EuroVis 2016
18th EG/VGTC Conference on Visualization
6-10 June 2016, Groningen, the Netherlands

Location-dependent generalization of road networks based on equivalent destinations

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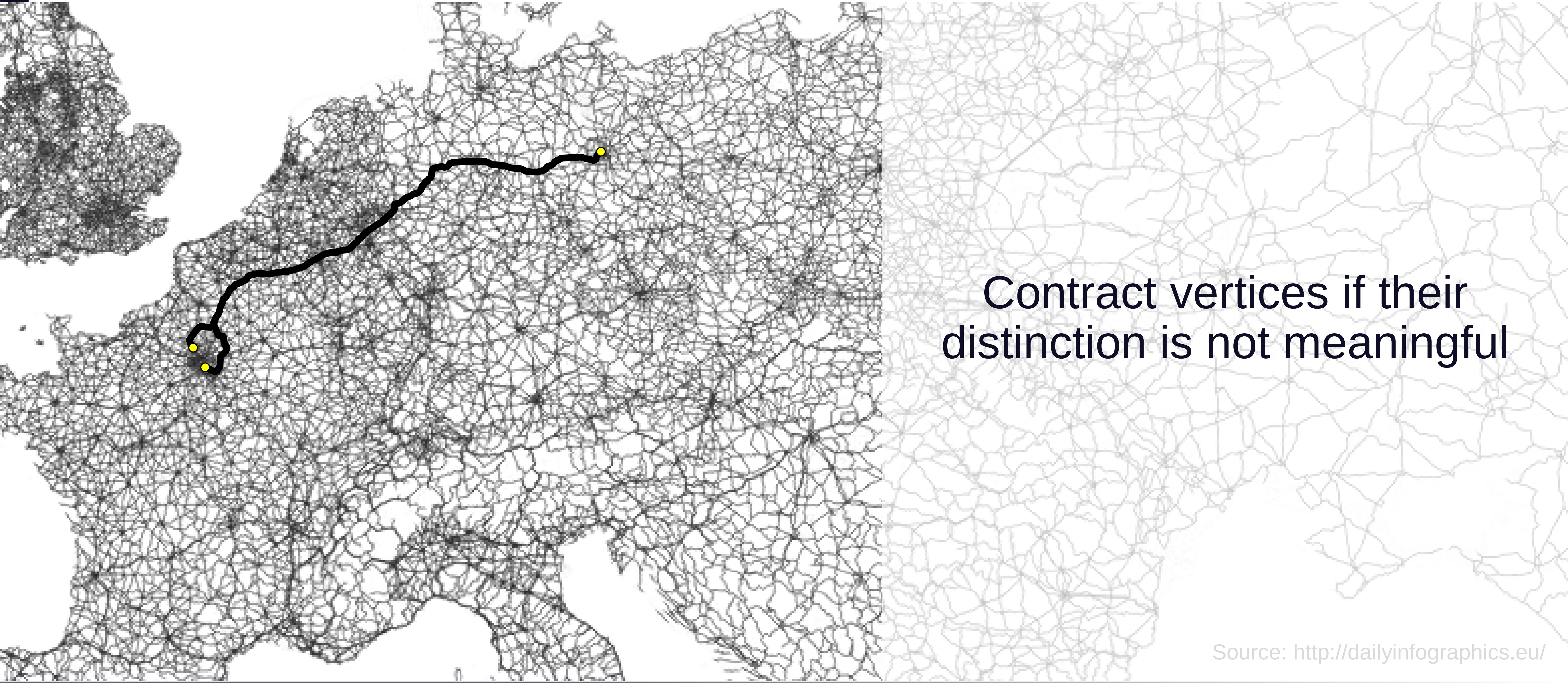
Motivation

Hey there! Could you please give me directions to Paris?
Of course! What’s your exact destination address?
221CDN75

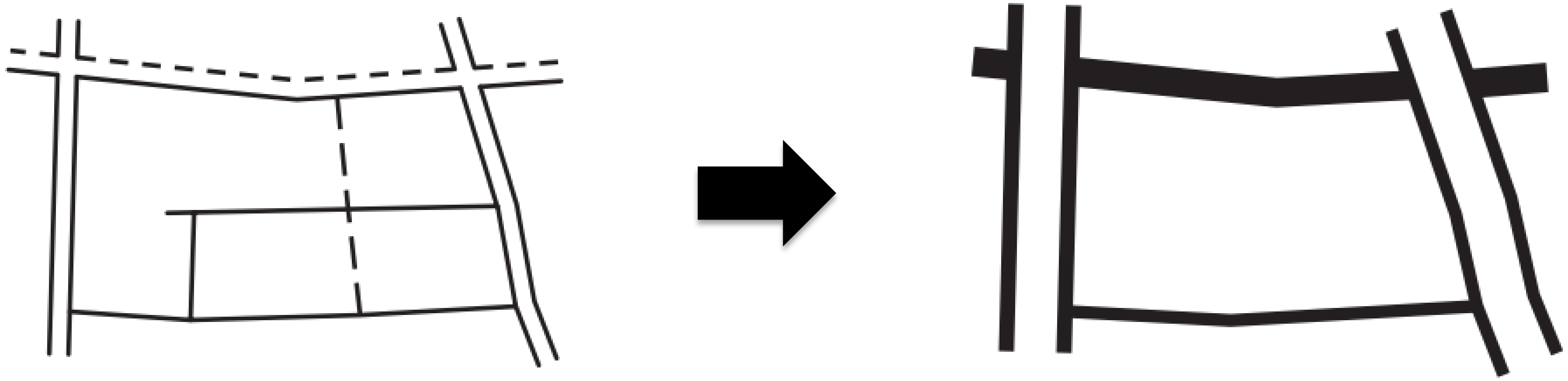
Idea



Contract vertices if their distinction is not meaningful

Source: http://dailyinfographics.eu/

Related Work: Map Generalization

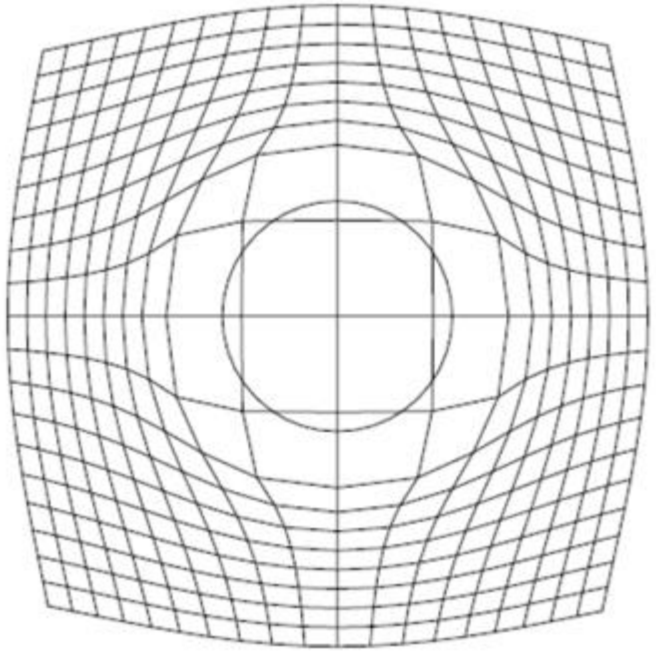


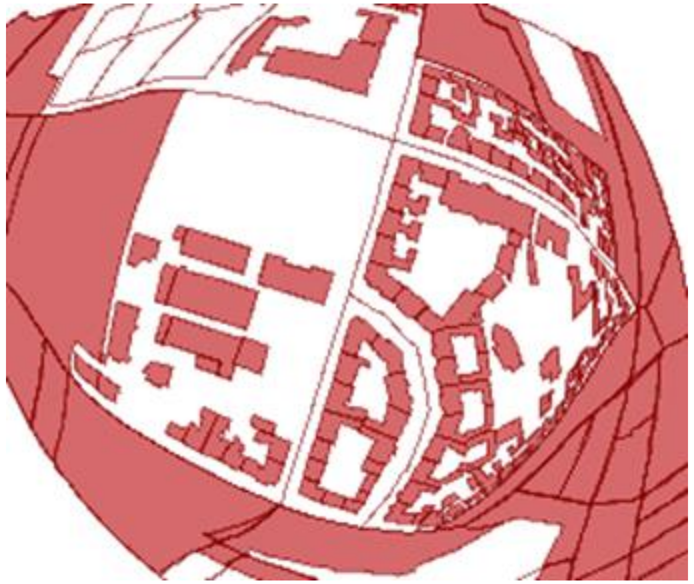
(Hake et al., 1994)

- Much work on road selection for static single-scale maps (e.g., Jiang & Claramunt, 2004; Thomson & Brooks, 2002)
- Selection is NP-hard even for rather simple models of the problem (Brunel et al., 2014)

Related Work: Variable-Scale Maps

- Fish-eye projections for user-centered navigation maps
- Level of detail (LoD) follows scale





(Hampe et al., 2004)

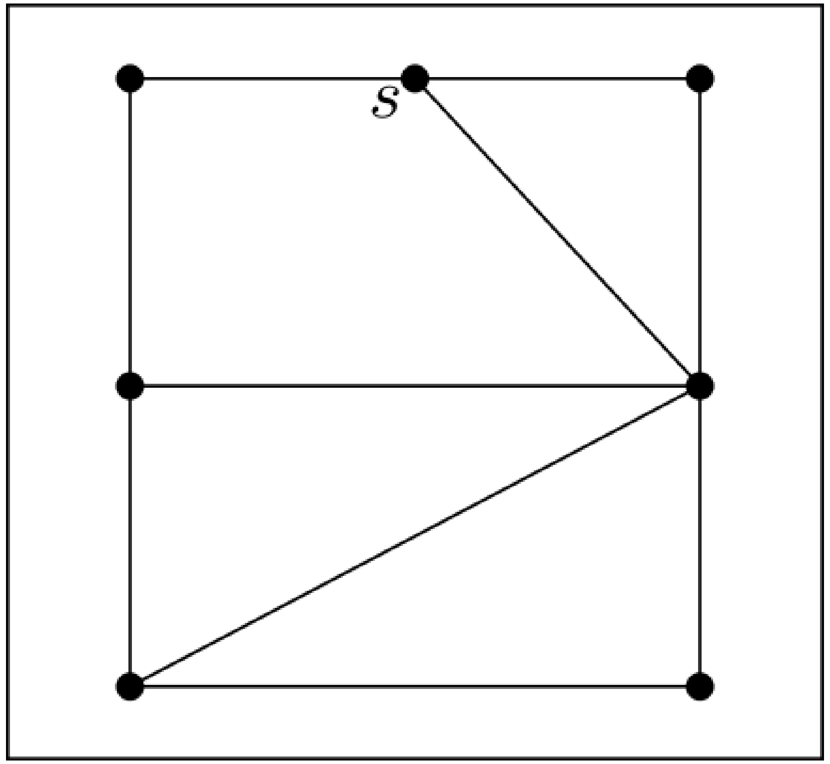
Related Work: Destination Maps

- Road selection based on shortest paths
- Scale follows LoD
- No guarantee of optimality with respect to a well-defined objective

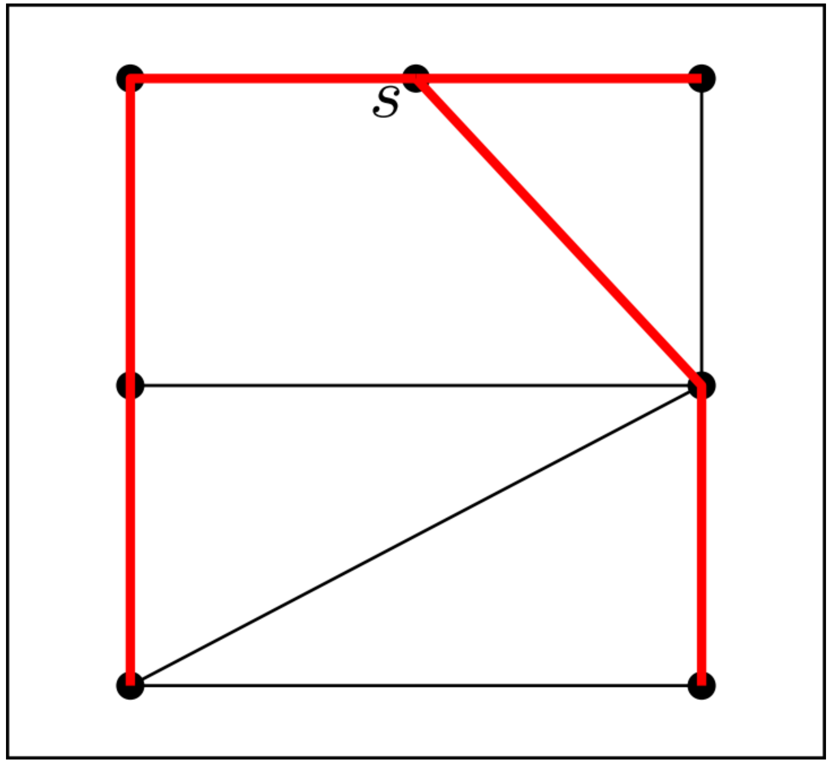
(Kopf et al., 2010)

Prerequisites

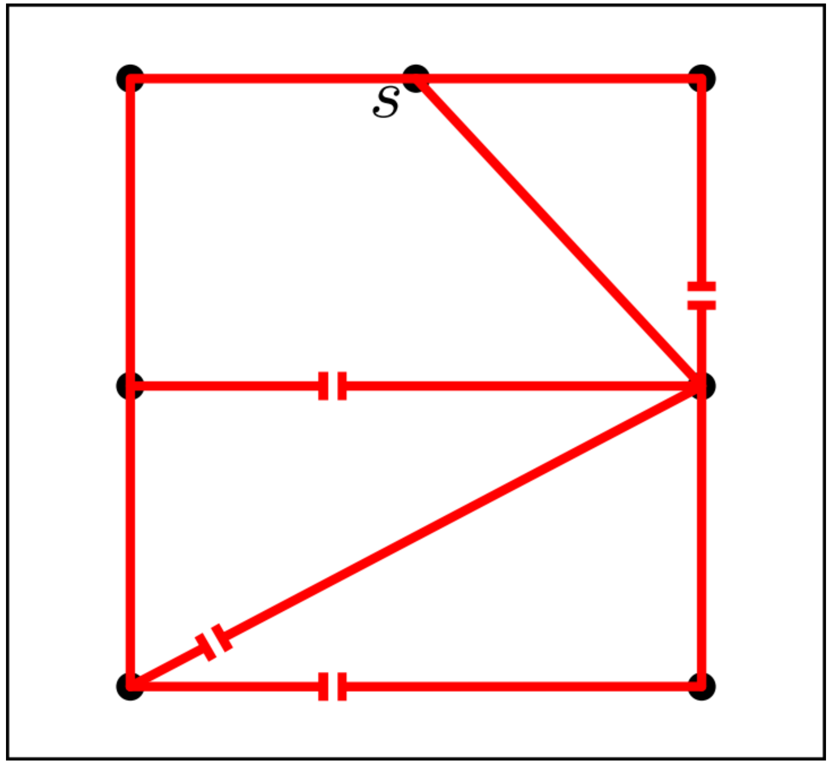
$\mathcal{T}$



road network: graph G
user location: vertex s



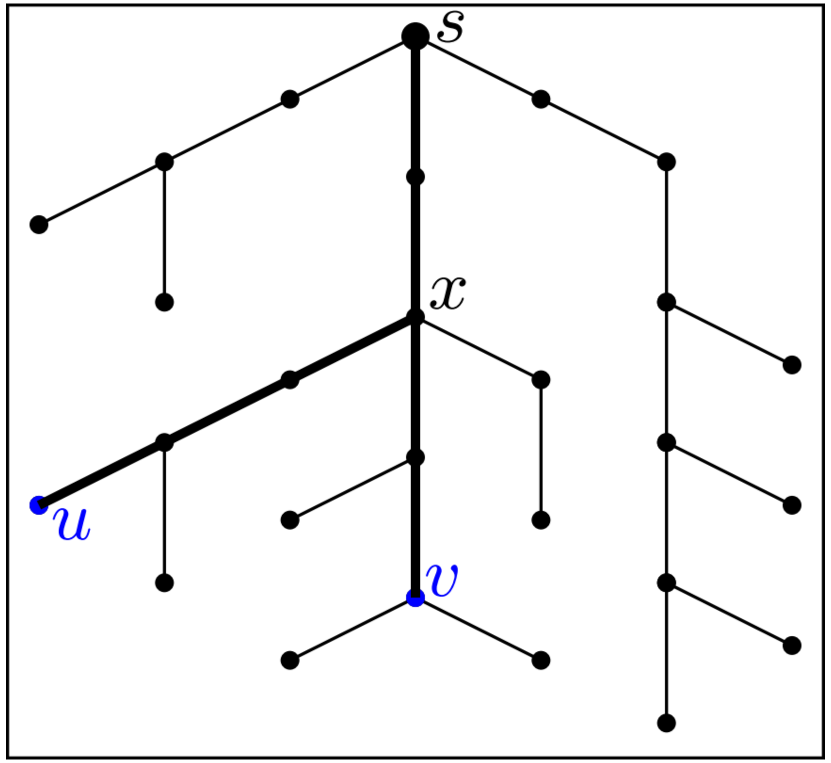
shortest paths from s
to all other vertices



shortest paths from s
to all points in G

Problem definition

- Given a tree $\mathcal{T} = (V, E_{\mathcal{T}})$ rooted at $s \in V$
- For any $u, v \in V, u \neq s$ define **directed similarity** as
$$\sigma(u, v) = \frac{w(P_{sx})}{w(P_{su})}$$
where $x \in V$ is the lowest common ancestor of u and v in $\mathcal{T}$.
- Any $u, v \in V$ are called ***α*-compatible** if $\sigma(u, v) \geq \alpha$ and $\sigma(v, u) \geq \alpha$ with $\alpha \in [0,1]$
- For fixed α this is expressed as $u \oplus v$



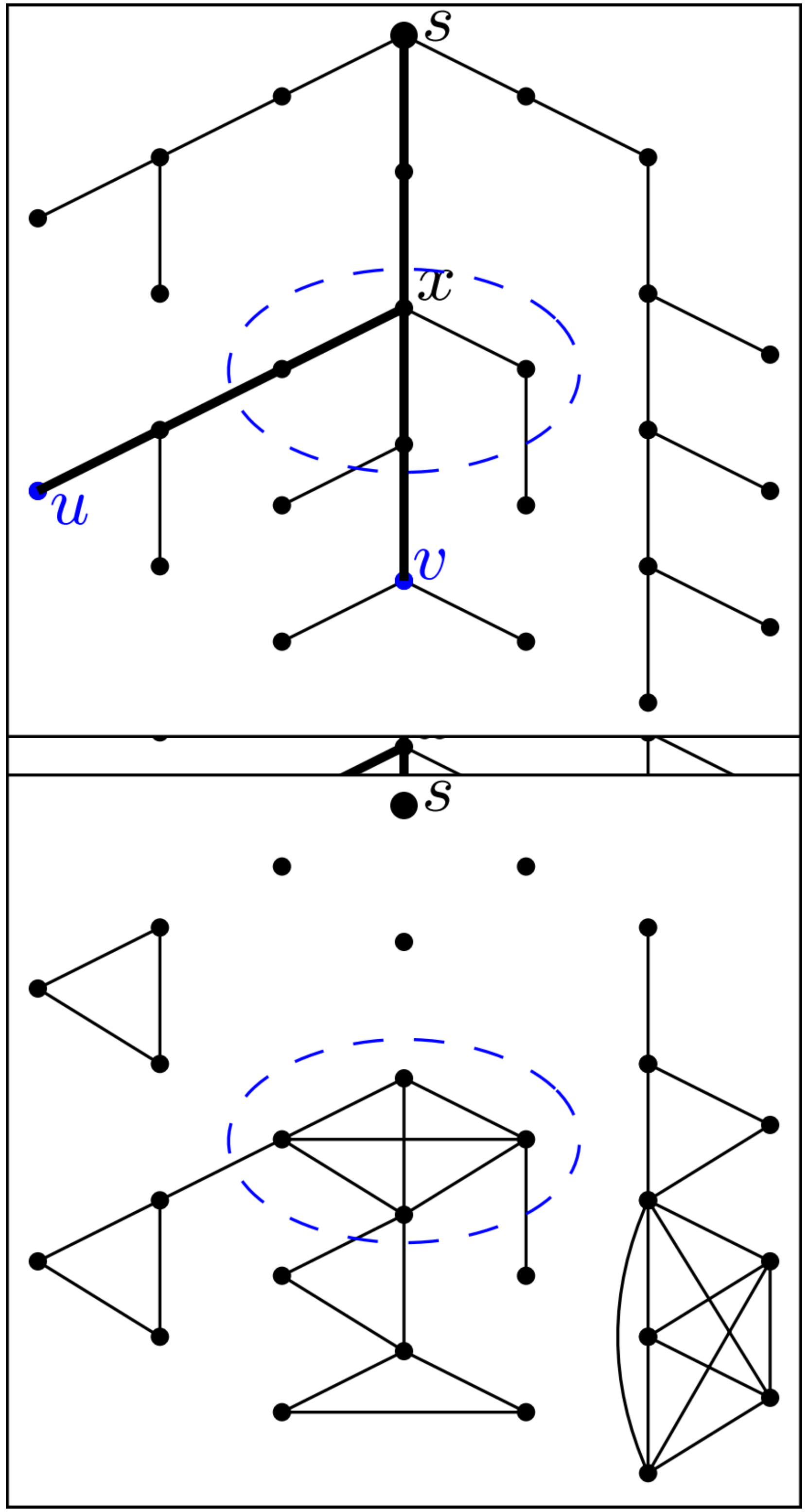
$\sigma(u, v) = {}^{2}/_{5}$

$\sigma(v, u) = {}^{1}/_{2}$

Problem definition

- Define a **compatibility graph** $G_{\oplus} = (V, E_{\oplus})$ with $E_{\oplus} = \{(u,v) \in V \times V : u \oplus v, u \neq v\}$
- Contracting $S \subseteq V$ is **allowed** if and only if
  - S is connected in $\mathcal{T}$
  - S is a clique in $G_{\oplus}$

(here: $\alpha = {}^{2}/_{3}$)



Problem: TreeSummary

- Instance:
  - A tree $\mathcal{T} = (V, E_{\mathcal{T}})$, rooted at $s \in V$
  - Weights on the edges $w: E_{\mathcal{T}} \rightarrow \mathbb{R}_{\geq 0}$
  - A compatibility threshold $\alpha \in [0,1]$

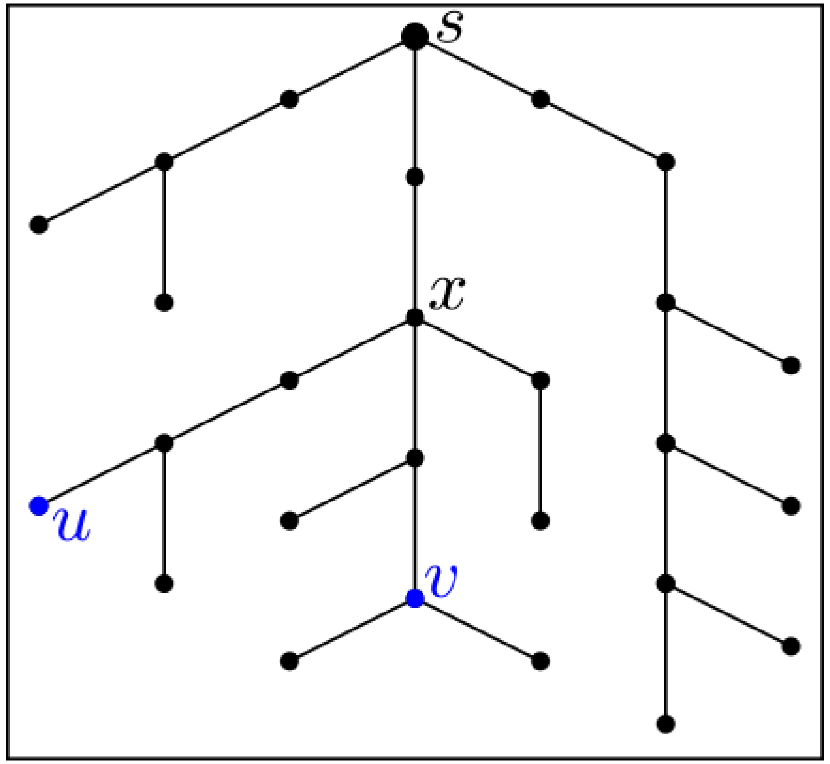
- Problem:

Find a partition of V into as few cells as possible, such that each cell is an allowed contraction!

Lemmata

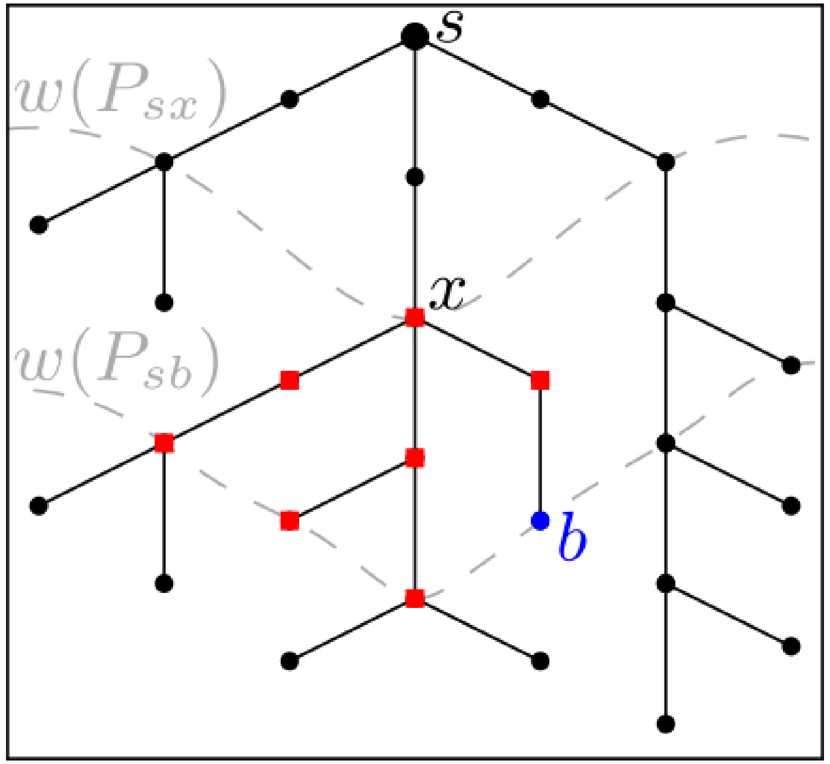
1. Let $u, v \in V$ be vertices and let x be their lowest common ancestor. Then:

$$u \oplus v \iff u \oplus x \wedge v \oplus x$$

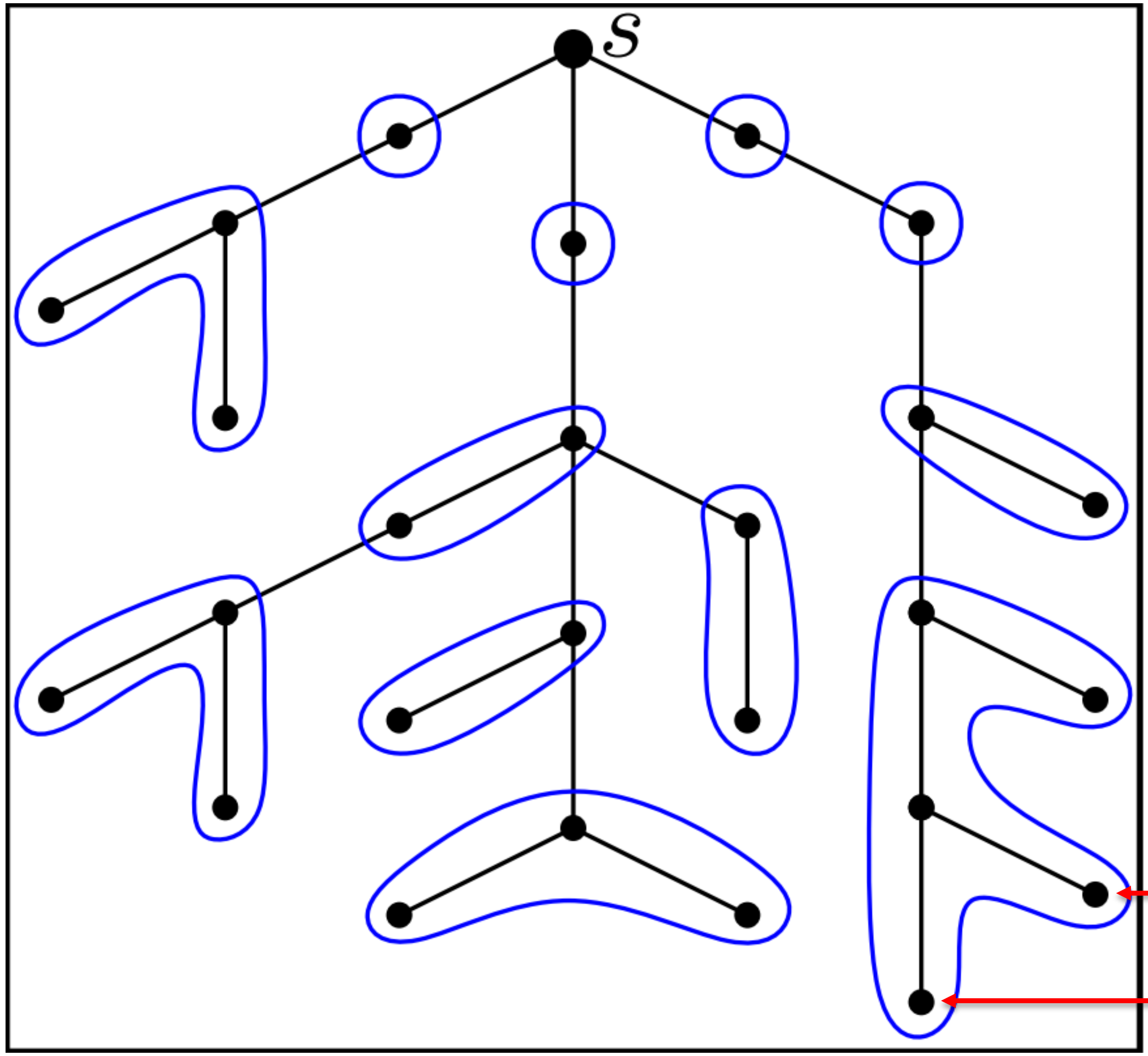


2. Let $x \in V$ and let $a, b \in V$ be descendants of x. Then:

$$w(P_{sa}) \leq w(P_{sb}) \quad \wedge \quad b \oplus x \implies a \oplus x \,.$$

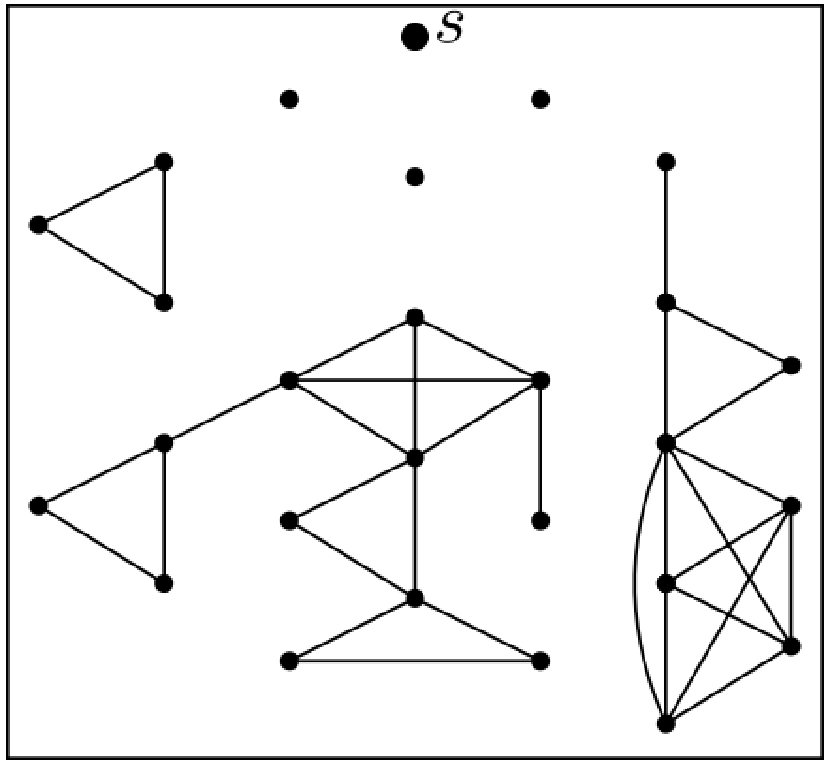


Algorithm: ContractTree



deep vertices of their cell

(here: $\alpha = {}^{2}/_{3}$)



Following invariants of a cell C hold:

- Vertices of C are connected in $\mathcal{T}$
- C is clique in $G_{\oplus}$

Algorithm: ContractTree

Data: Rooted Tree $\mathcal{T}$ with edge weights

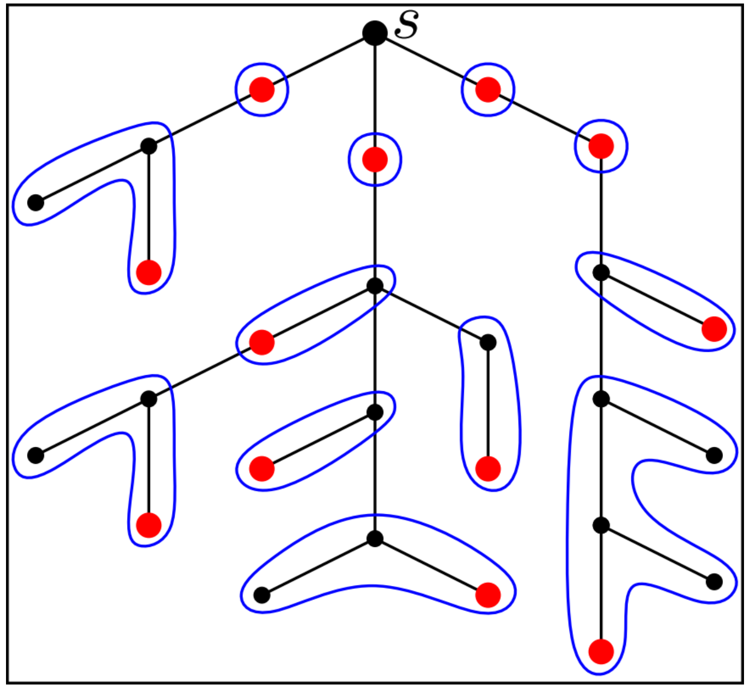
Result: Minimum-cardinality allowed contraction $\boldsymbol{\mathcal{C}}$

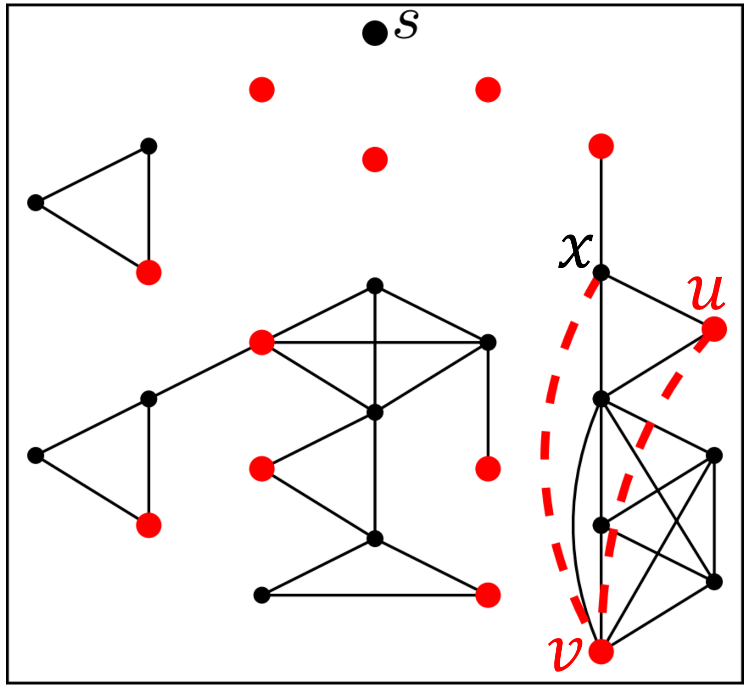
1. $\boldsymbol{\mathcal{C}} \leftarrow$ the set with a singleton cell for each vertex of $\mathcal{T}$;
2. **For all** the vertices $x \in \mathcal{T}$, in post-order **do**
3. $\quad S_{\oplus} \leftarrow \{v \in Children(x) : x \oplus Deep(Cell(v))\}$;
4. $\quad$ Merge $Cell(x)$ and all $Cell(v)$ for $v \in S_{\oplus}$
5. **End**
6. **Return** $\boldsymbol{\mathcal{C}}$;

run-time: $\mathcal{O}(|V|)$

Algorithm: Result is optimal

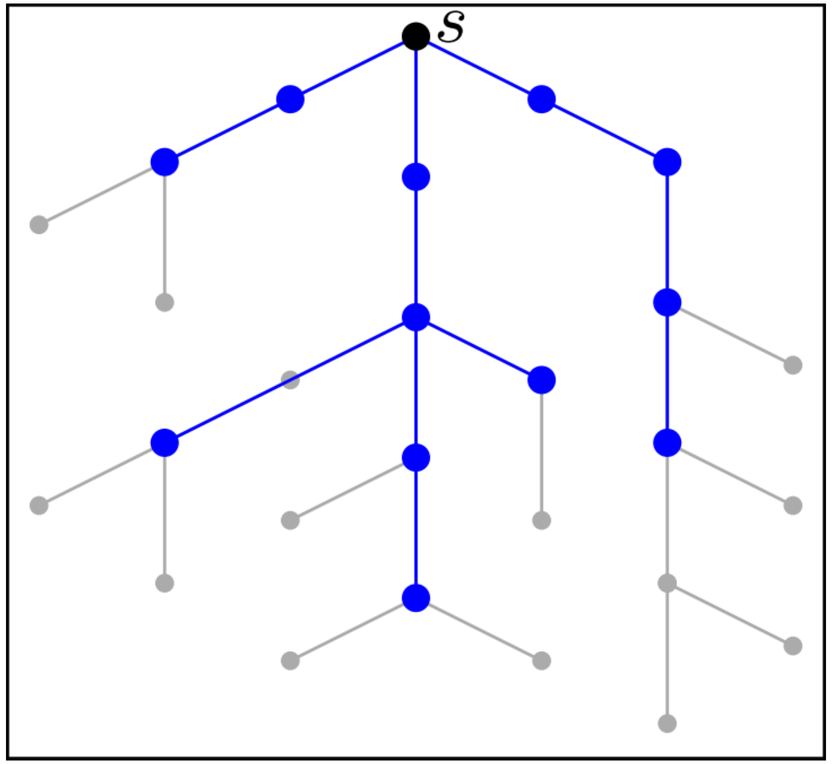
- Let $\boldsymbol{\mathcal{C}}$ be the set of cells of $\mathcal{T}$ computed with the algorithm
- $\boldsymbol{\mathcal{C}}$ is a clique cover of $G_\oplus$
- Consider $\boldsymbol{\mathcal{I}} := \{Deep(C) : C \in \boldsymbol{\mathcal{C}}\}$
- $\boldsymbol{\mathcal{I}}$ is an independent set of $G_\oplus$:
    - Assume $(u, v) \in E_\oplus$ for any $u, v \in \boldsymbol{\mathcal{I}}$
    - Let x be the lowest common ancestor of u and v
    - $u \oplus v \quad \Longrightarrow \quad x \oplus u$ and $x \oplus v$
    - $Cell(u)$ and $Cell(v)$ would have been merged ↯
- $|\boldsymbol{\mathcal{I}}| = |\boldsymbol{\mathcal{C}}|$
- $\boldsymbol{\mathcal{C}}$ is a minimal clique cover of $G_\oplus$





Visualization

- Represent each cell by its root vertex.
- The relation between the cells is a tree structure induced by $\mathcal{T}$.



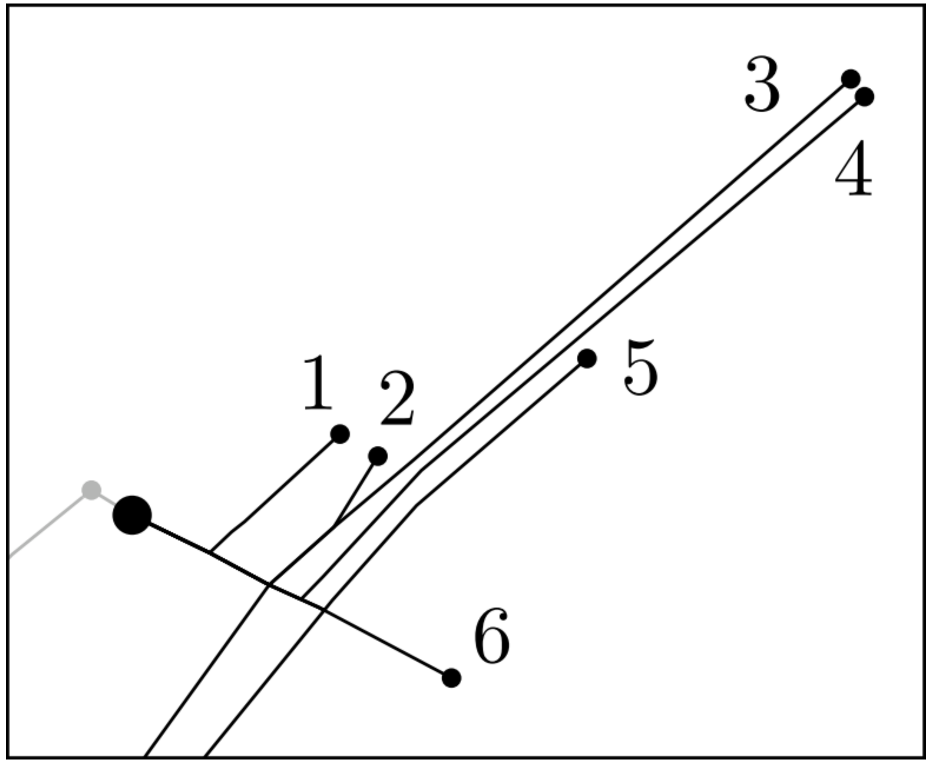
- How to visualize this tree?

Visualization: Three proposals

1. Detailed drawing

   For every cell c and its parent p draw P_{pc}

   + topologically correct
   ± same level of detail as input
   – internal branches

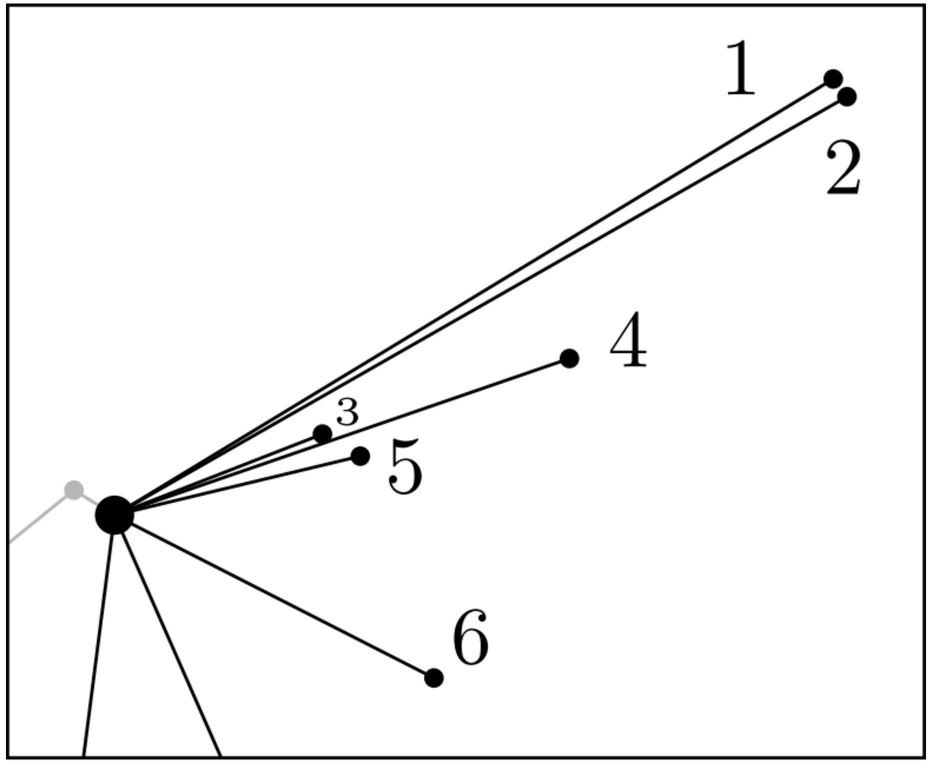


Visualization: Three proposals

1. Detailed drawing
2. Direct drawing

   For every cell c and its parent p draw a direct line between p and c

   + simple and highly generalized
   + shows the actual clustering
   – not topologically safe

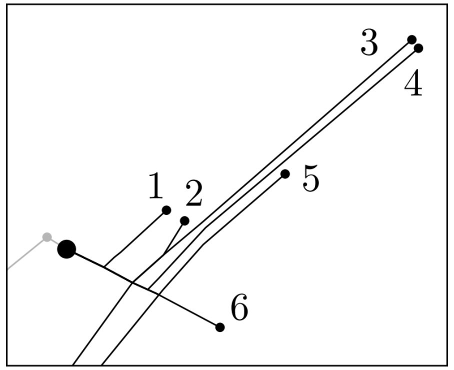


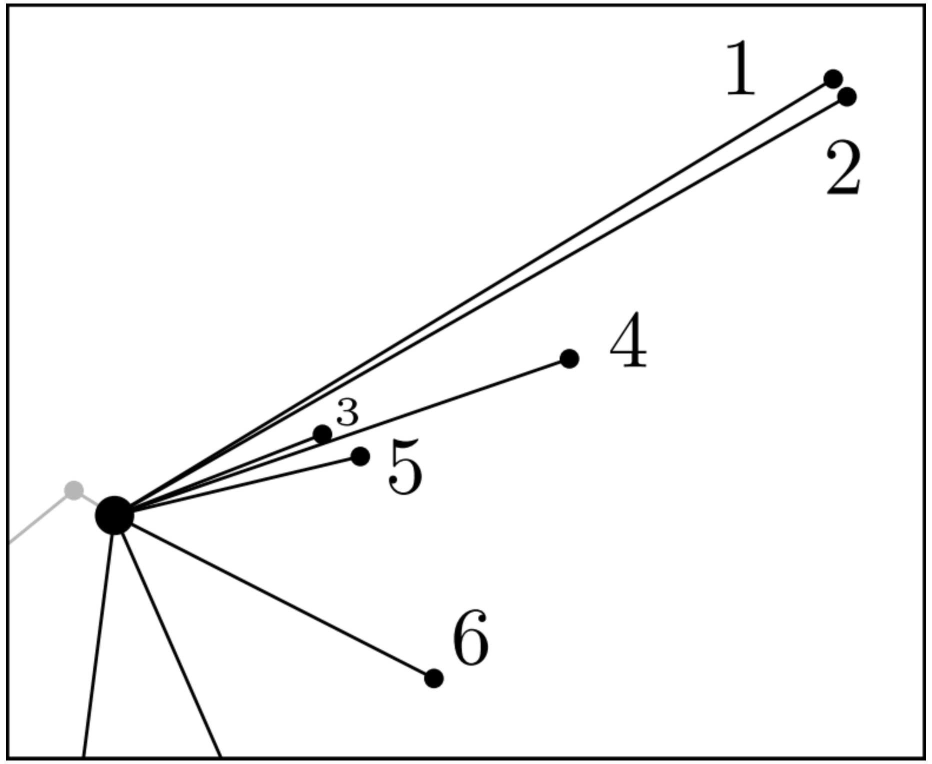
Visualization: Three proposals

1. Detailed drawing
2. Direct drawing
3. Simplified drawing

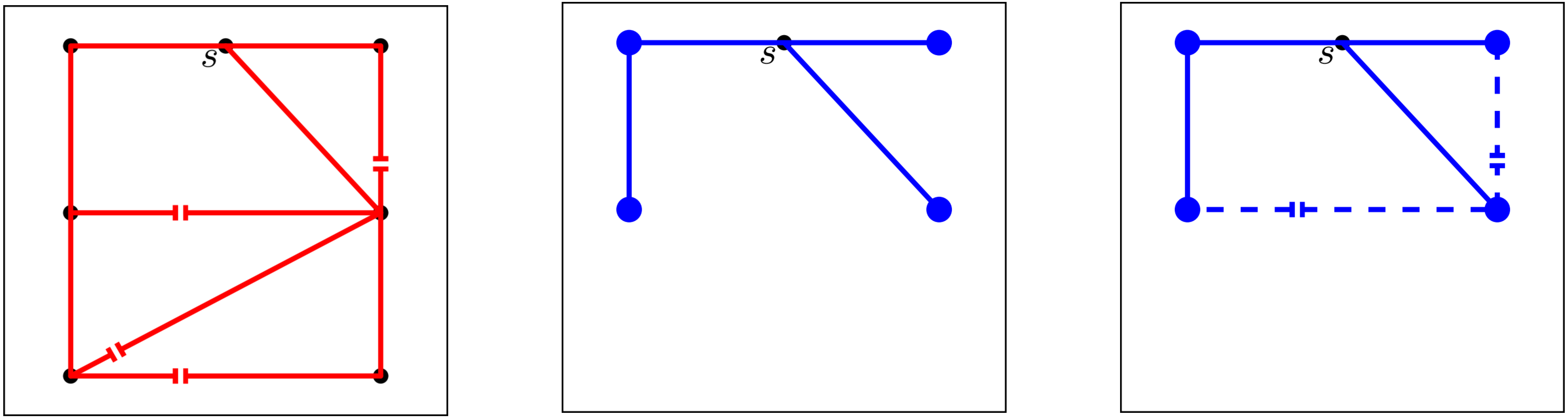
   Construct detailed drawing and apply topologically-safe simplification algorithm (Dyken et al., 2009)

   \+ topologically safe
   ± less internal branches
   – heuristic



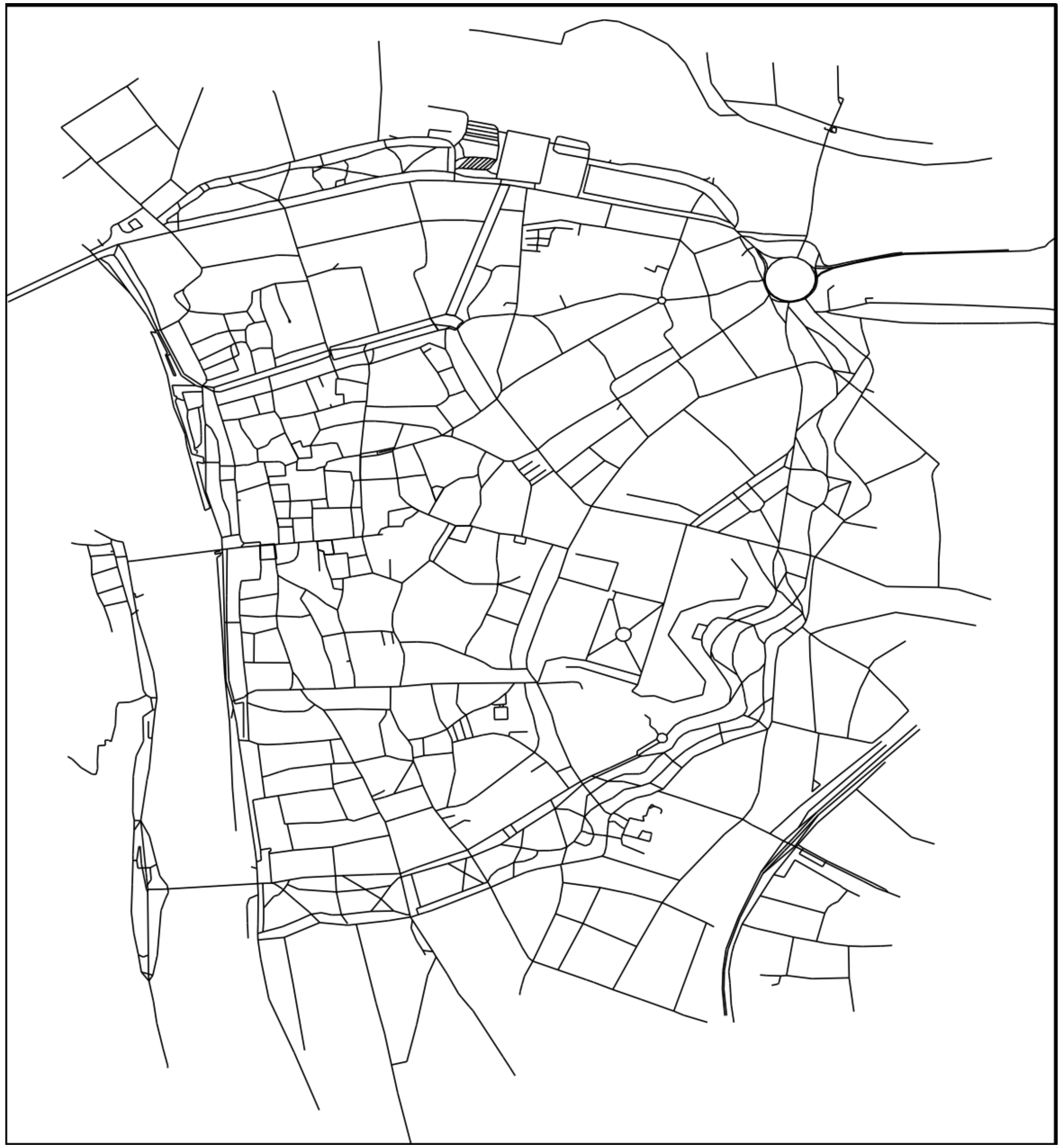


Visualization: Cross connections



- Resulting tree gives no information about cell adjacency
- Draw cross connections between neighboring cells

Example results

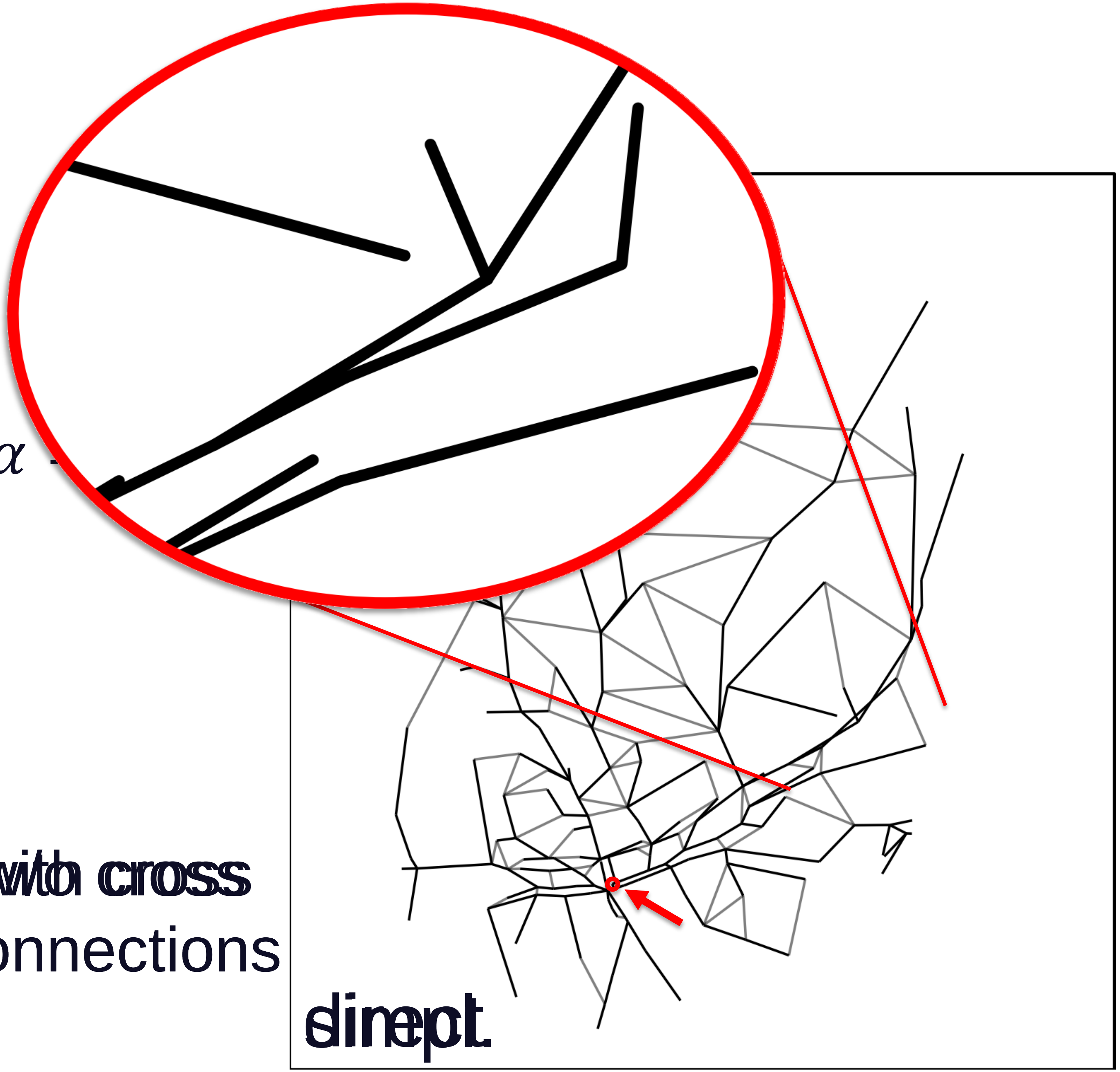


$\alpha = 50\%$

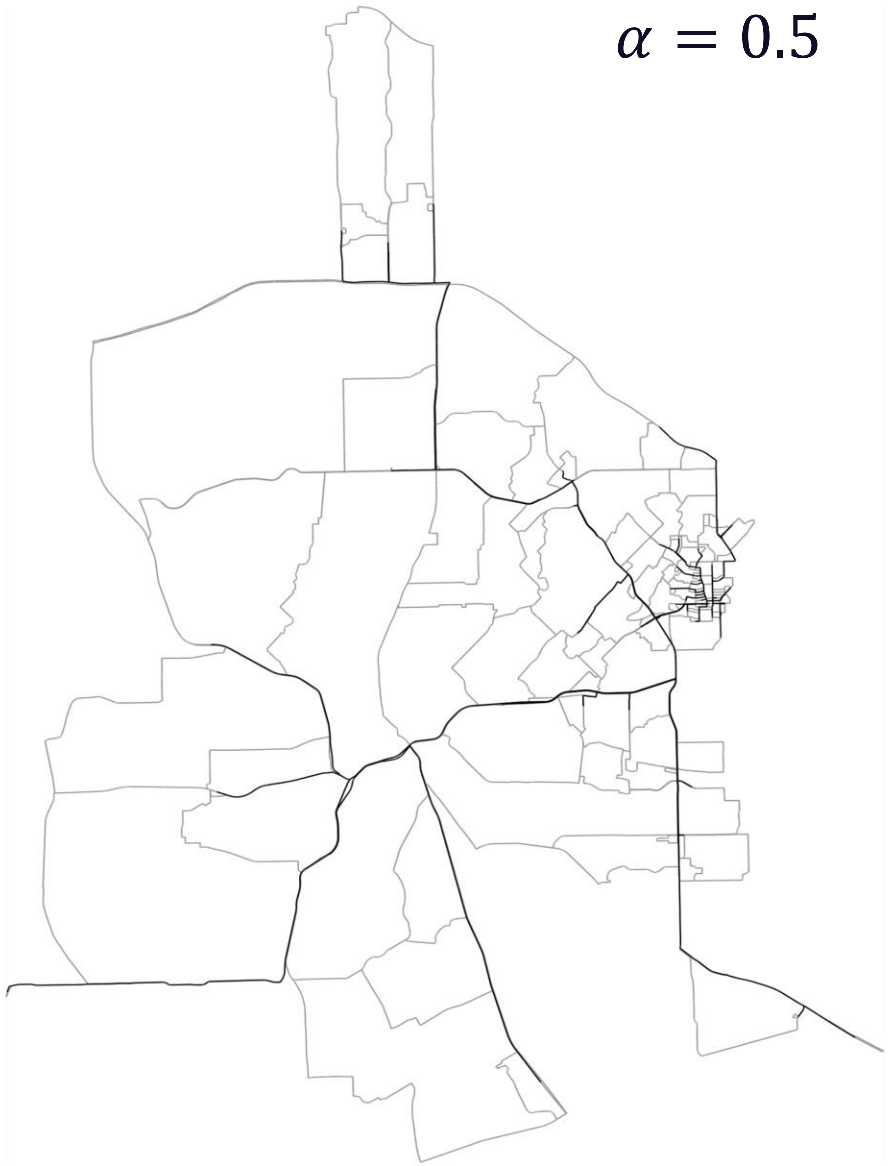
Example results

α

with cross
connections

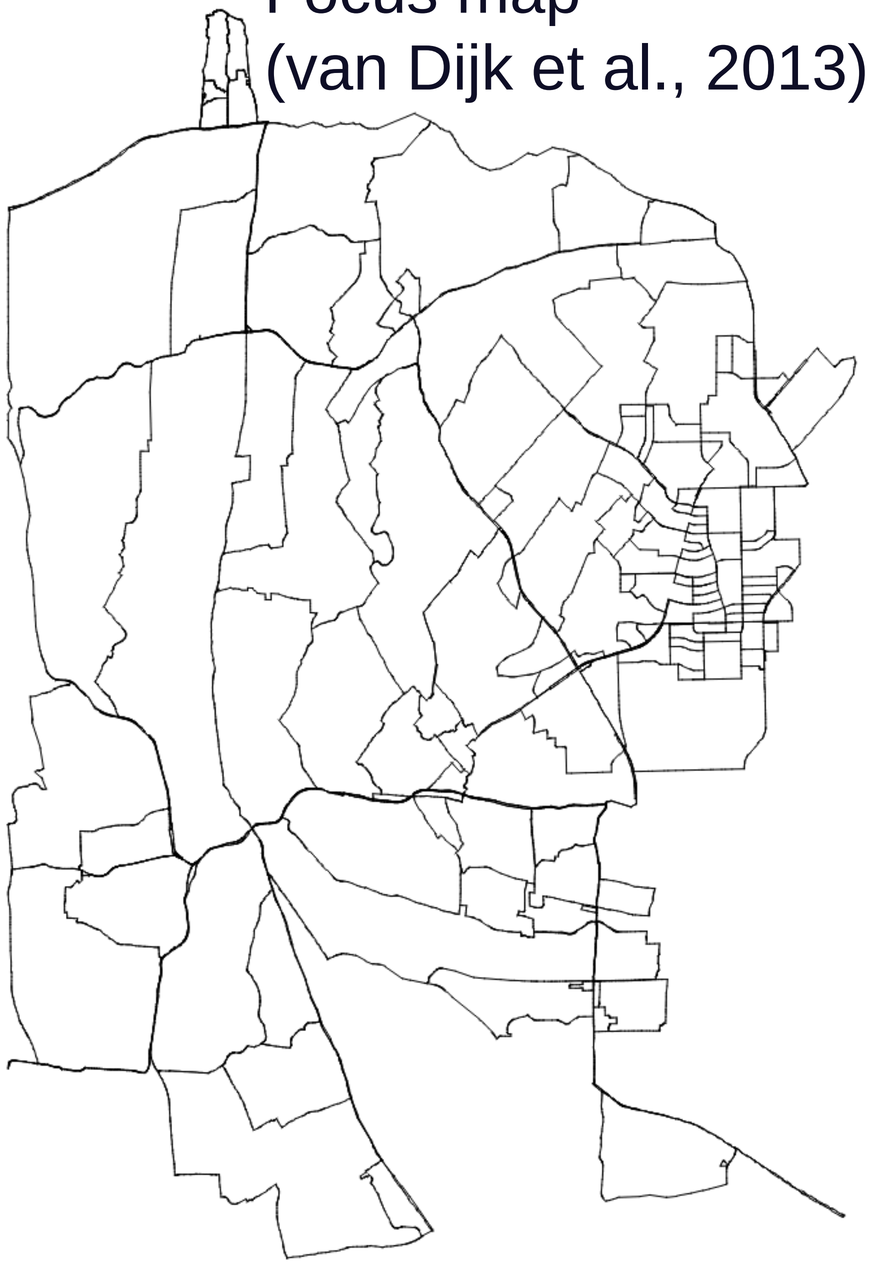


Example results



$\alpha = 0.5$

Focus map
(van Dijk et al., 2013)



Summary

- Problem TreeSummary: Contraction of compatible destination
- Optimal linear-time algorithm (traversing tree in post-order)
- Three kinds of drawings:
  - Detailed
  - Direct
  - Simplified
- Cross connections