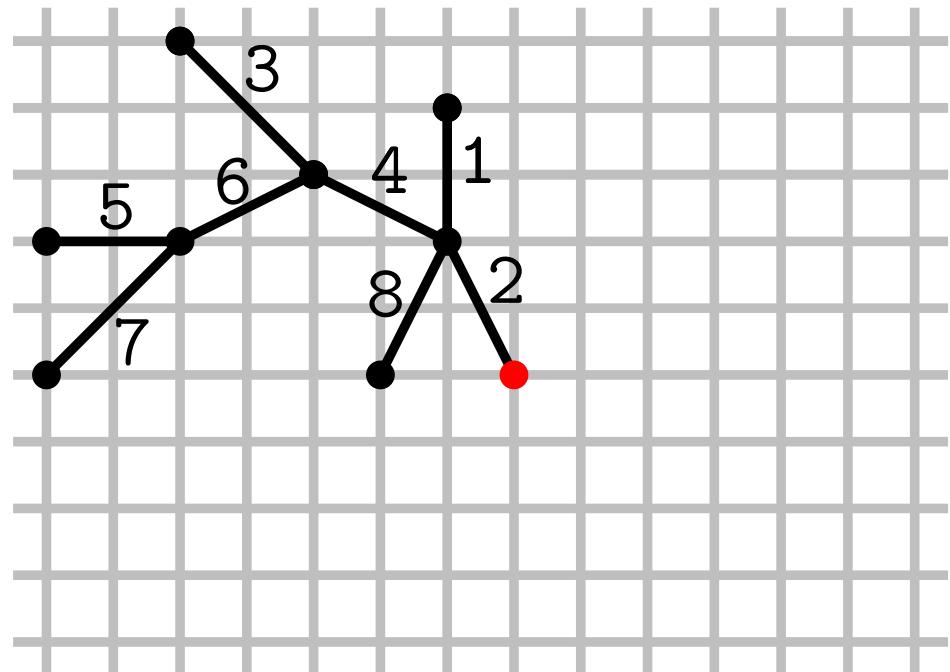
Schritt II: Wähle Vektoren



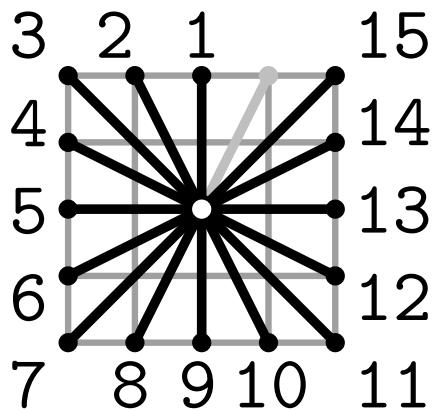
Schritt I: Beschrifte Kanten



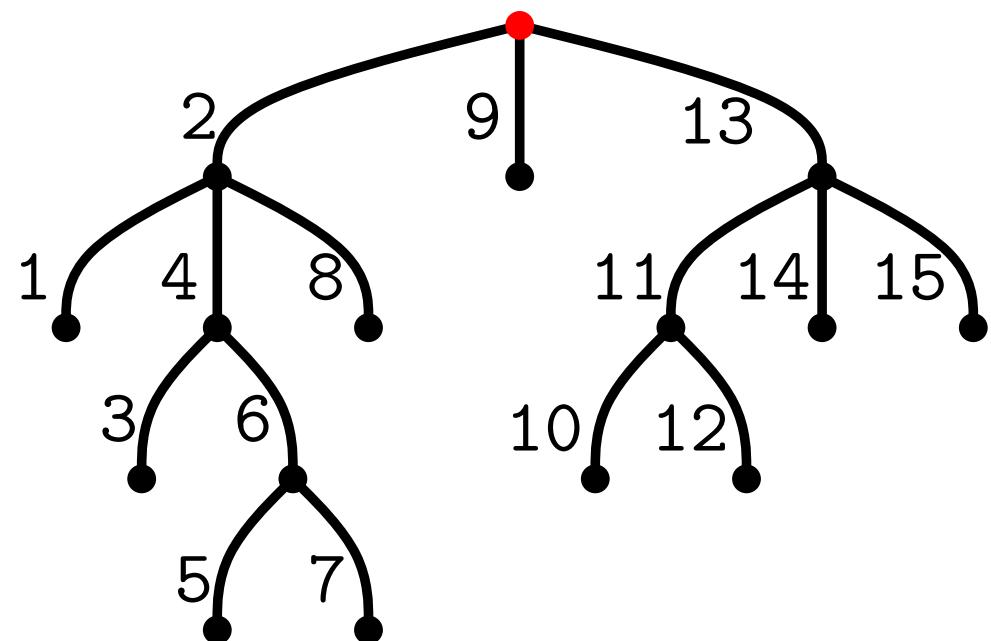
Schritt III: Zeichne Baum



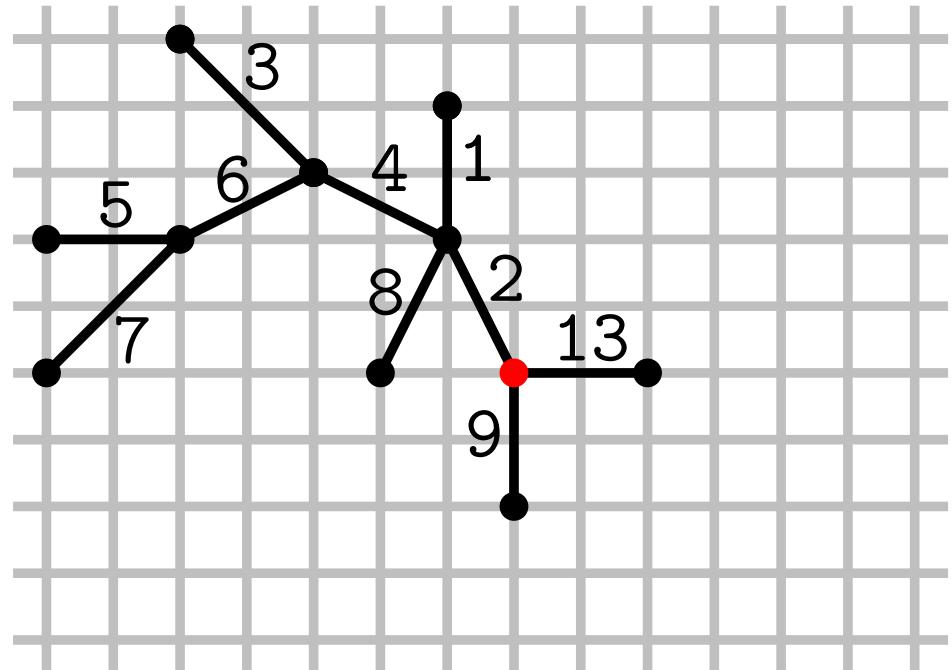
Schritt II: Wähle Vektoren



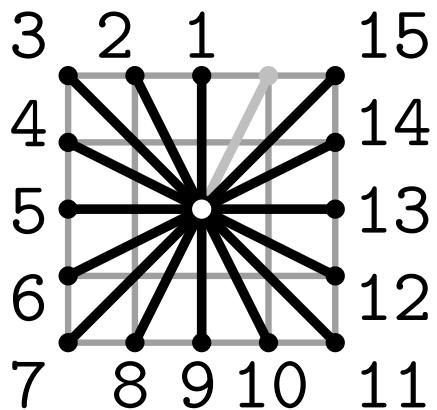
Schritt I: Beschrifte Kanten



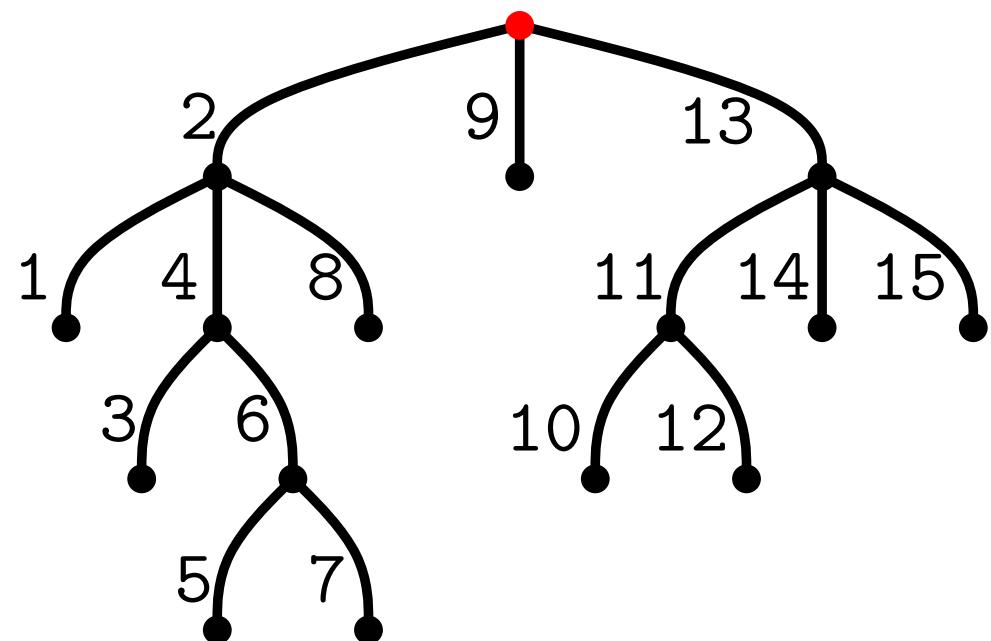
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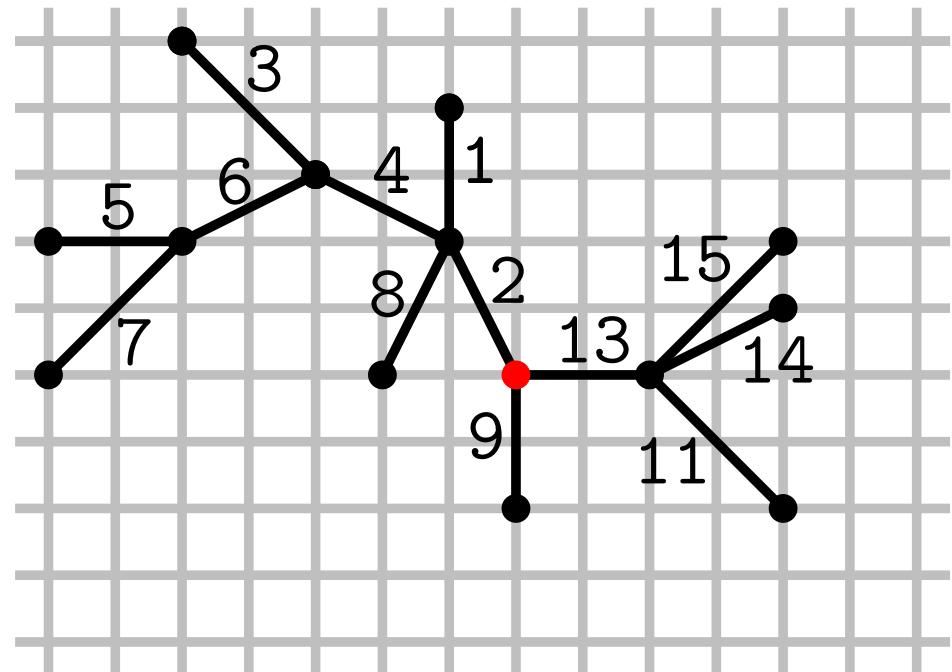
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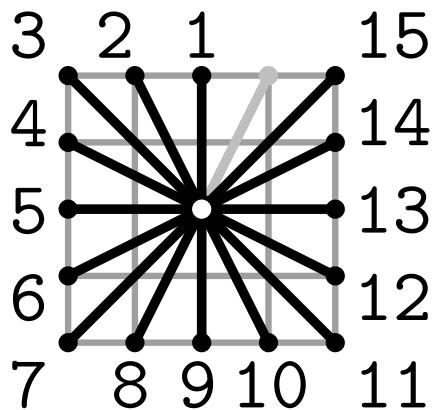
Schritt I: Beschrifte Kanten



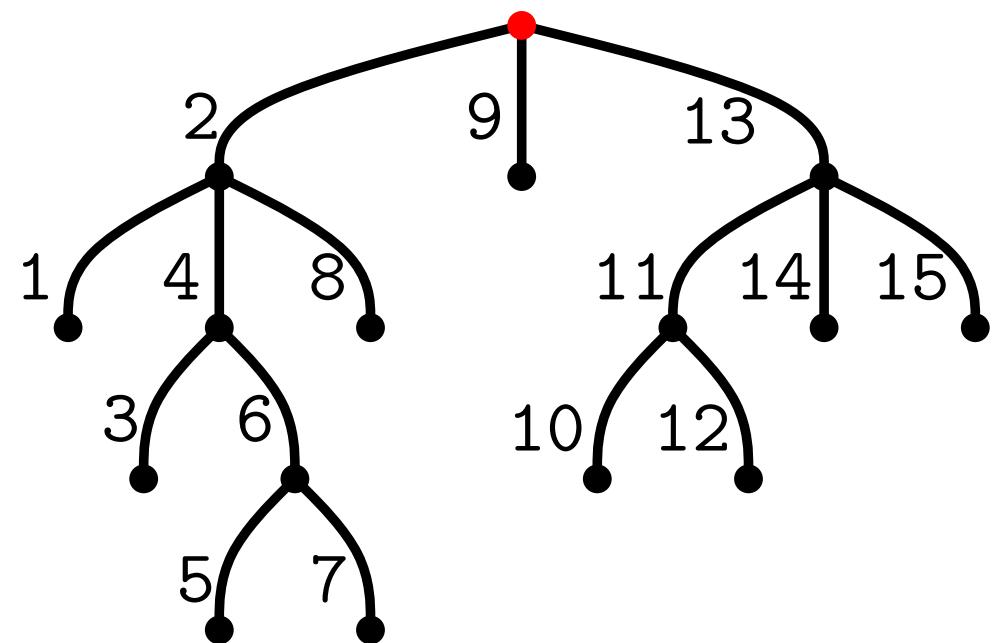
Schritt III: Zeichne Baum



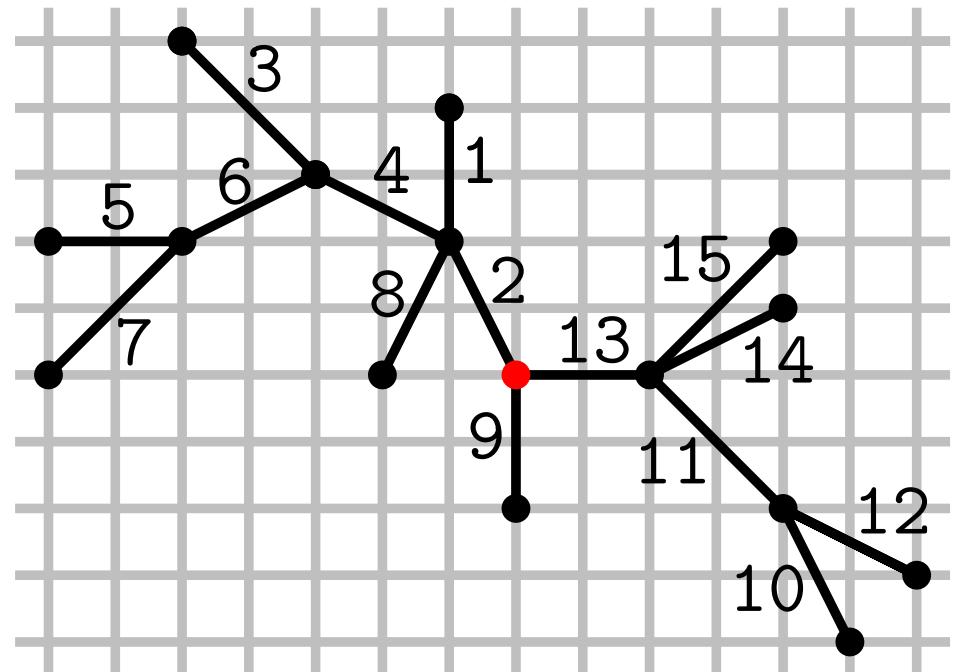
Schritt II: Wähle Vektoren



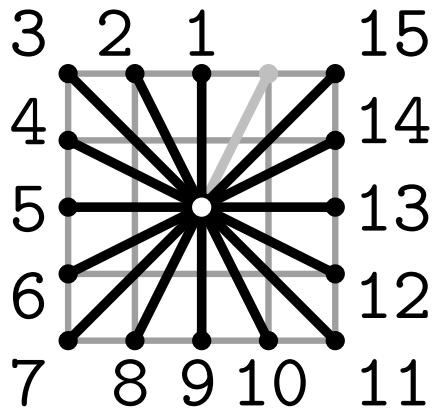
Schritt I: Beschrifte Kanten



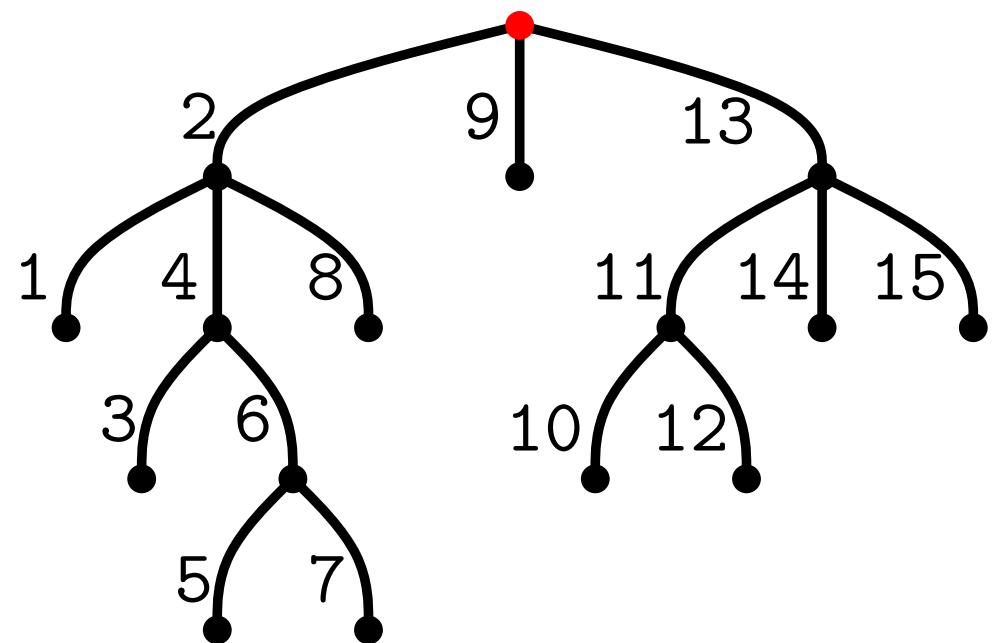
Schritt III: Zeichne Baum



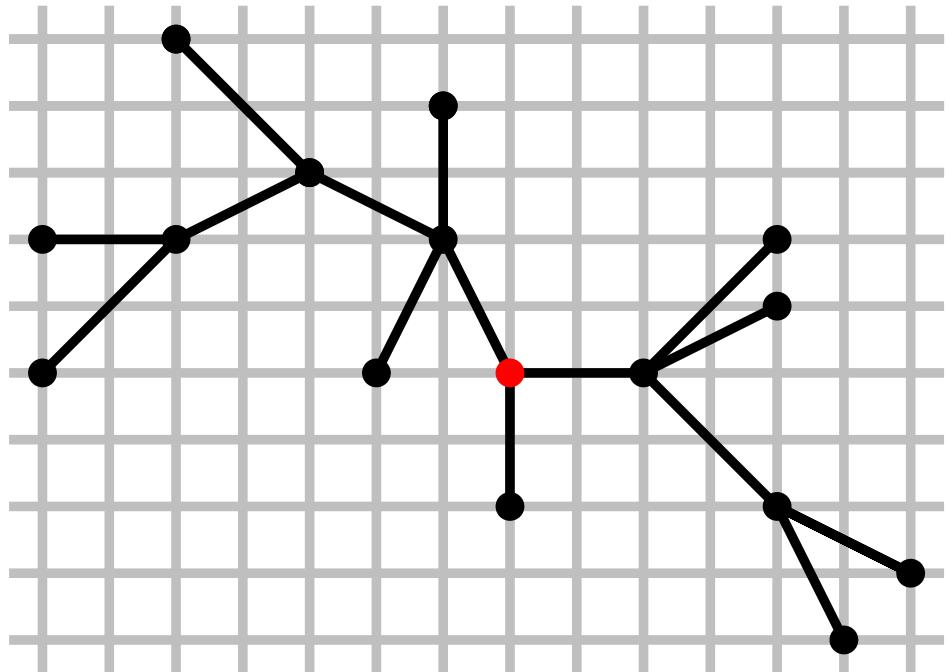
Schritt II: Wähle Vektoren



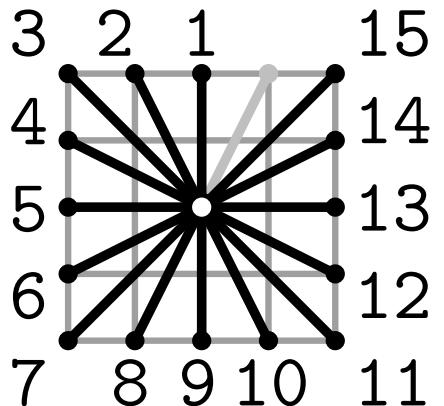
Schritt I: Beschrifte Kanten



Schritt III: Zeichne Baum



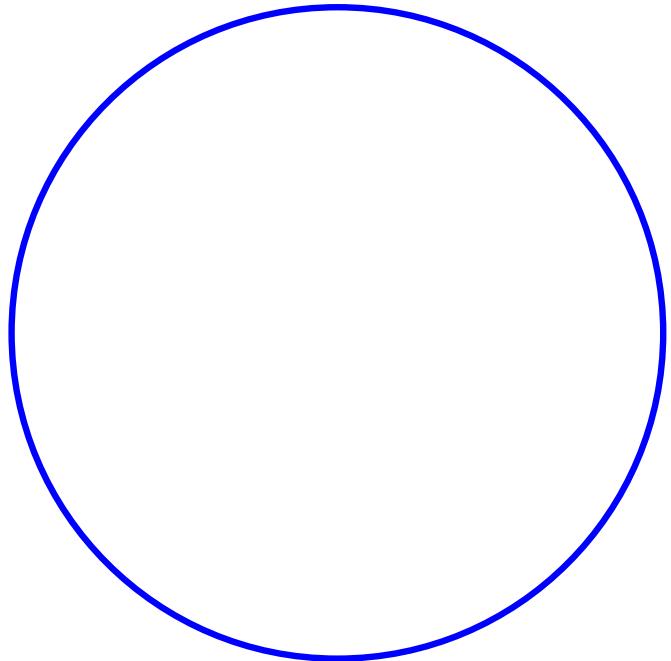
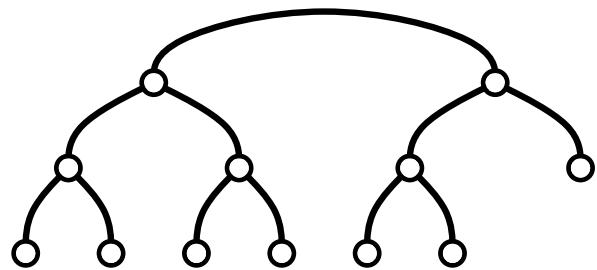
Schritt II: Wähle Vektoren



Baum \Rightarrow
monotone konvexe Zeichnung,
 $O(n^{1.5}) \times O(n^{1.5})$ Gitter

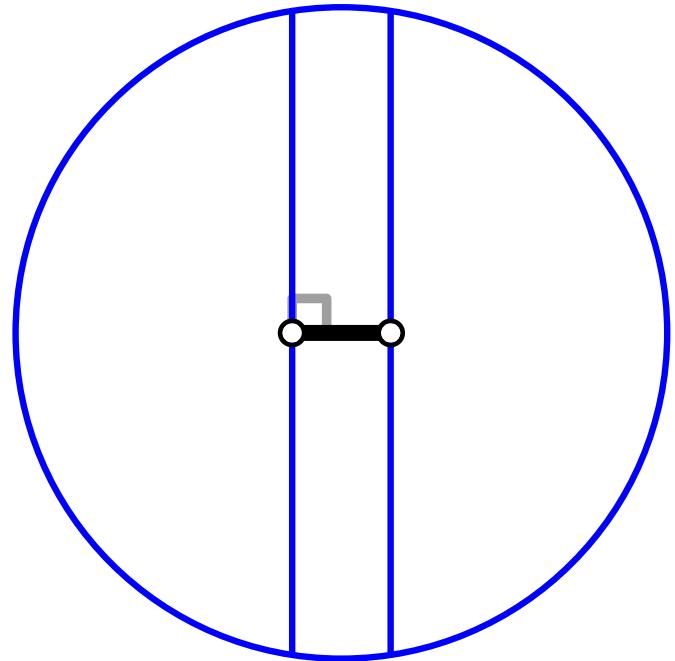
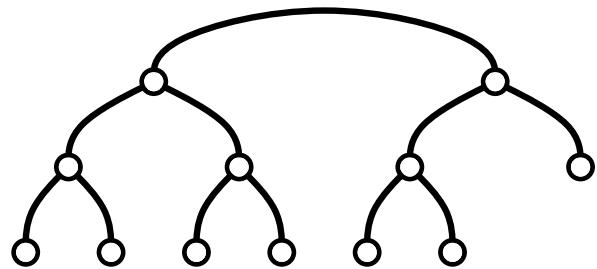
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



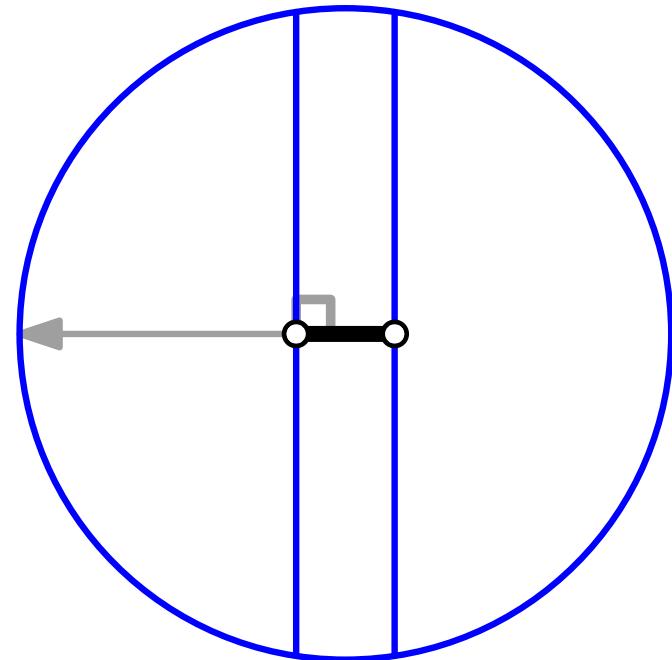
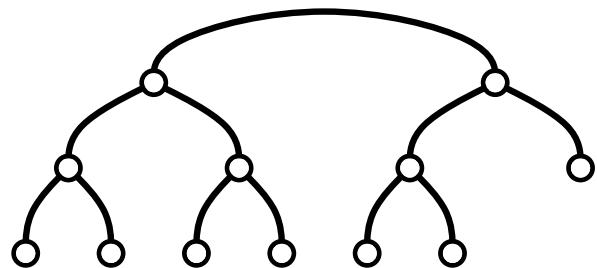
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



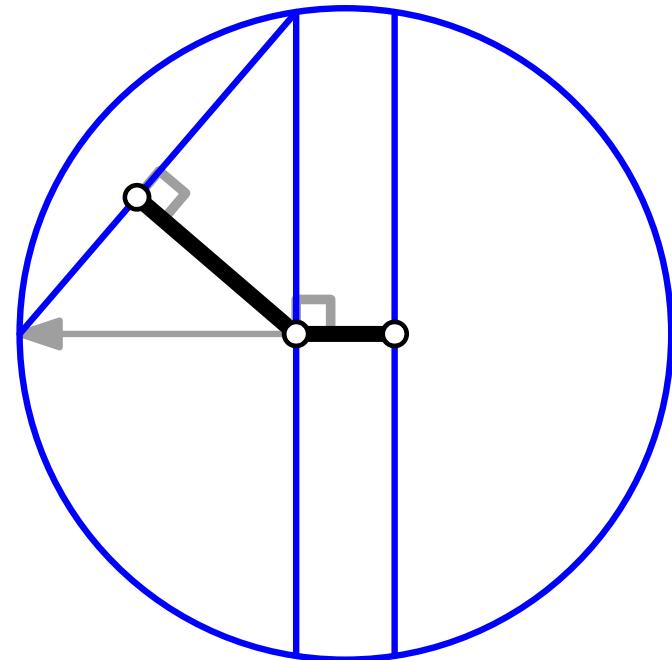
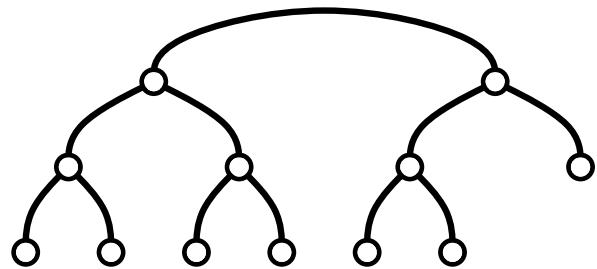
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



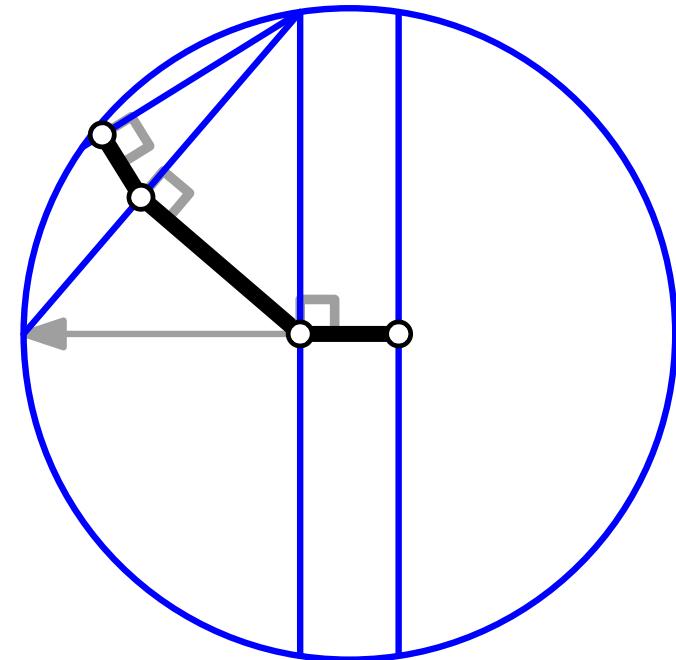
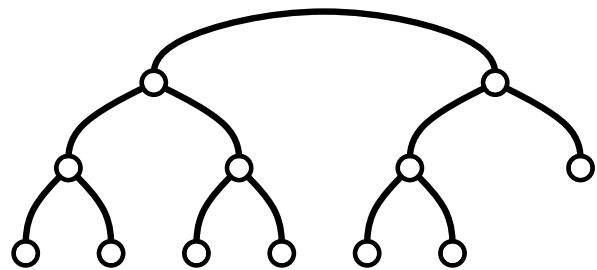
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



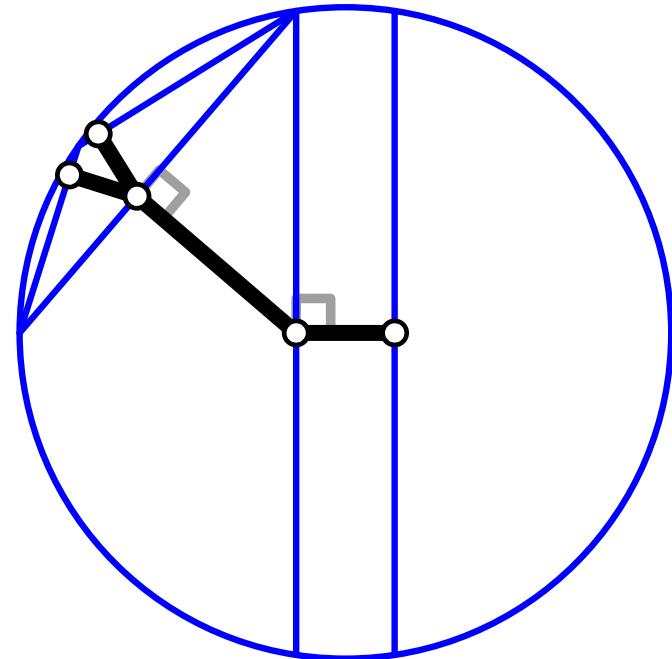
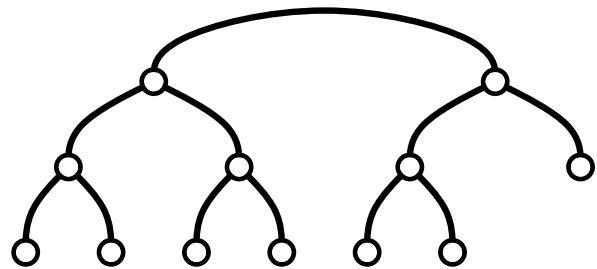
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



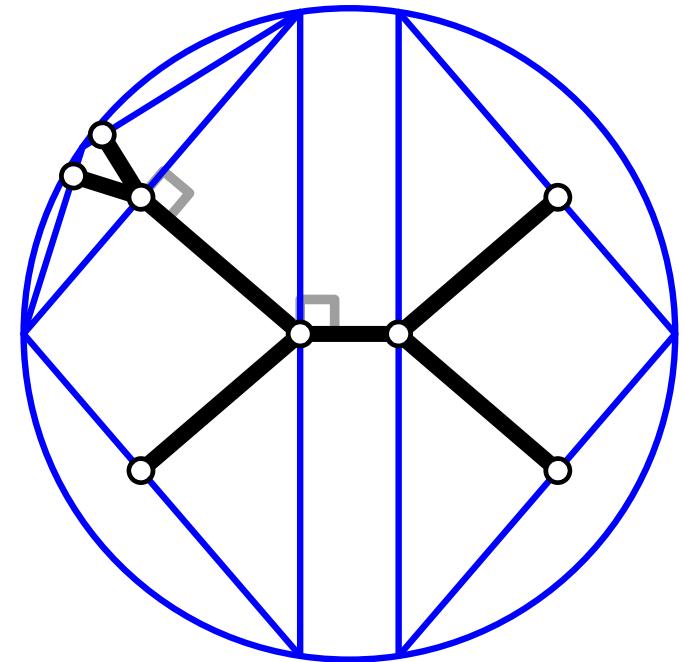
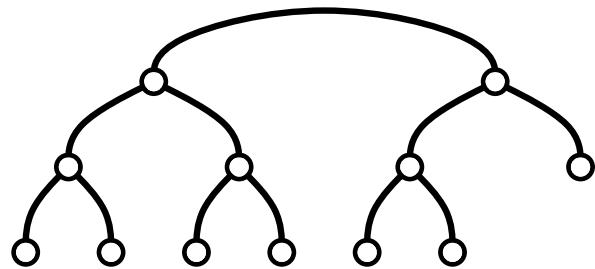
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



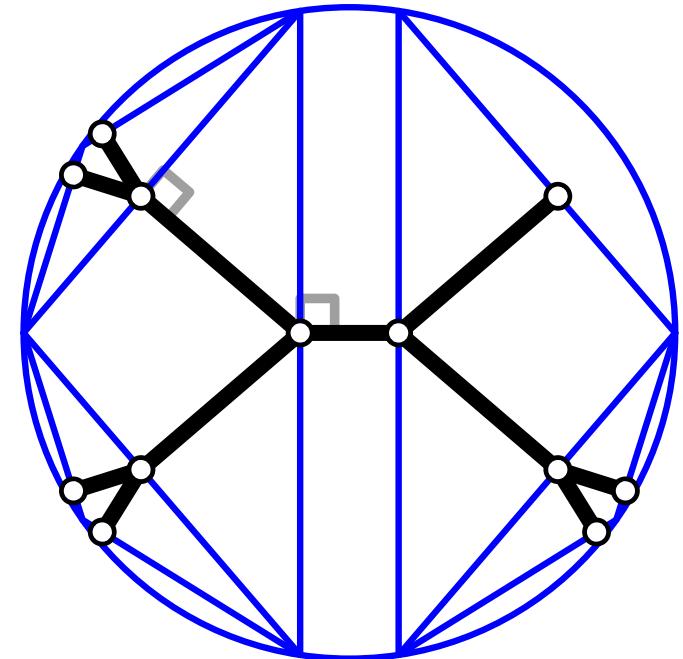
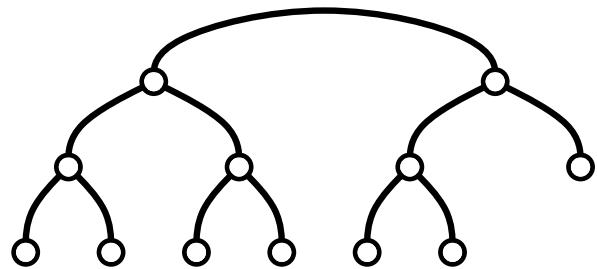
Streng Monotone Zeichnungen

Ordnlicher Binärbaum:
Kein Grad-2 Knoten



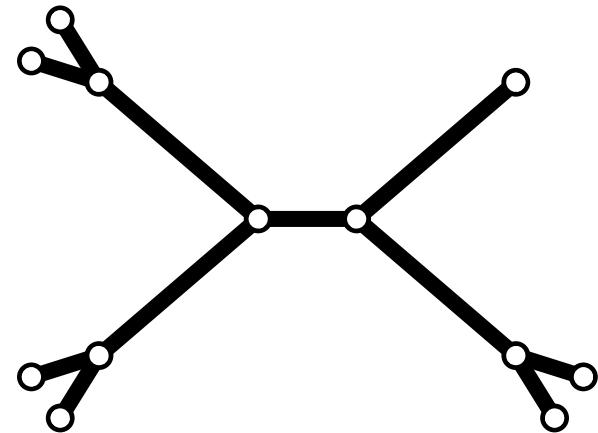
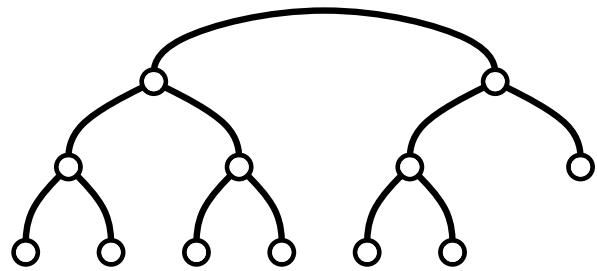
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



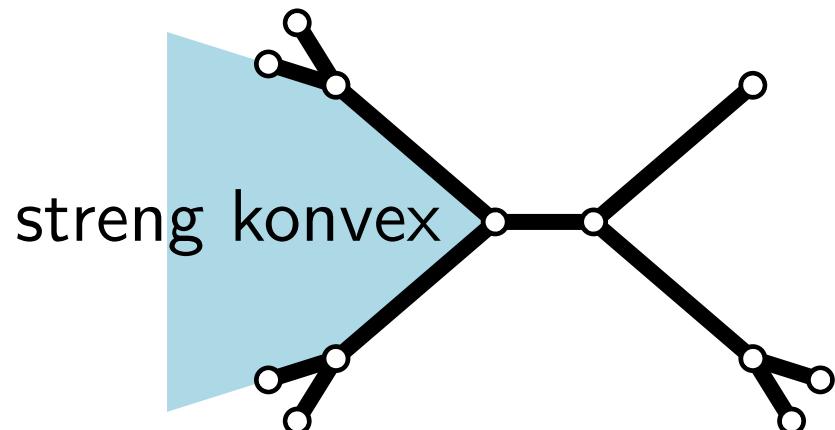
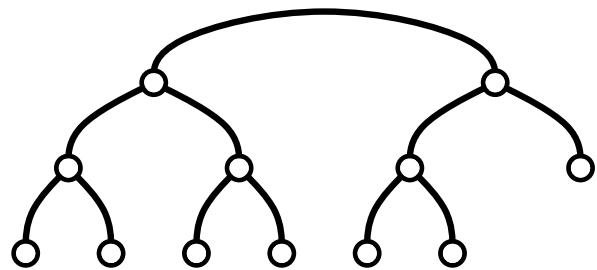
Streng Monotone Zeichnungen

Ordentlicher Binärbaum:
Kein Grad-2 Knoten



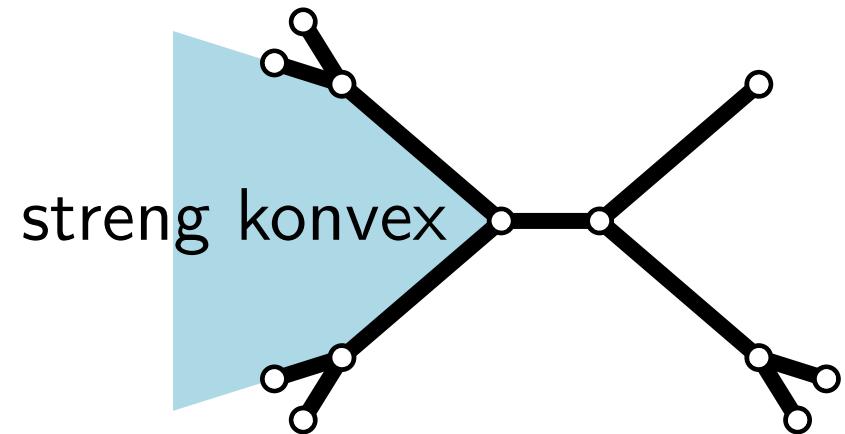
Streng Monotone Zeichnungen

Ordnlicher Binärbaum:
Kein Grad-2 Knoten



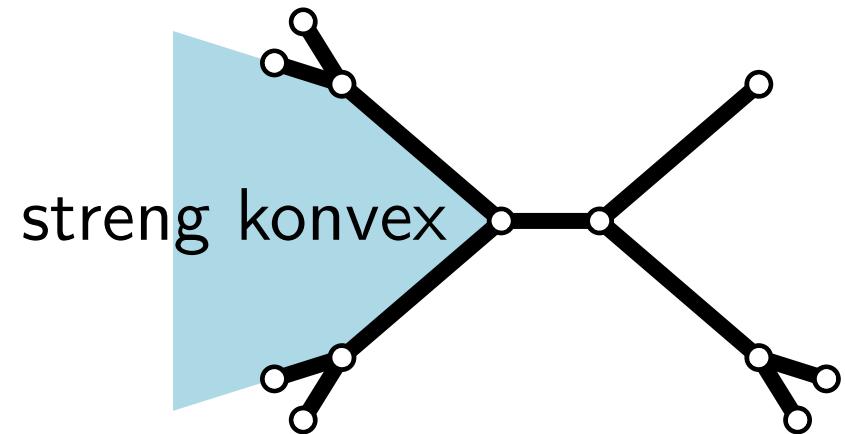
Streng Monotone Zeichnungen

Ordentlicher Binärbaum \Rightarrow
streng monotone,
streng konvexe Zeichnung,
exponentielle Fläche



Streng Monotone Zeichnungen

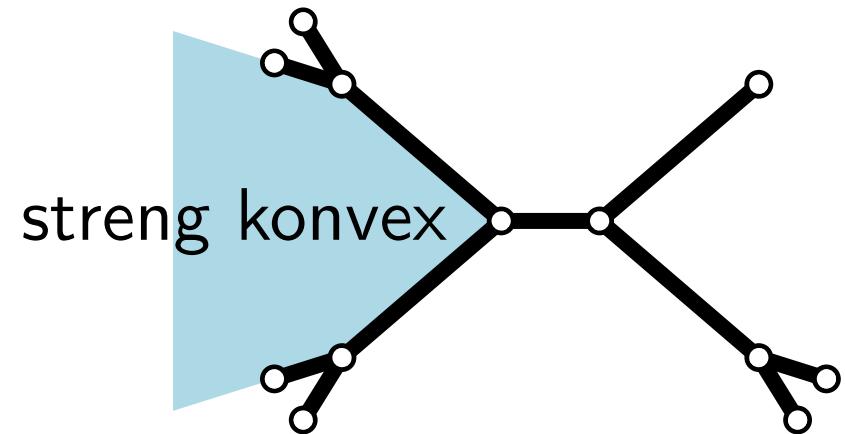
Ordentlicher Binärbaum \Rightarrow
streng monotone,
streng konvexe Zeichnung,
exponentielle Fläche



Baum \Rightarrow streng monotone Zeichnung, exponentielle Fläche

Streng Monotone Zeichnungen

Ordentlicher Binärbaum \Rightarrow
streng monotone,
streng konvexe Zeichnung,
exponentielle Fläche



Baum \Rightarrow streng monotone Zeichnung, exponentielle Fläche

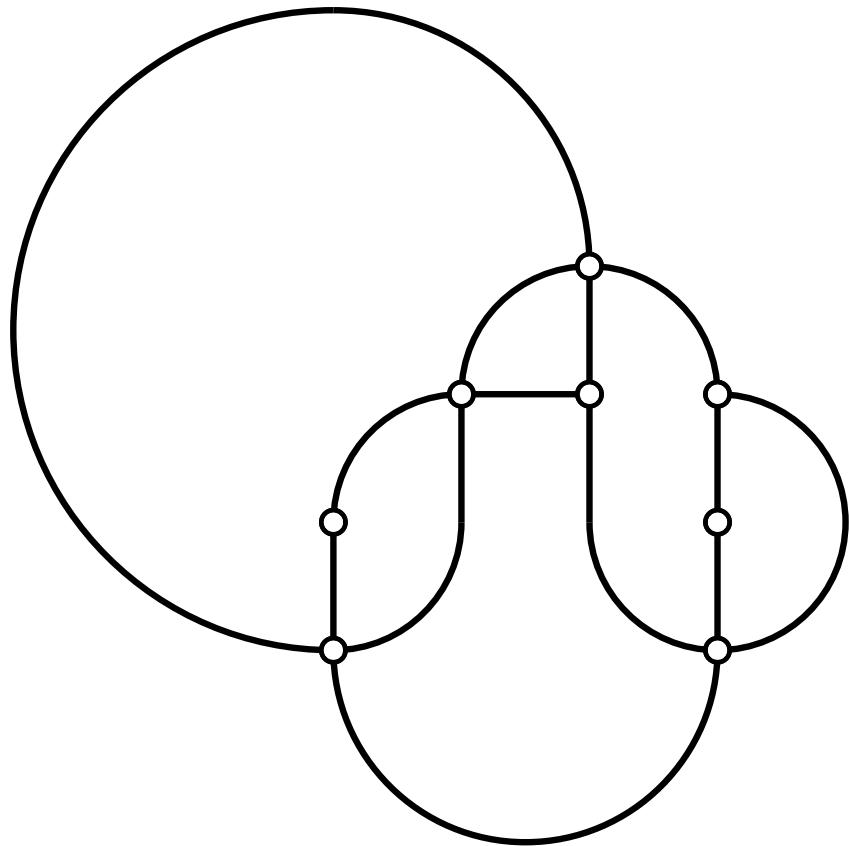
Nöllenburg et al.

Exponentielle Fläche wird benötigt.

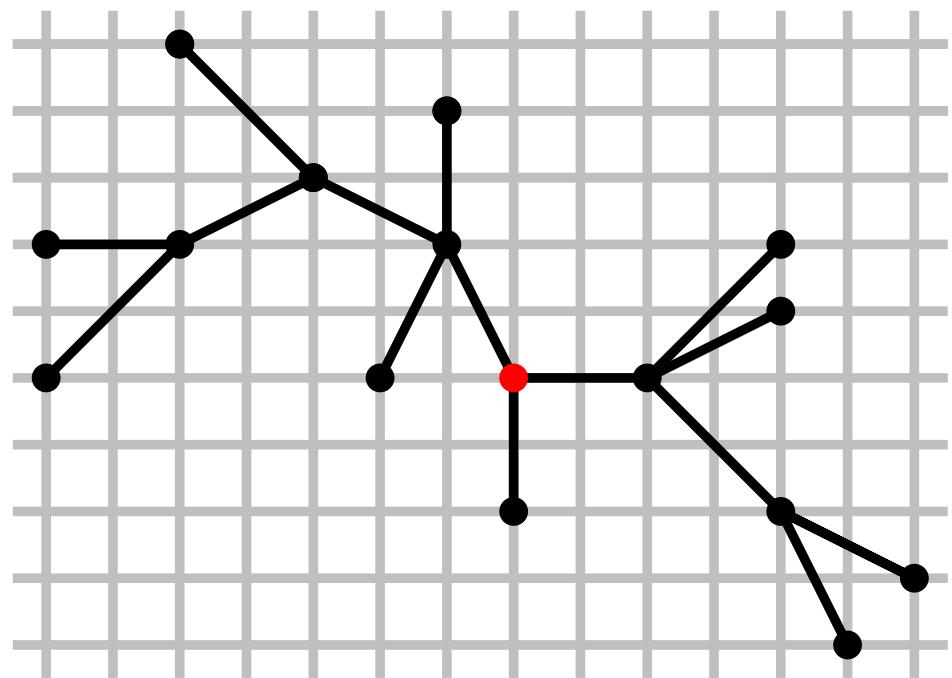
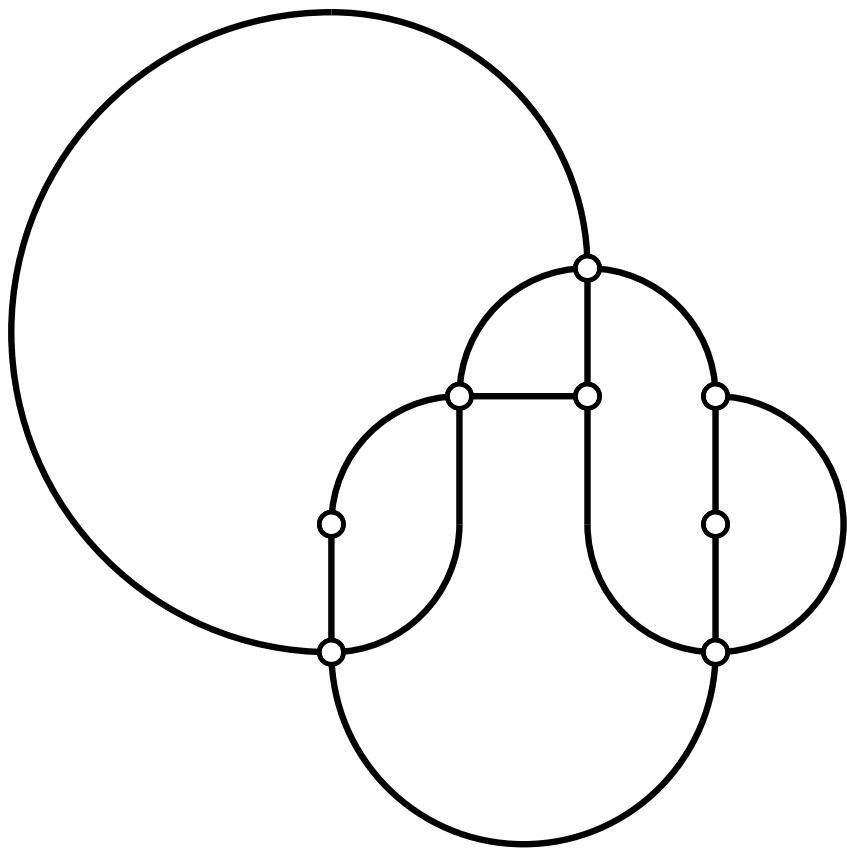
[arXiv'14]

Zusammenfassung

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