# GraphMaps

## Browsing Large Graphs as Interactive Maps

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September 23, 2015

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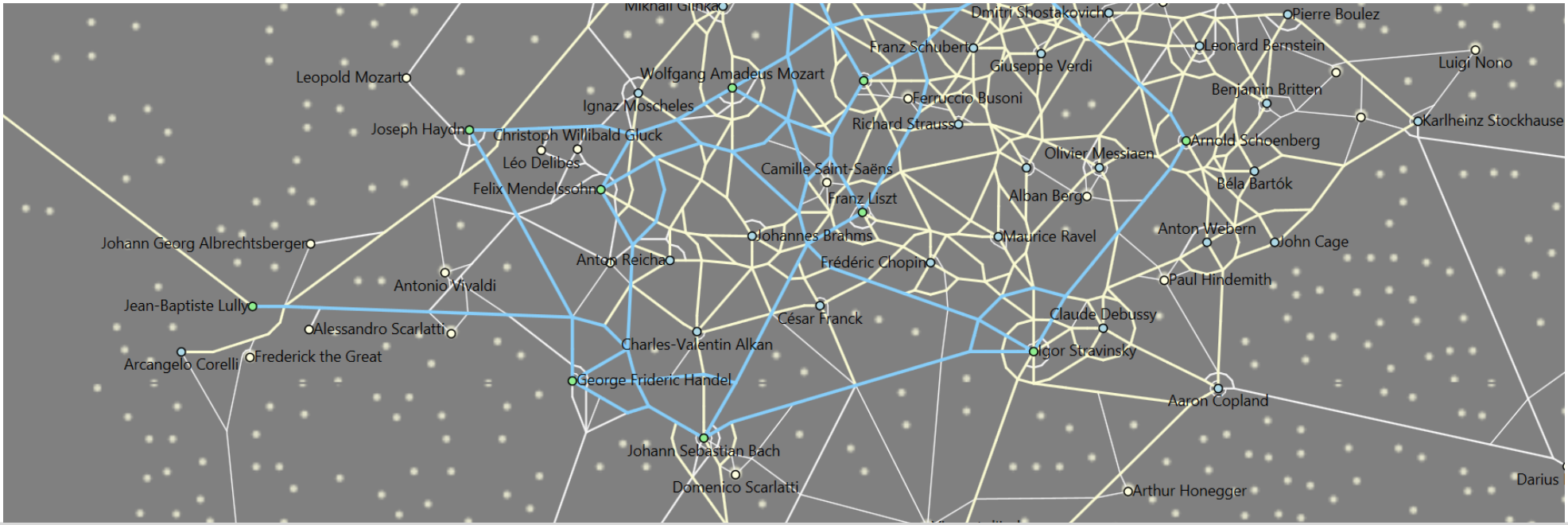
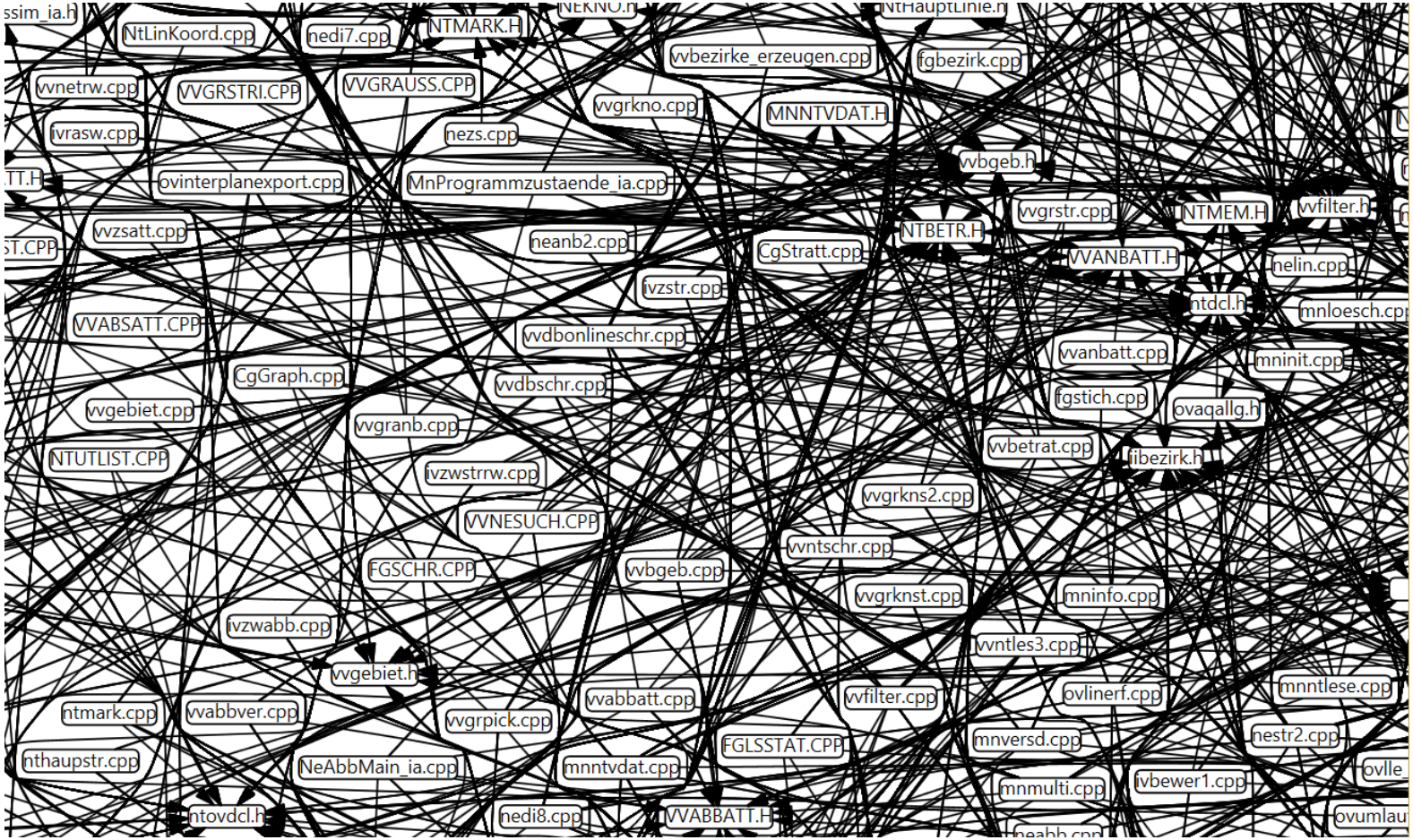


# Why consider exploration of large graphs?

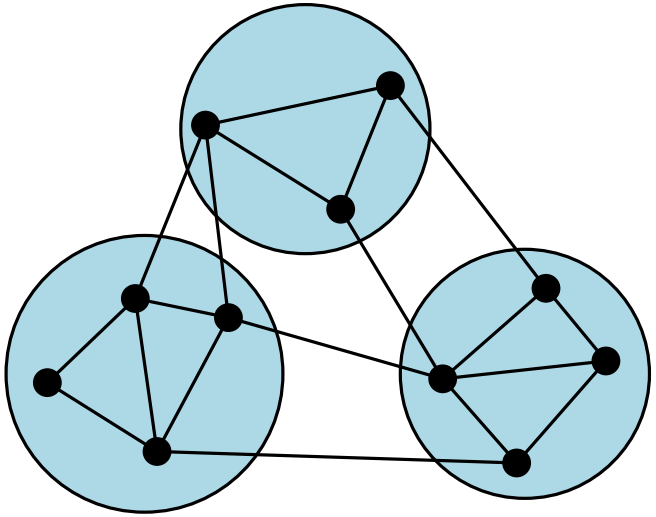
- readable drawings of large graphs still a challenge
- good and fast vertex placement algorithms are known
- displaying readable connectivity information is challenging




View of a graph *b100*: files in a C++ project.

# Related approaches : **aggregation** and **multiscale** techniques

- **partition** and group nodes/edges, draw resulting smaller graph
- **drawing**: use hierarchy; coarsen, lay out, uncoarsen
- **browsing**: display a ”graph of graphs”



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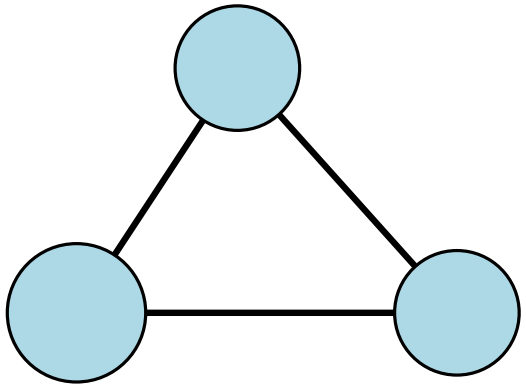

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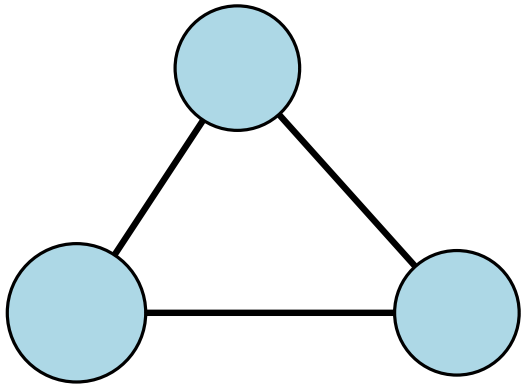

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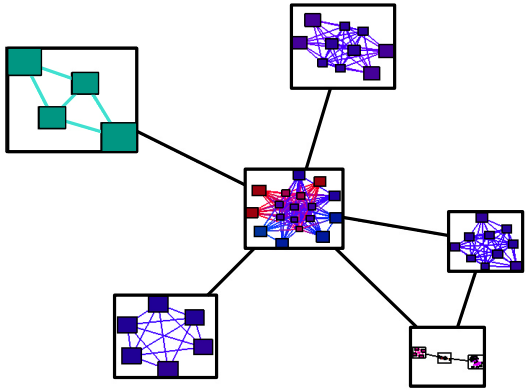

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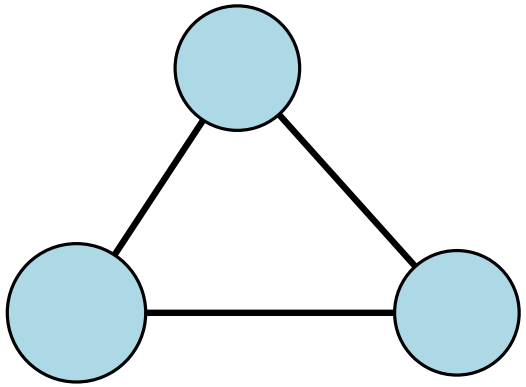

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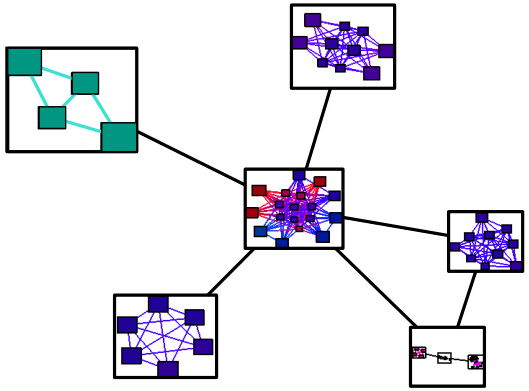

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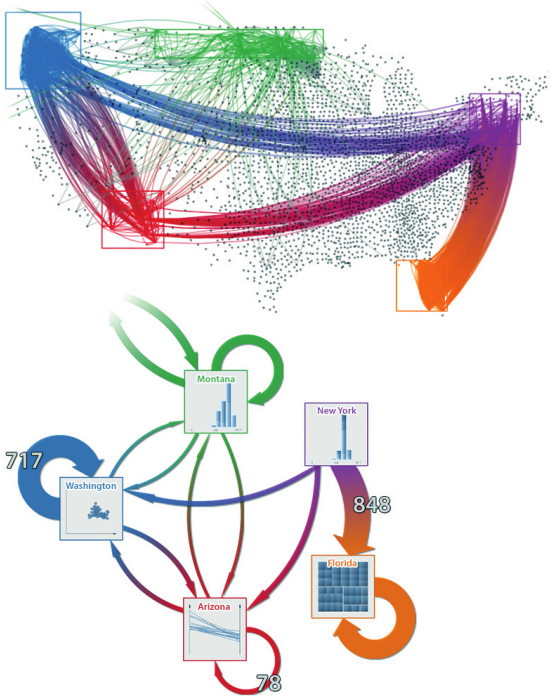


[van den Elzen and
van Wijk, 2014]

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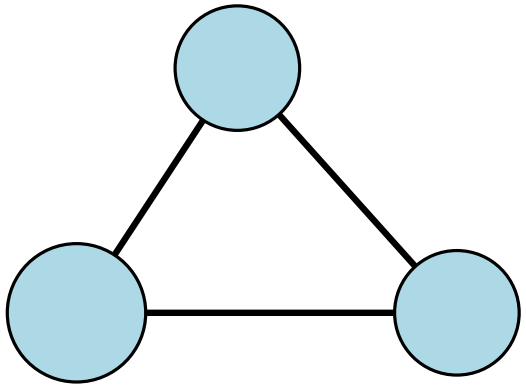
**scale** up to millions of nodes/edges; **drawbacks**:

- misleading information on inter- and intra-connectivity
- spatial instability confuses the user



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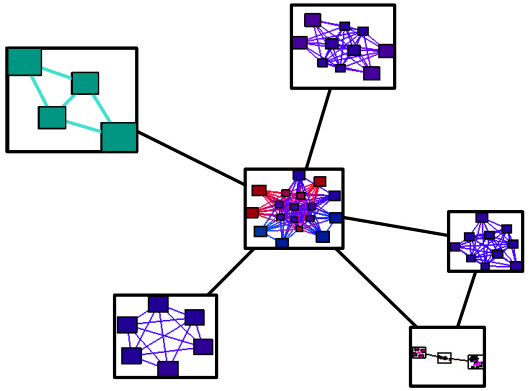

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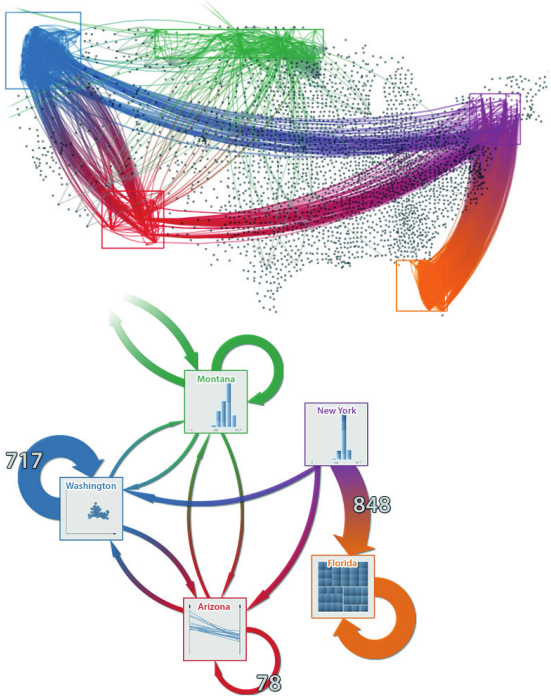


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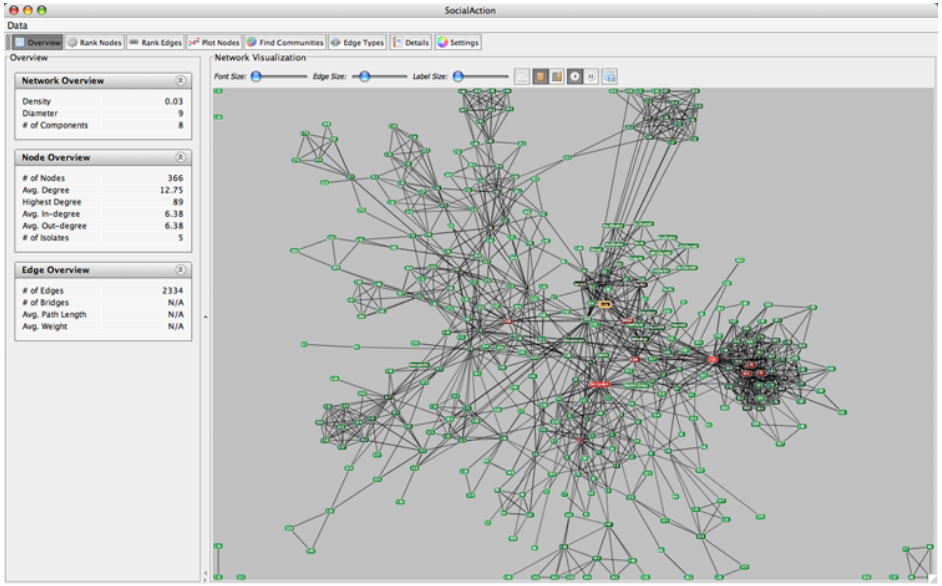
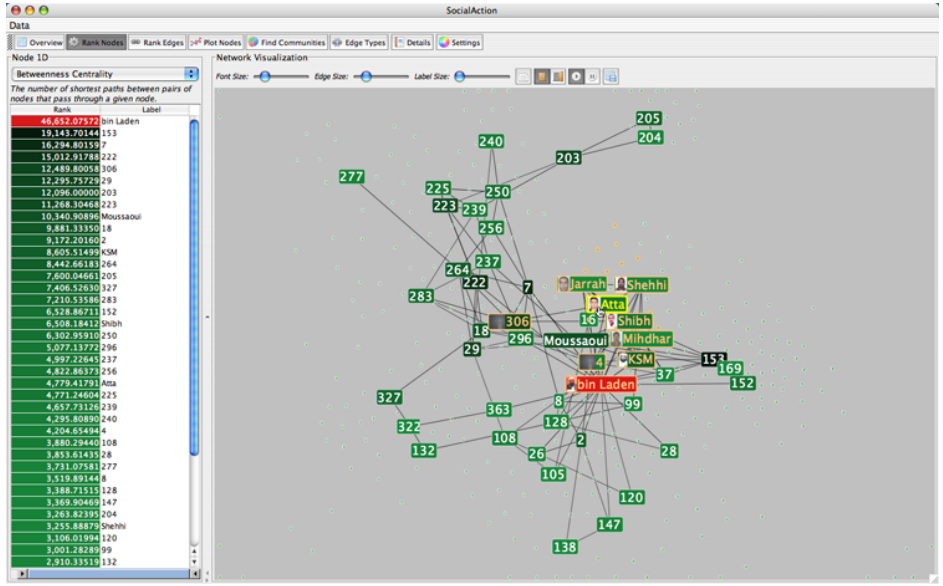
# Related approaches : **filtering** techniques

- rank nodes/edges by importance
- show important nodes first

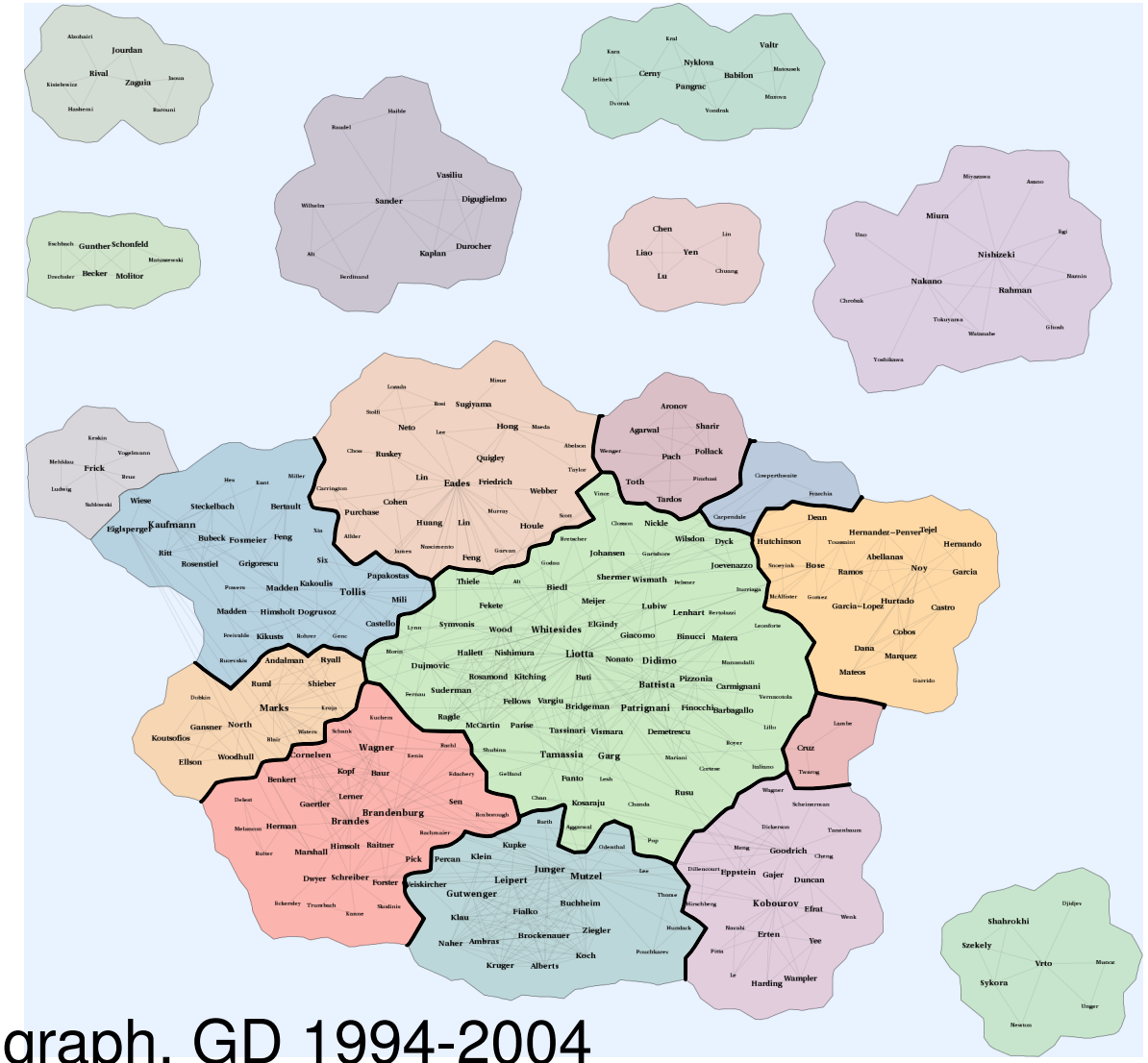



A complete and filtered view of a network. [*SocialAction*. Perer and Shneiderman]

# Related approaches : **political map** metaphor

**Gmap** [Gansner, Hu, Kobourov 2010]. Focus on showing **clusters**: as **countries** with map-like borders and coloring; graph on top




collaboration graph, GD 1994-2004

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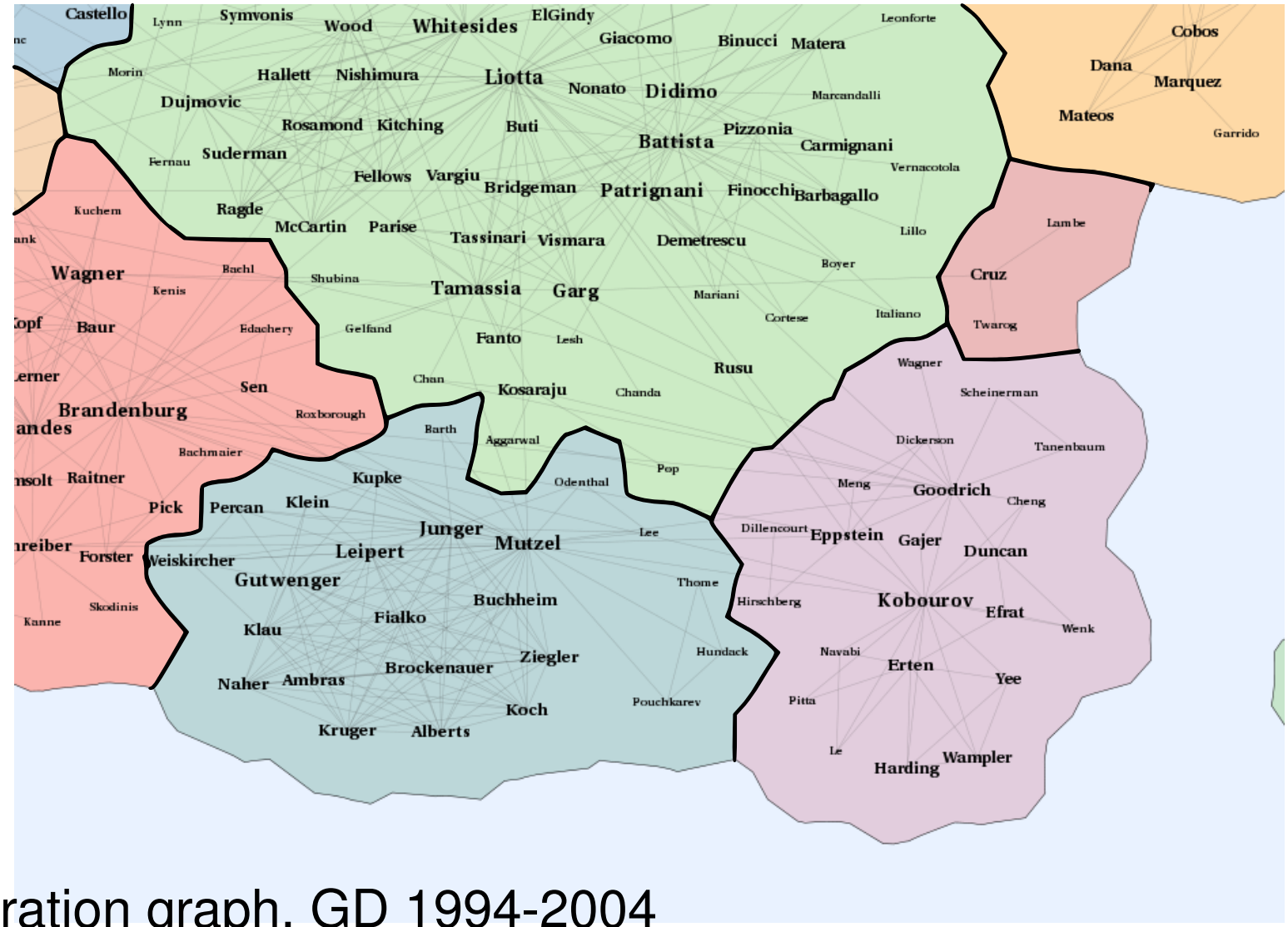
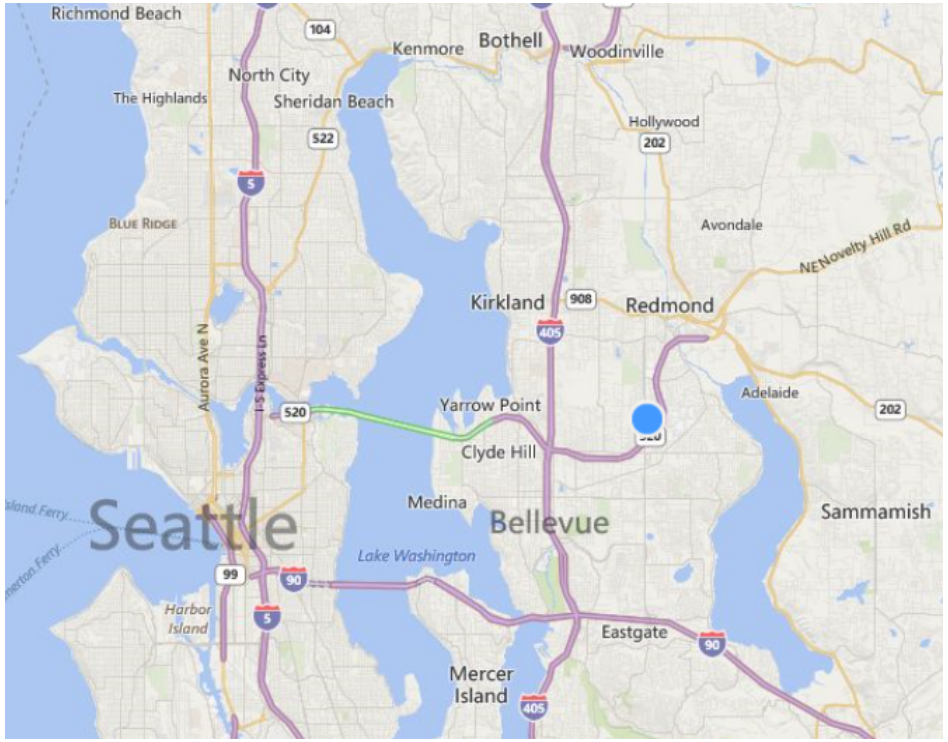



collaboration graph, GD 1994-2004

# Our inspiration: **online street maps**

- showing everything at all times unnecessary
- high-level graph structure should be visible
  - show important nodes and edges between them
- ability to zoom in: nodes/edges appear gradually with increasing zoom level

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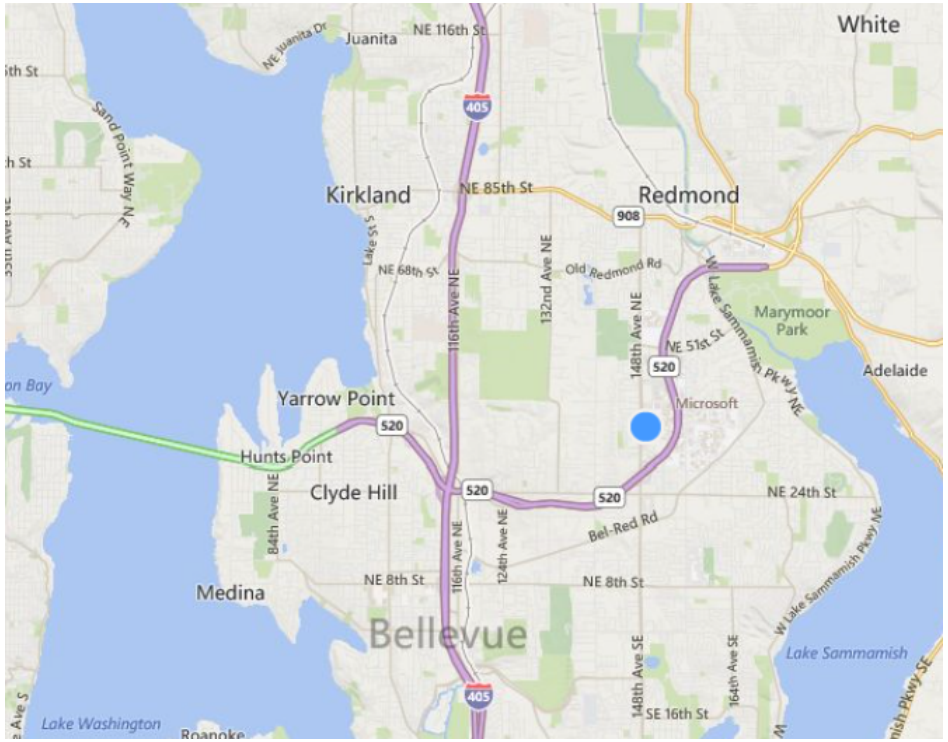


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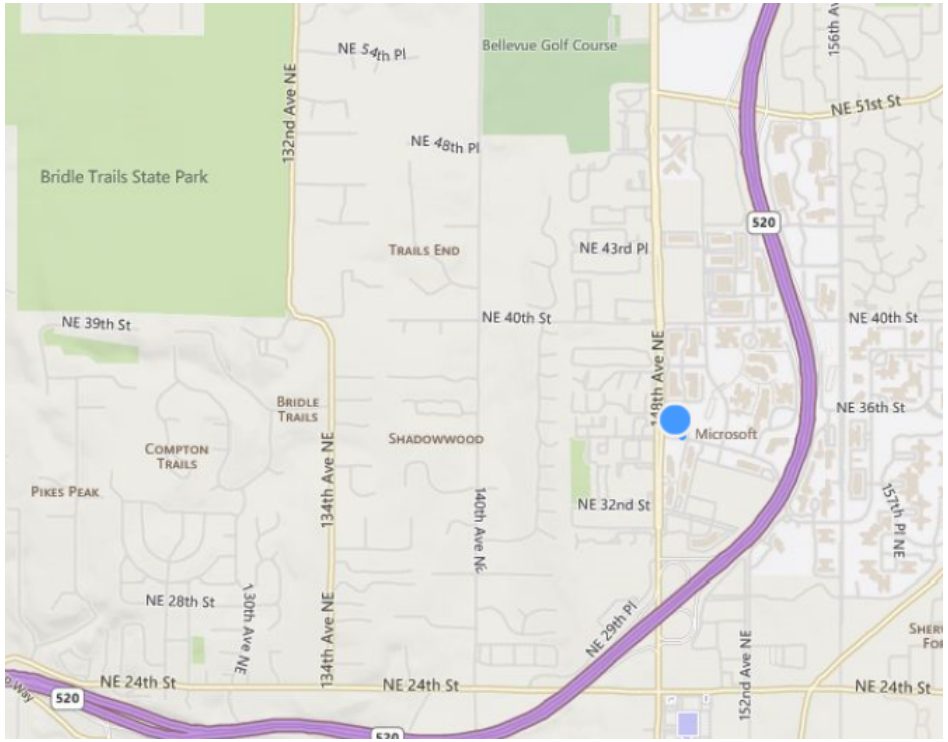


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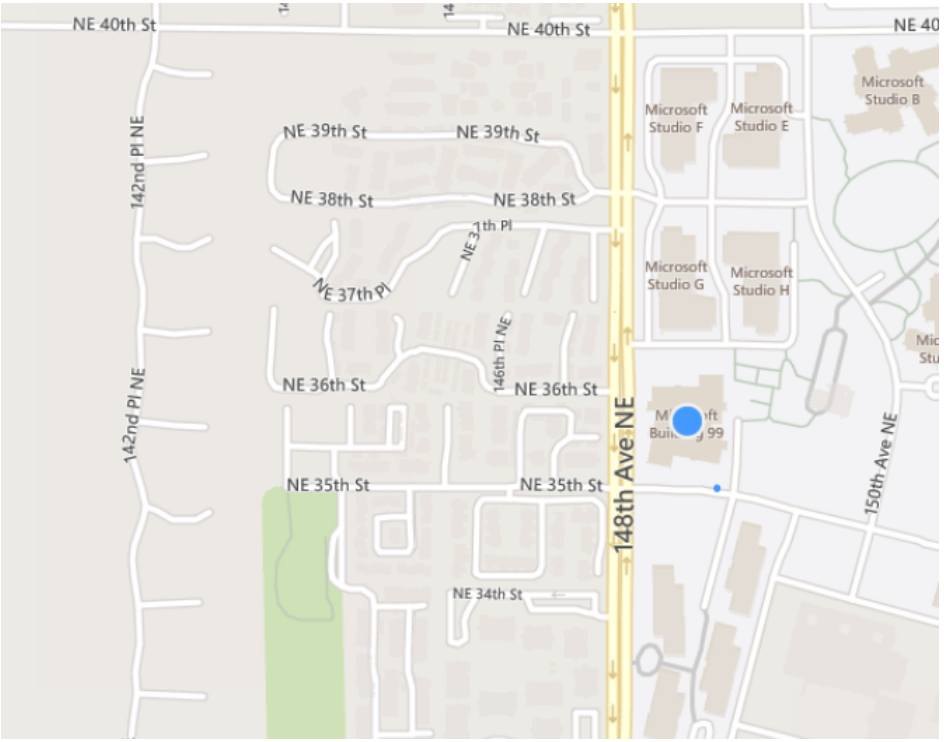


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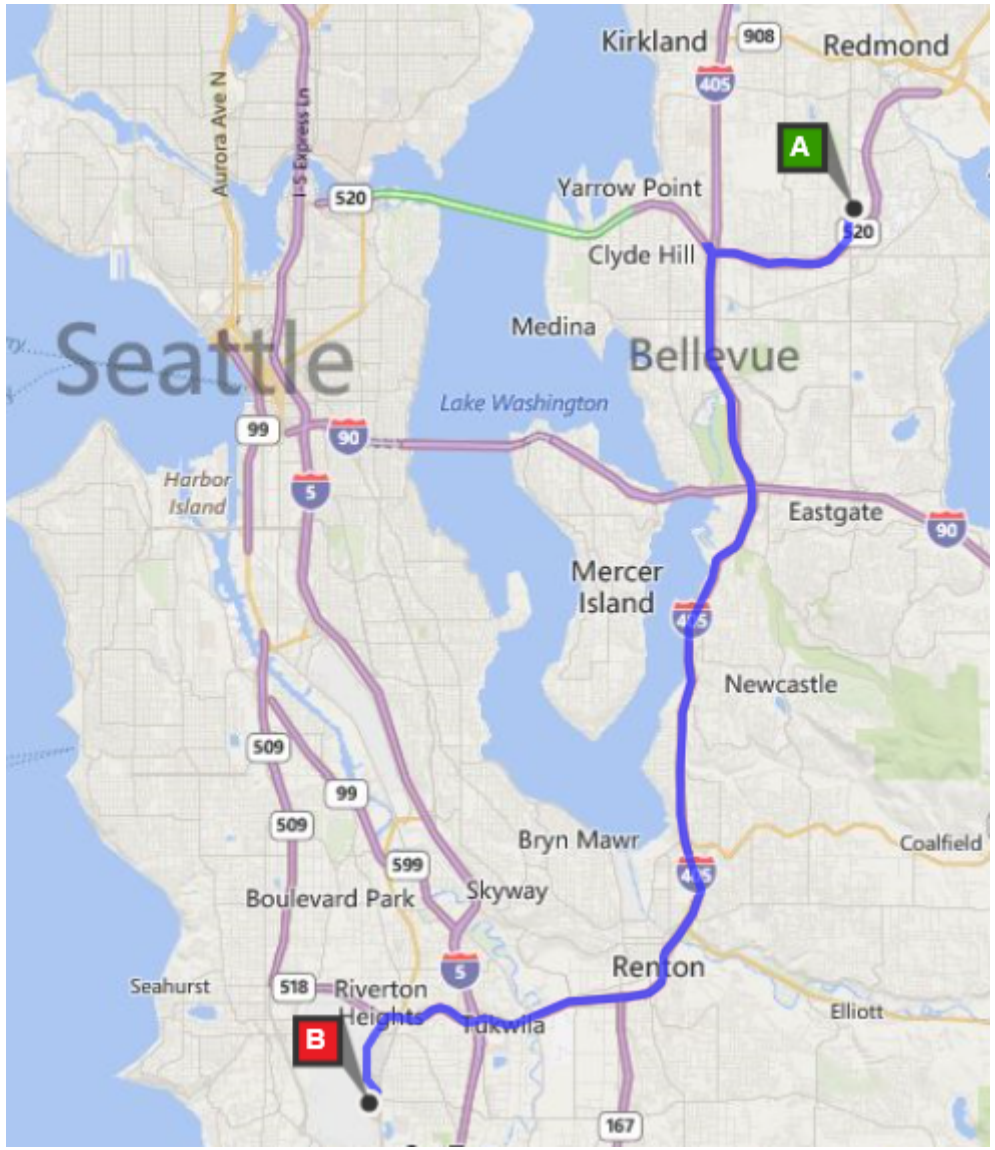
- help navigate by highlighting edges

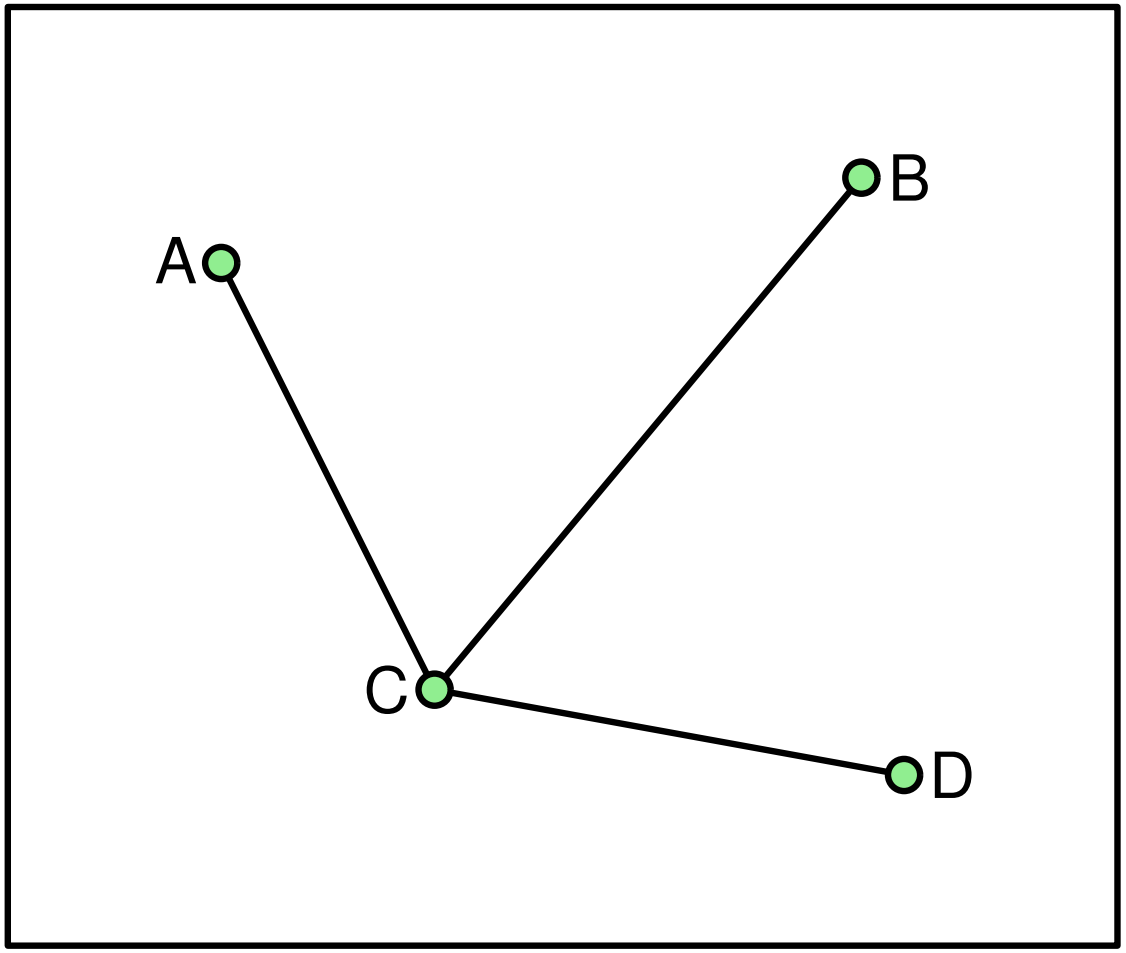



Bing maps

# Design goals

① no restriction on input graphs

② reveal key structure through **zoom in/out** and **pan**




vertices and edges of level 1

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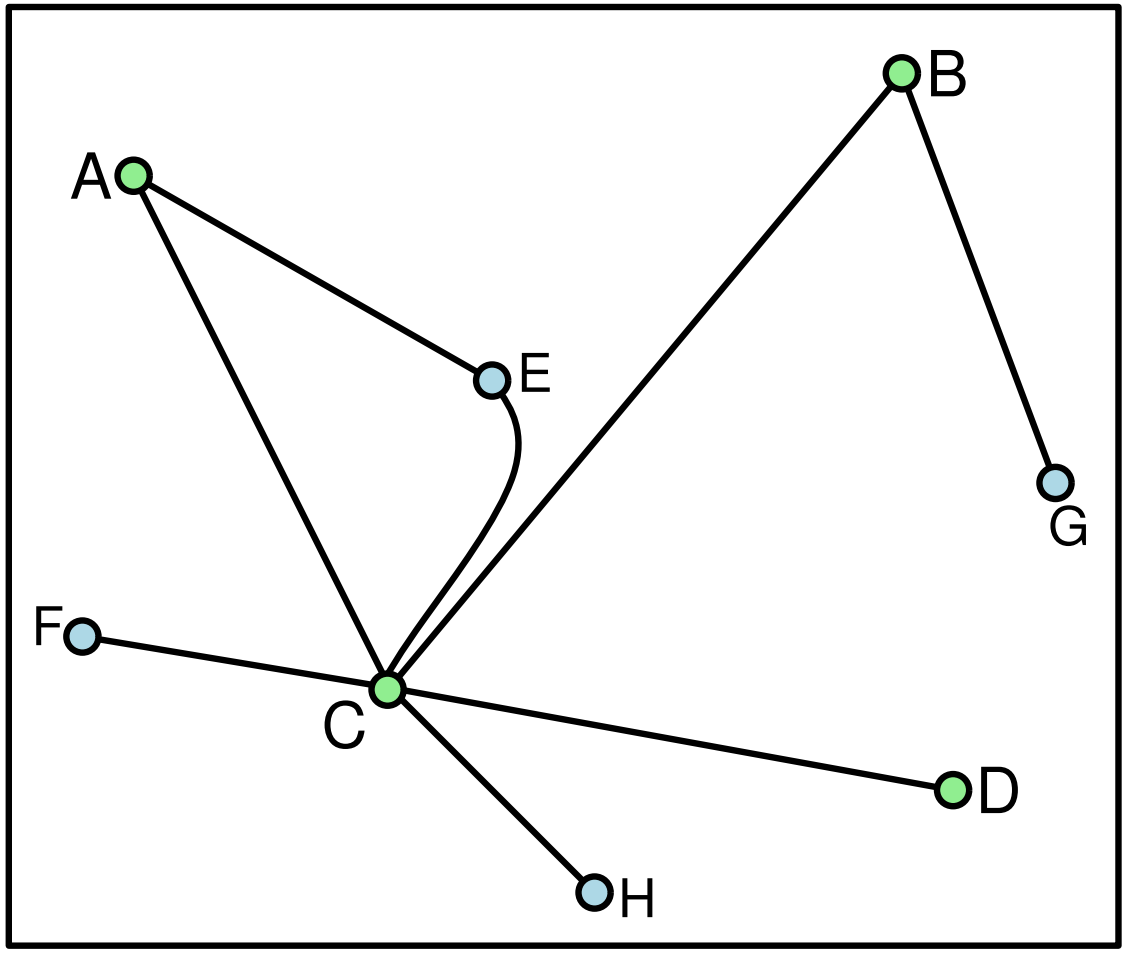


vertices and edges of level 1 and 2

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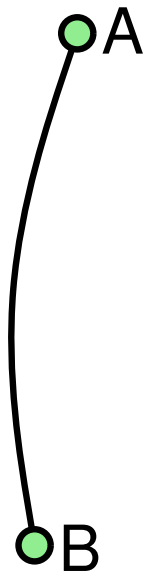
**edge trajectories** don't change on zoom



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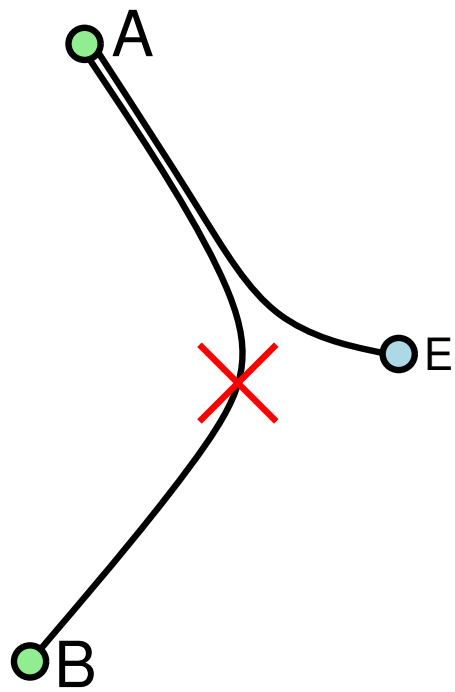

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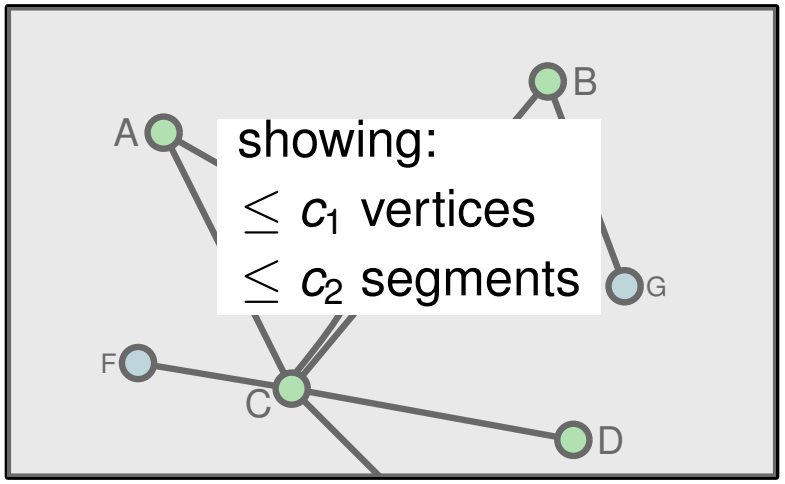
bound the number of displayed geometric objects




current view

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1. no restriction on input graphs
2. overview through **zoom** and **pan**
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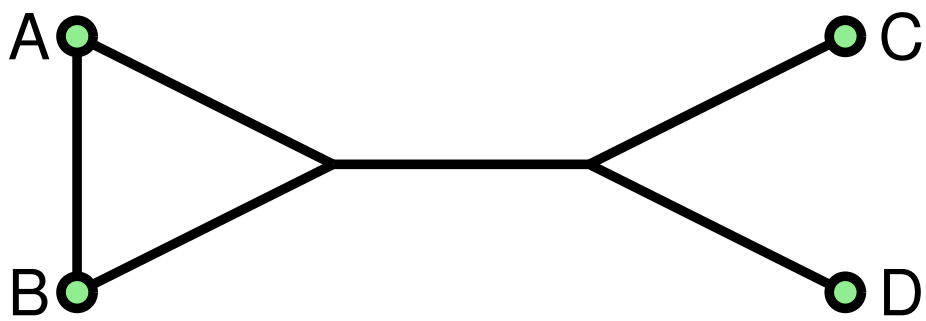
**Decision**: use **edge bundling** using polygonal mesh

**Problems**: low-level connectivity lost inside bundles

no guarantees (unlike, e.g., for **confluent** drawings)

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**no edge** between $C$, $D$

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should suffice for an overview

for more details: highlight incident edges

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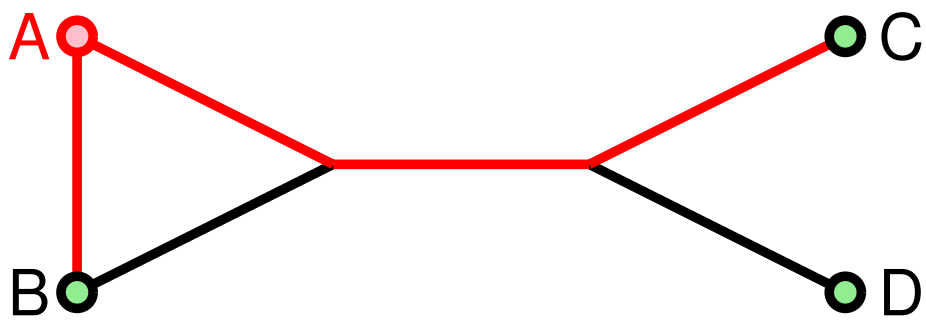


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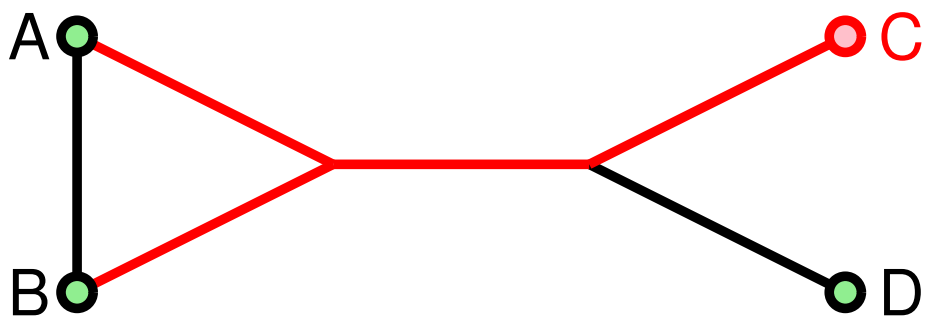


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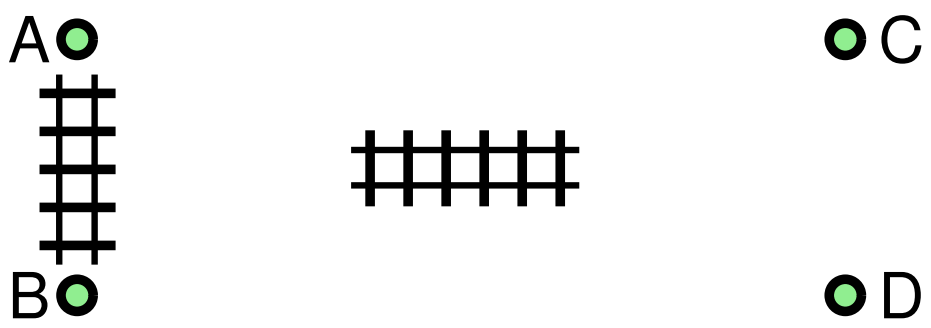


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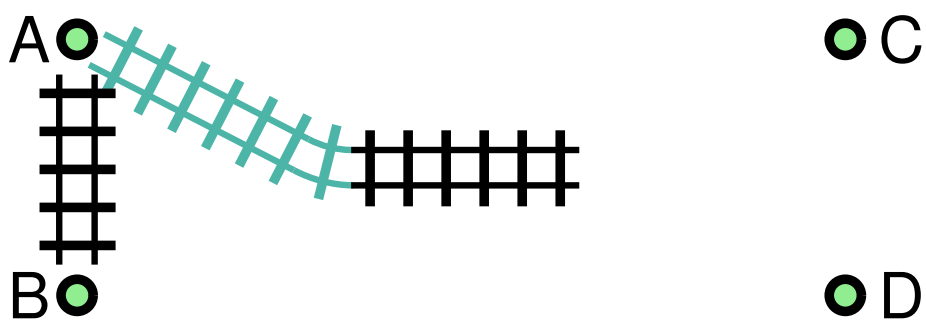


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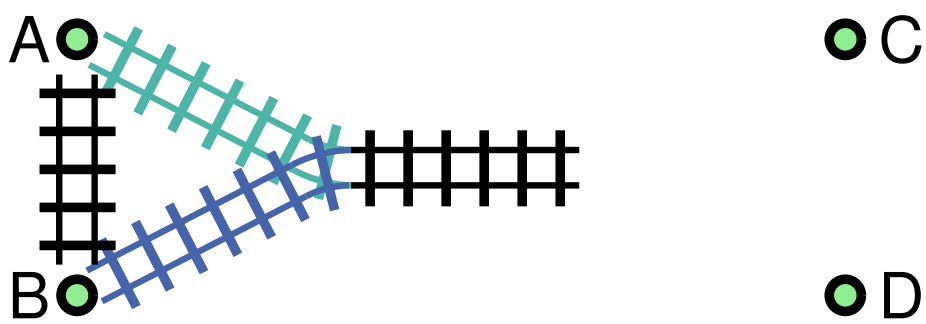


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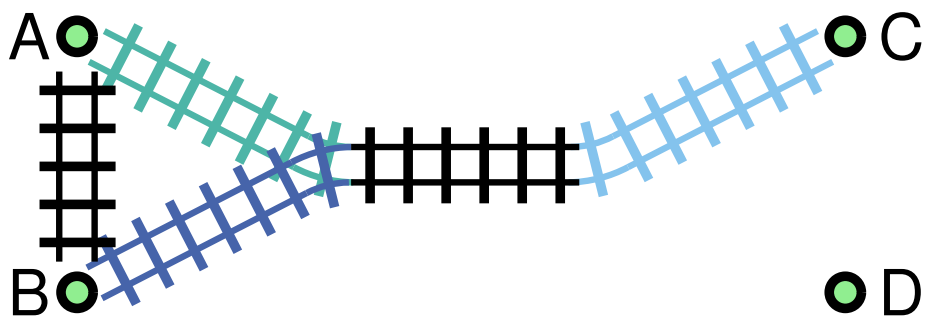


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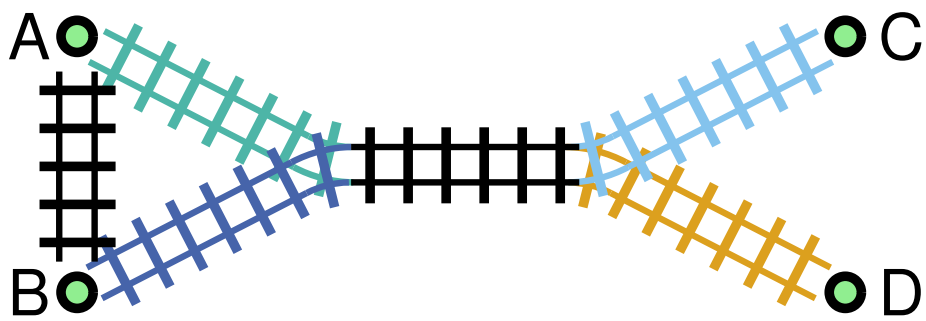


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# Design decisions: choosing visible level of detail?

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**Node layout**: MDS, force-directed, . . . , user input

**Node ranking**: sorted by decreasing importance using betweenness centrality, PageRank, degree, . . . , user input

$$SortedV = \big( \text{Seattle}, \text{Tacoma}, \text{Redmond}, \ldots \big)$$

assign **zoom levels**:

$v \in V \mapsto z(v) \in \{1.0,\ 2.0,\ 4.0,\ 8.0,\ \ldots\}$

**show** $v$ **iff** $z(v) \leq$ **current zoom**


**motivation**: on maps, never show **Redmond** without **Seattle** if both inside view

# Demo

- *Composers* graph
- largest connected component: 2743 nodes, 13769 edges
- vertices: Wikipedia articles about composers
- edges: links between these articles
- benchmark graph from the **Graph Drawing 2011** contest

# Algorithm overview: **zoom level** assignment

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initial node layout

node ranking

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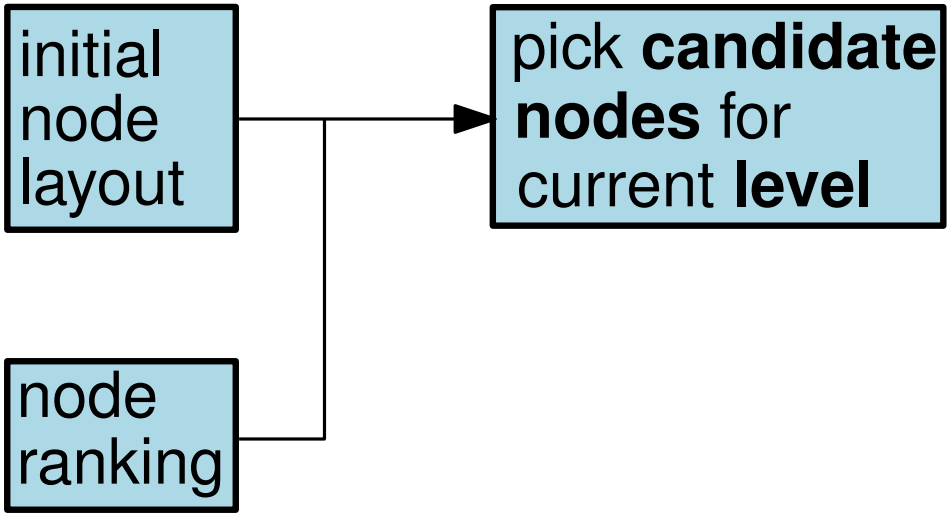

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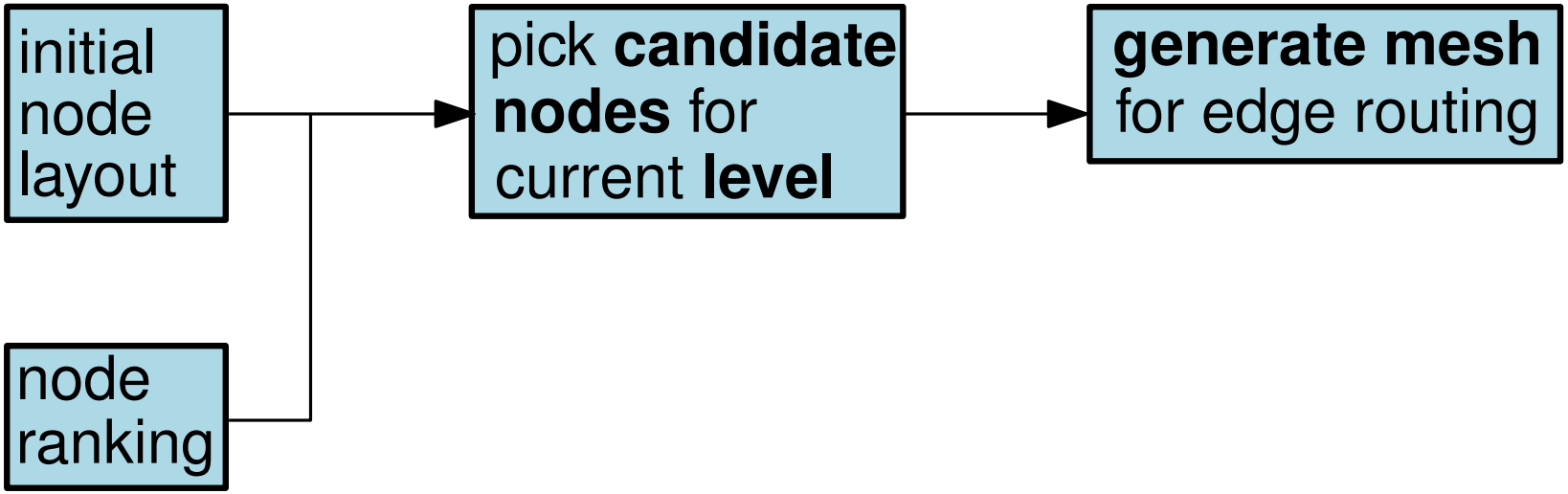

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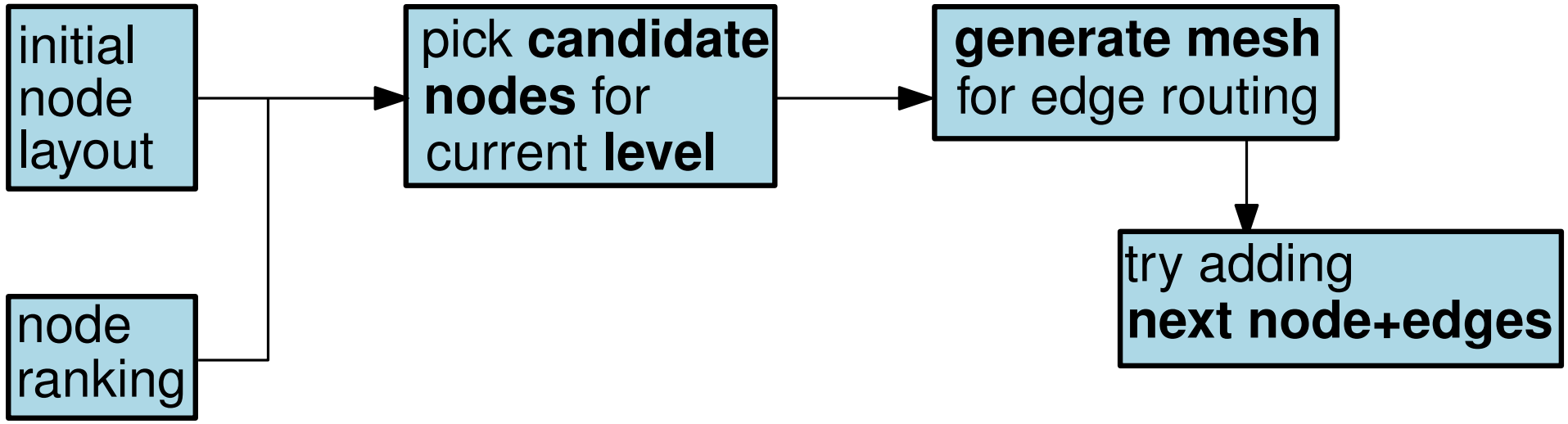

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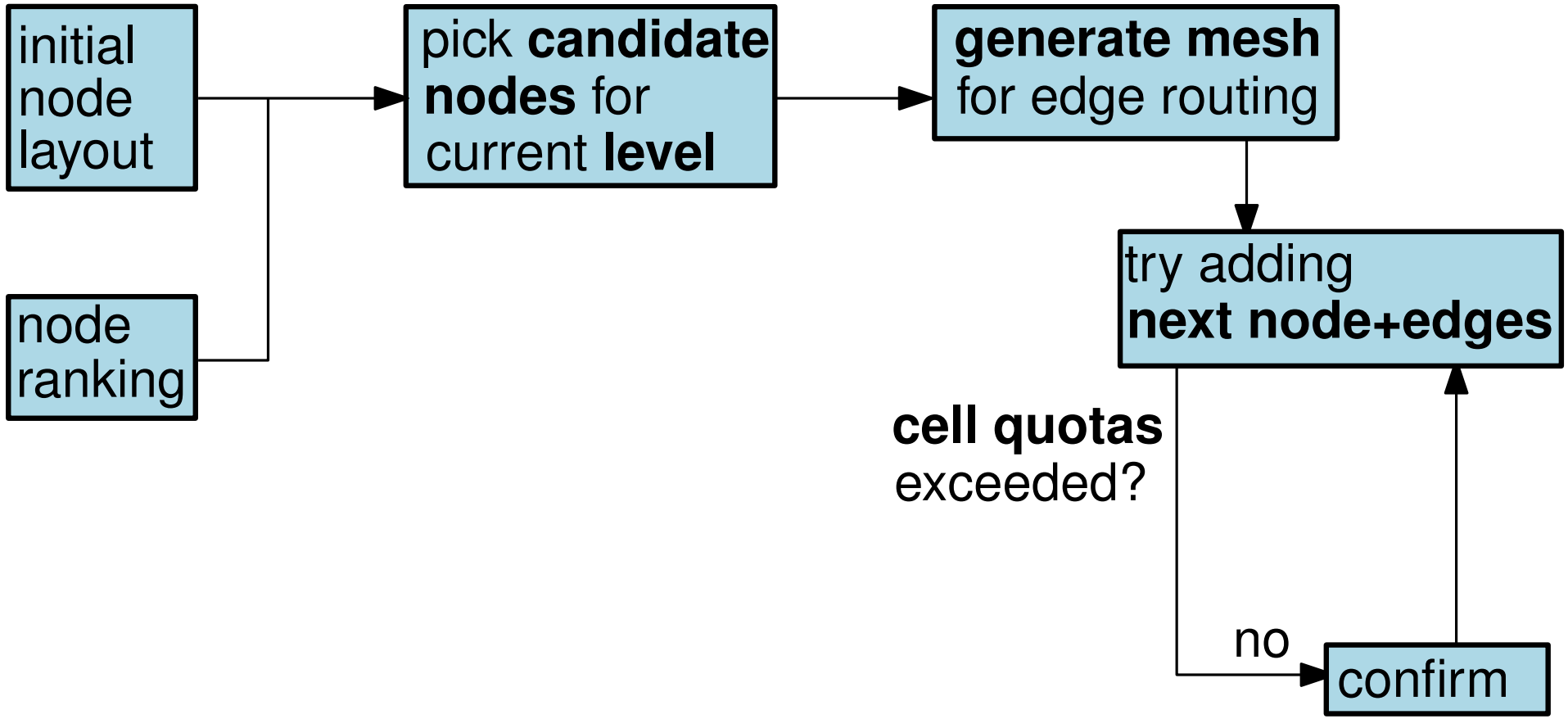
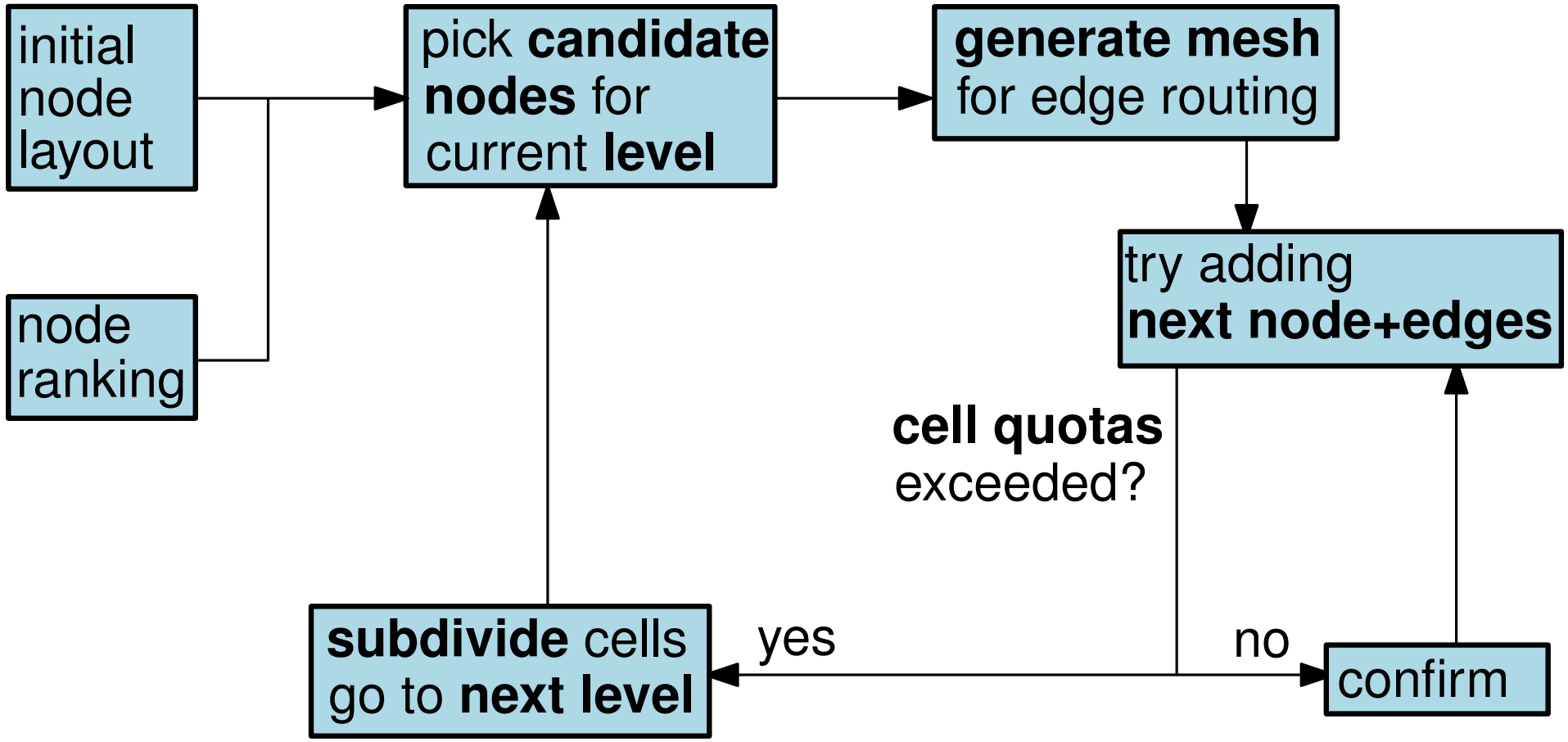


# Algorithm overview: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

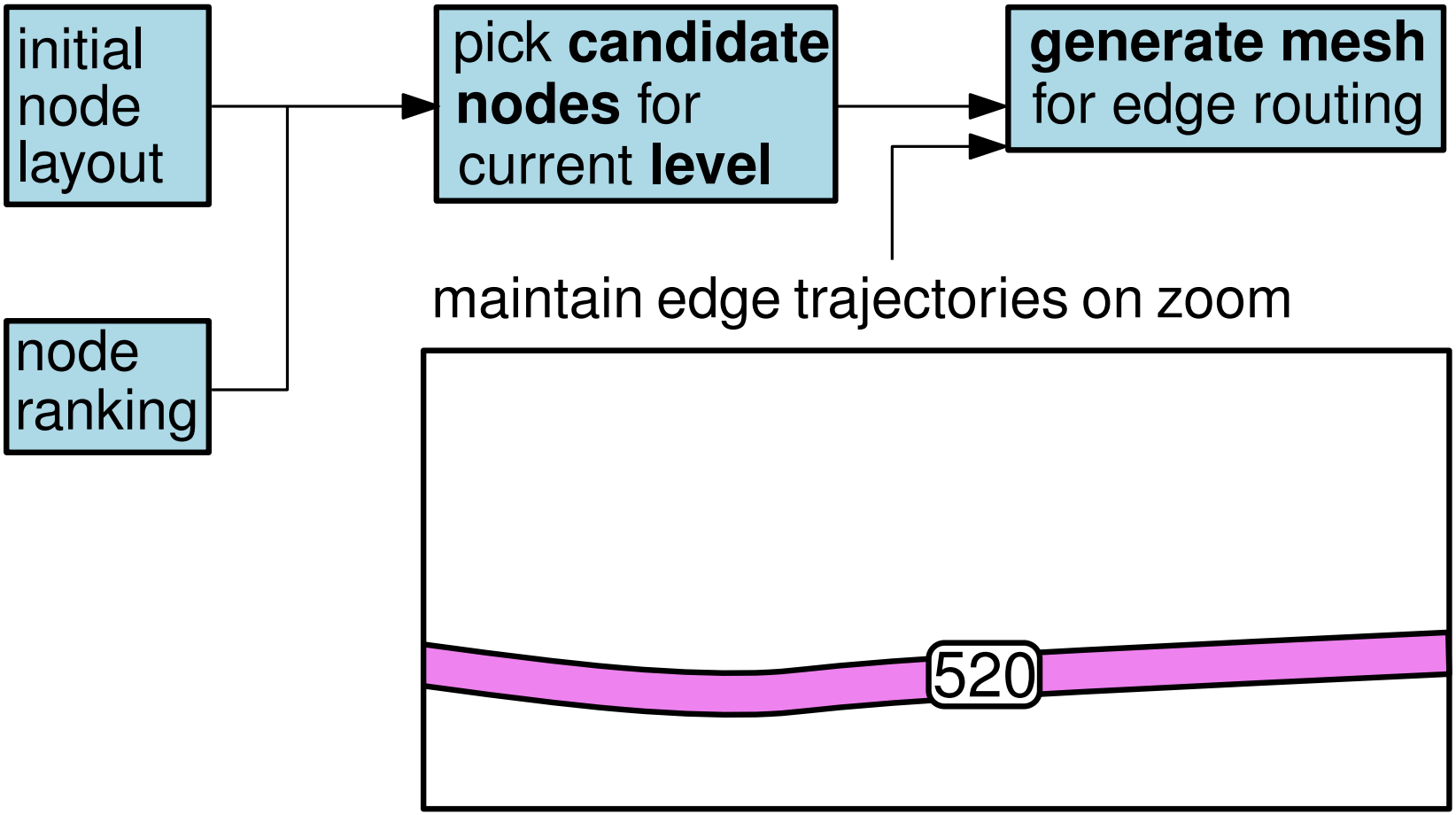
③ preserve **mental map** of the user ④ limit **clutter** and **complexity**



# Algorithm overview: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

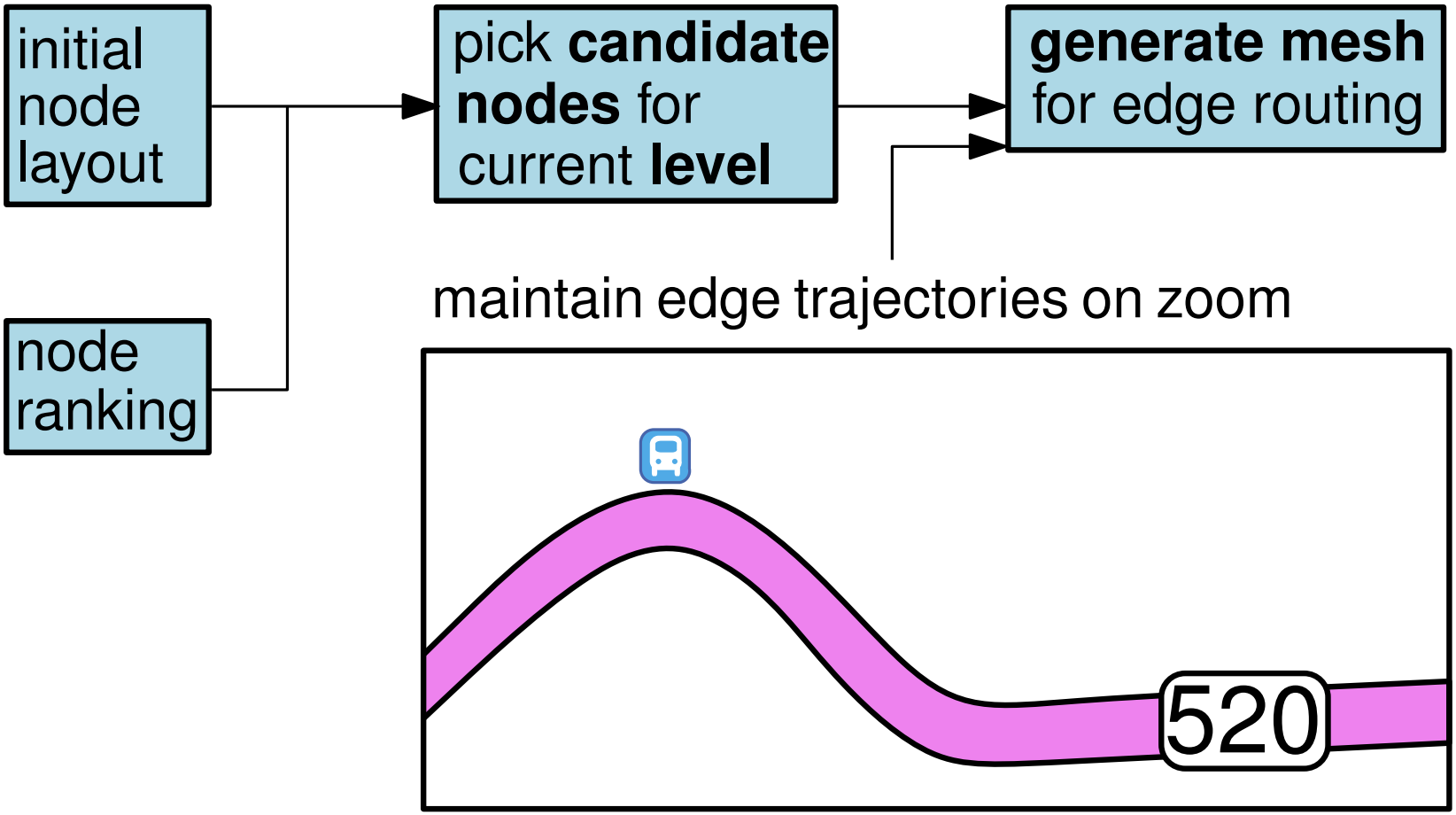
③ preserve **mental map** of the user ④ limit **clutter** and **complexity**



# Algorithm overview: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

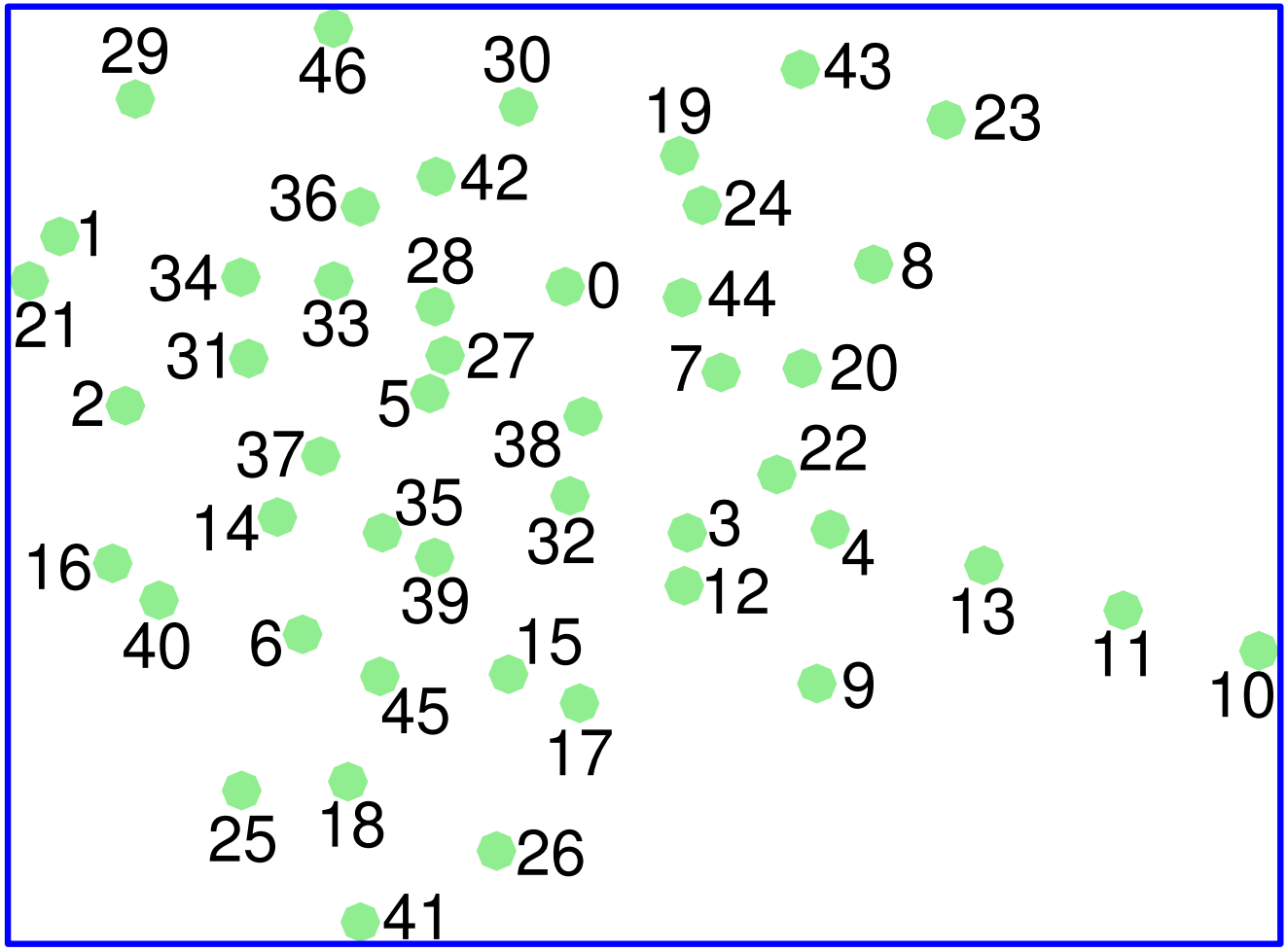


# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

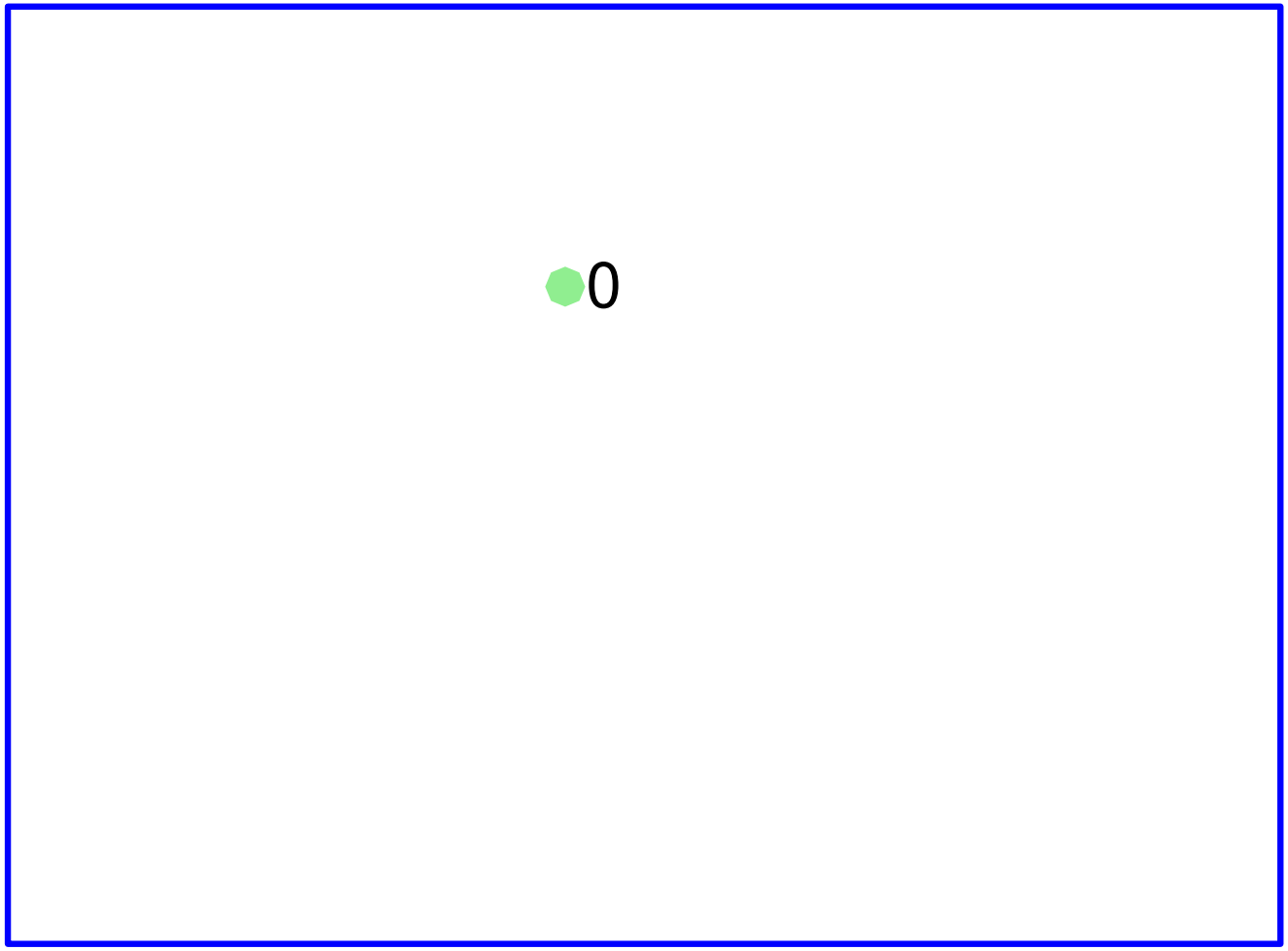
$Q_N = 20$;

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges
(for presentation)

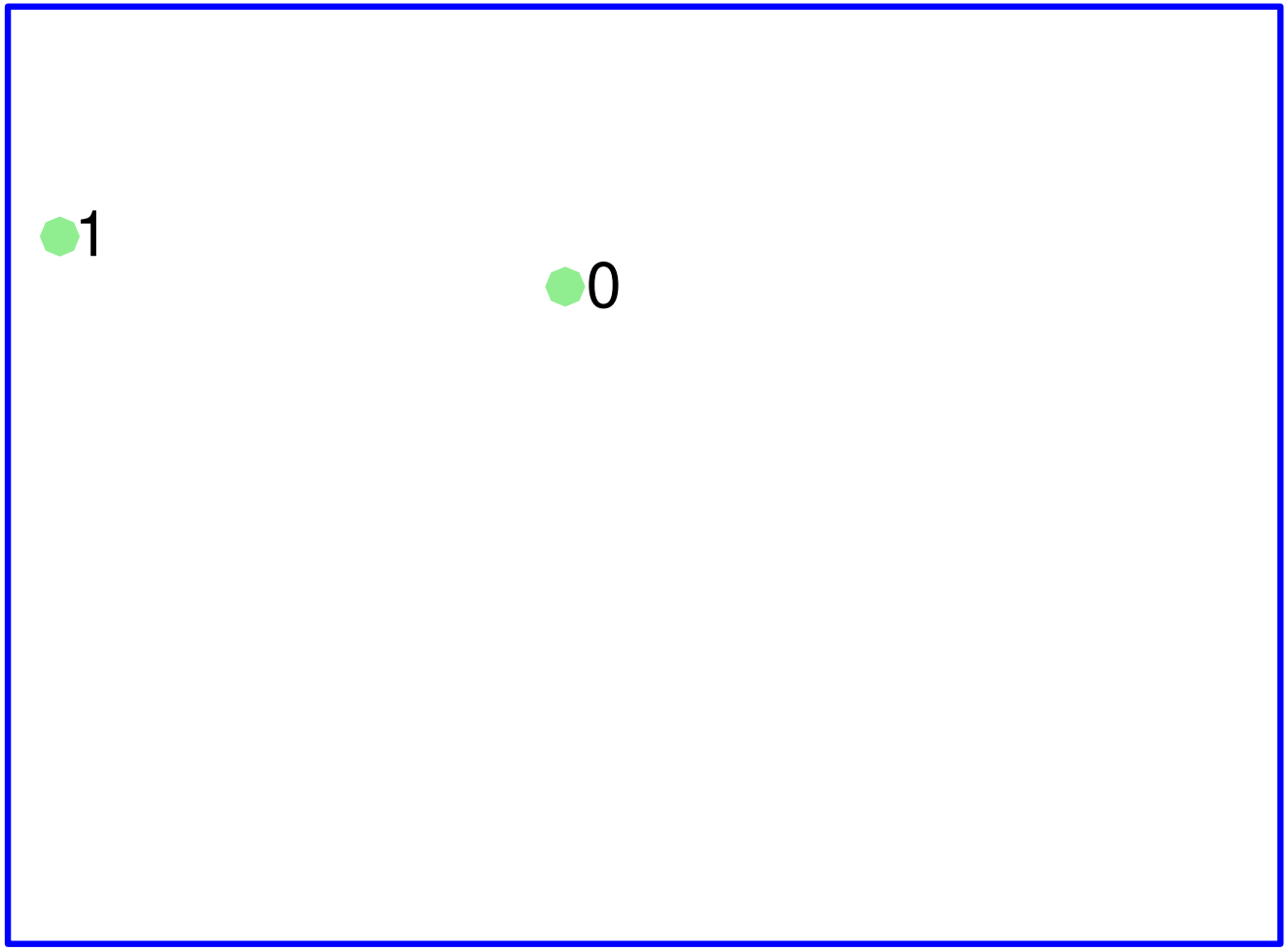
$Q_N = 20$; filling **level** 1.0
set $z(v)$ **= 1.0**

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges
(for presentation)

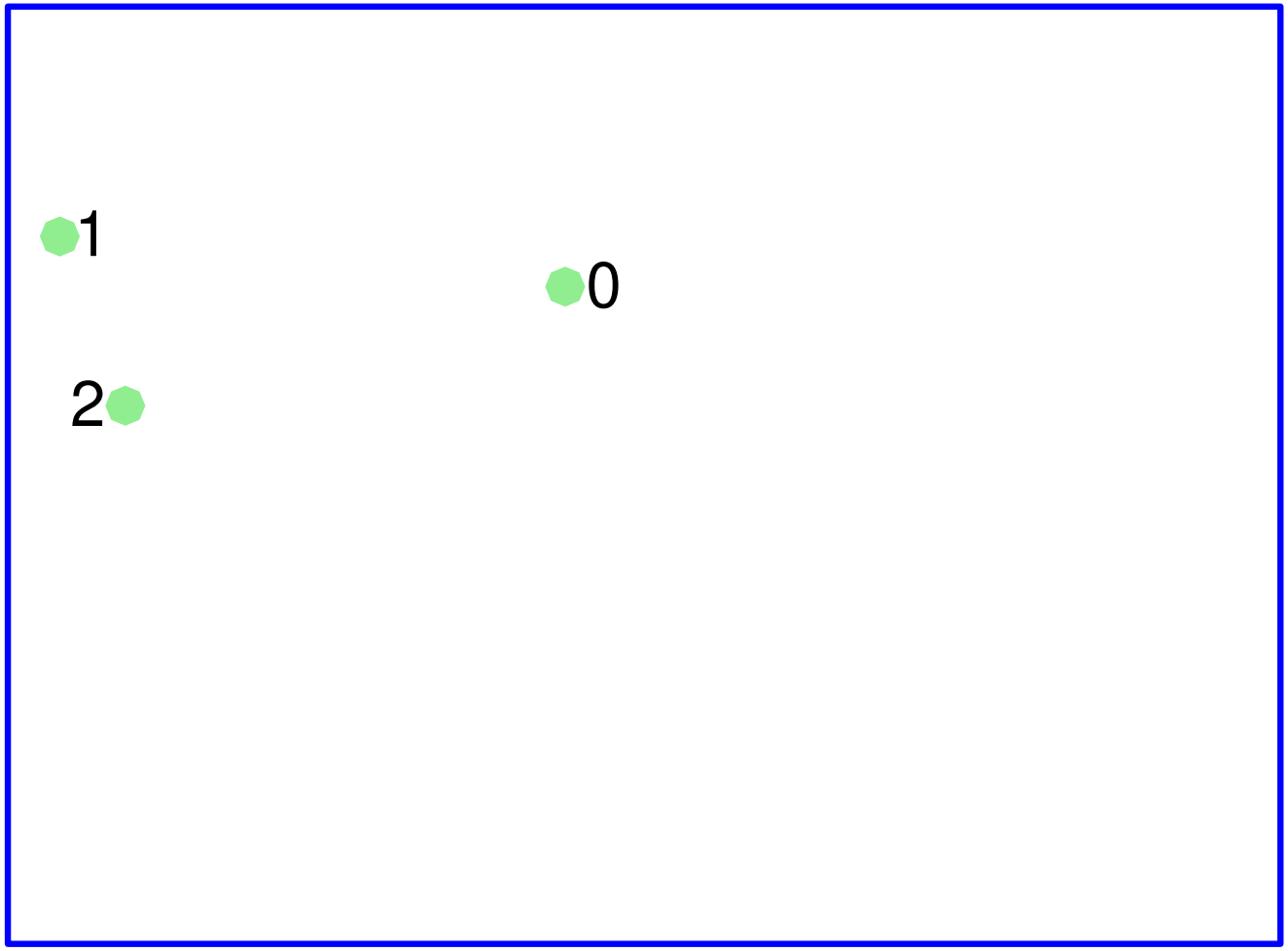
$Q_N = 20$; filling **level** 1.0
set $z(v)$ **= 1.0**

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges
(for presentation)

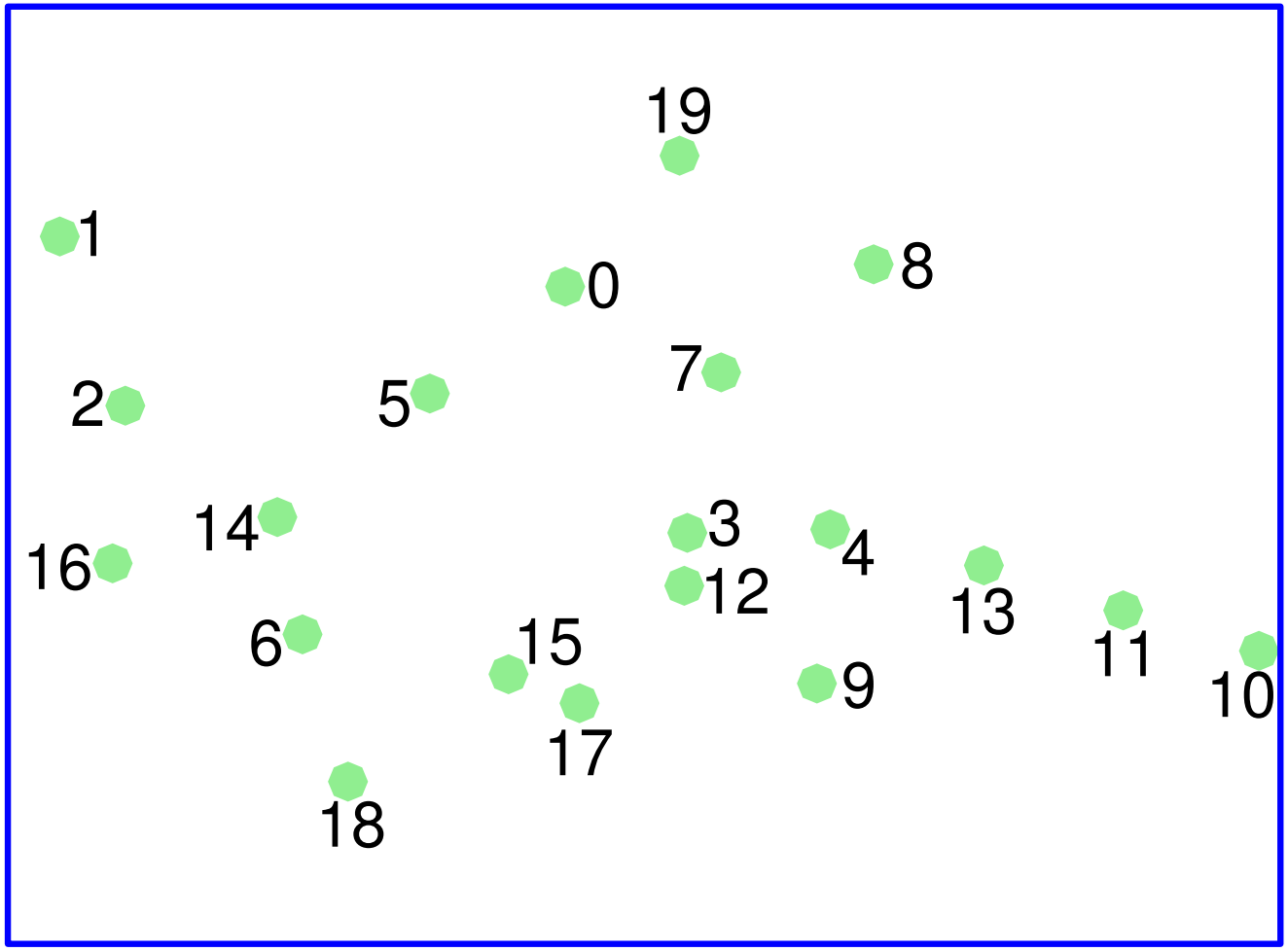
$Q_N = 20$; filling **level** 1.0
set $z(v)$ **= 1.0**

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

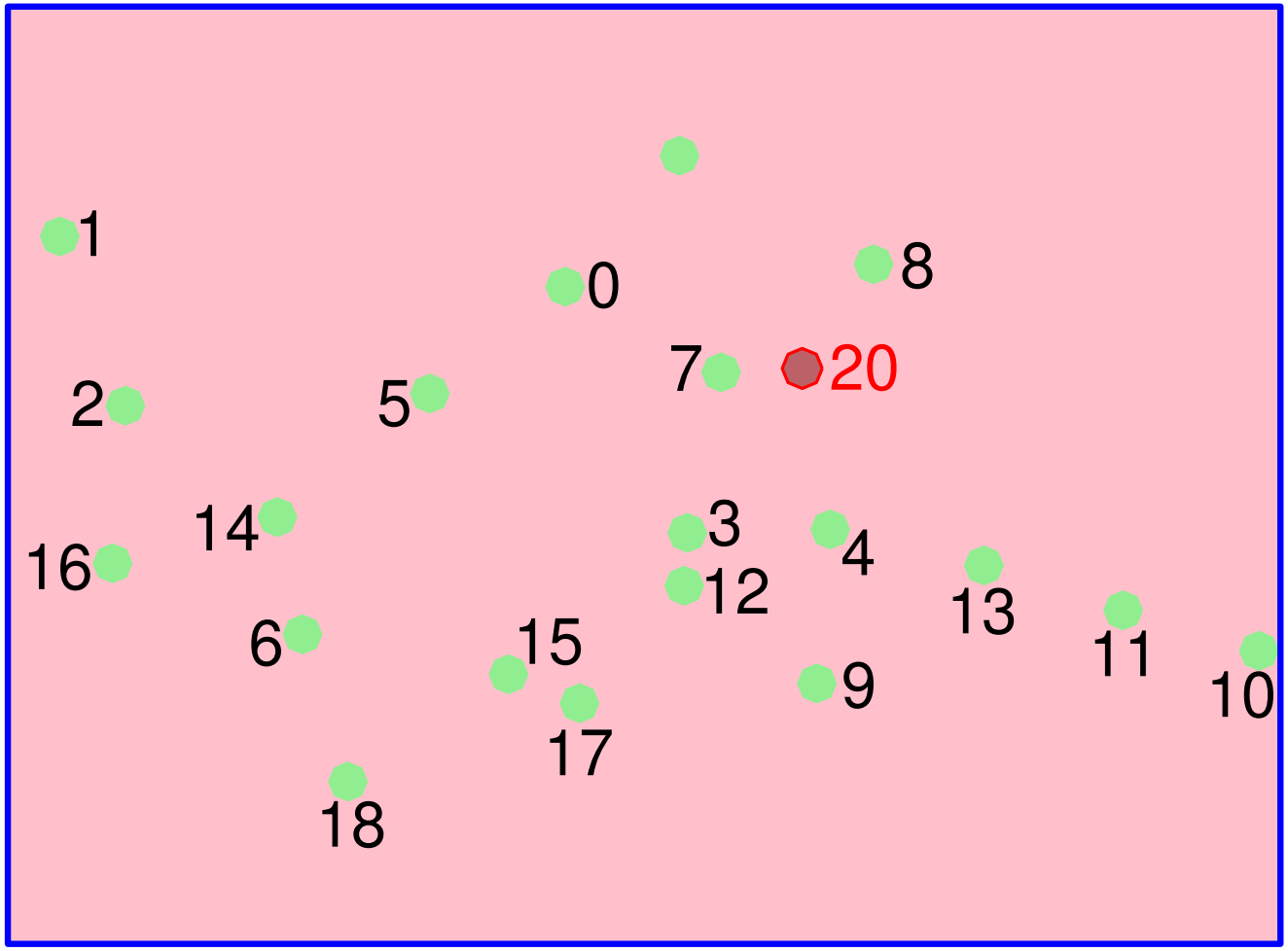
$Q_N = 20$; **level** 1.0 full

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

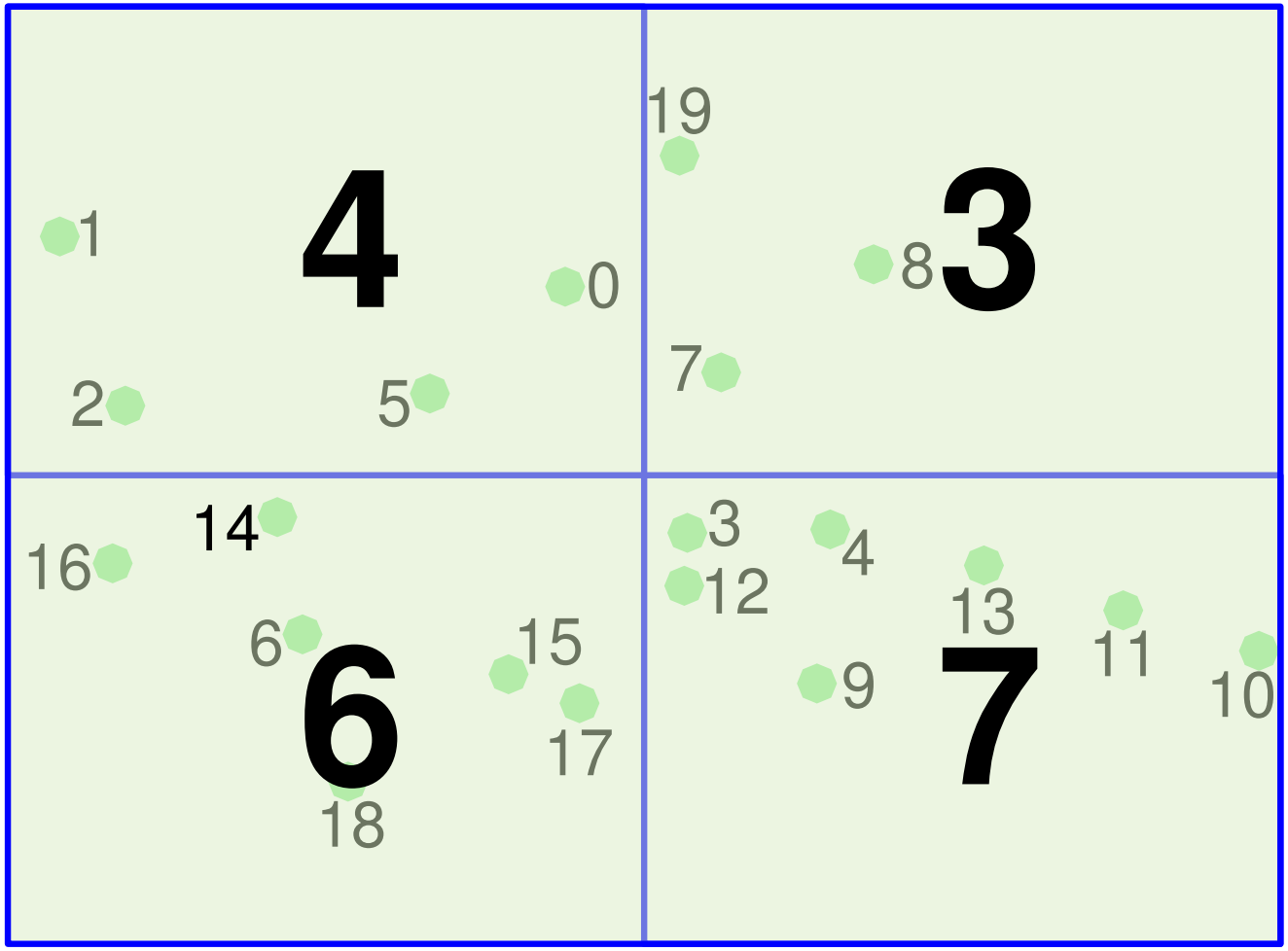
$Q_N = 20$; **level** 1.0 full

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

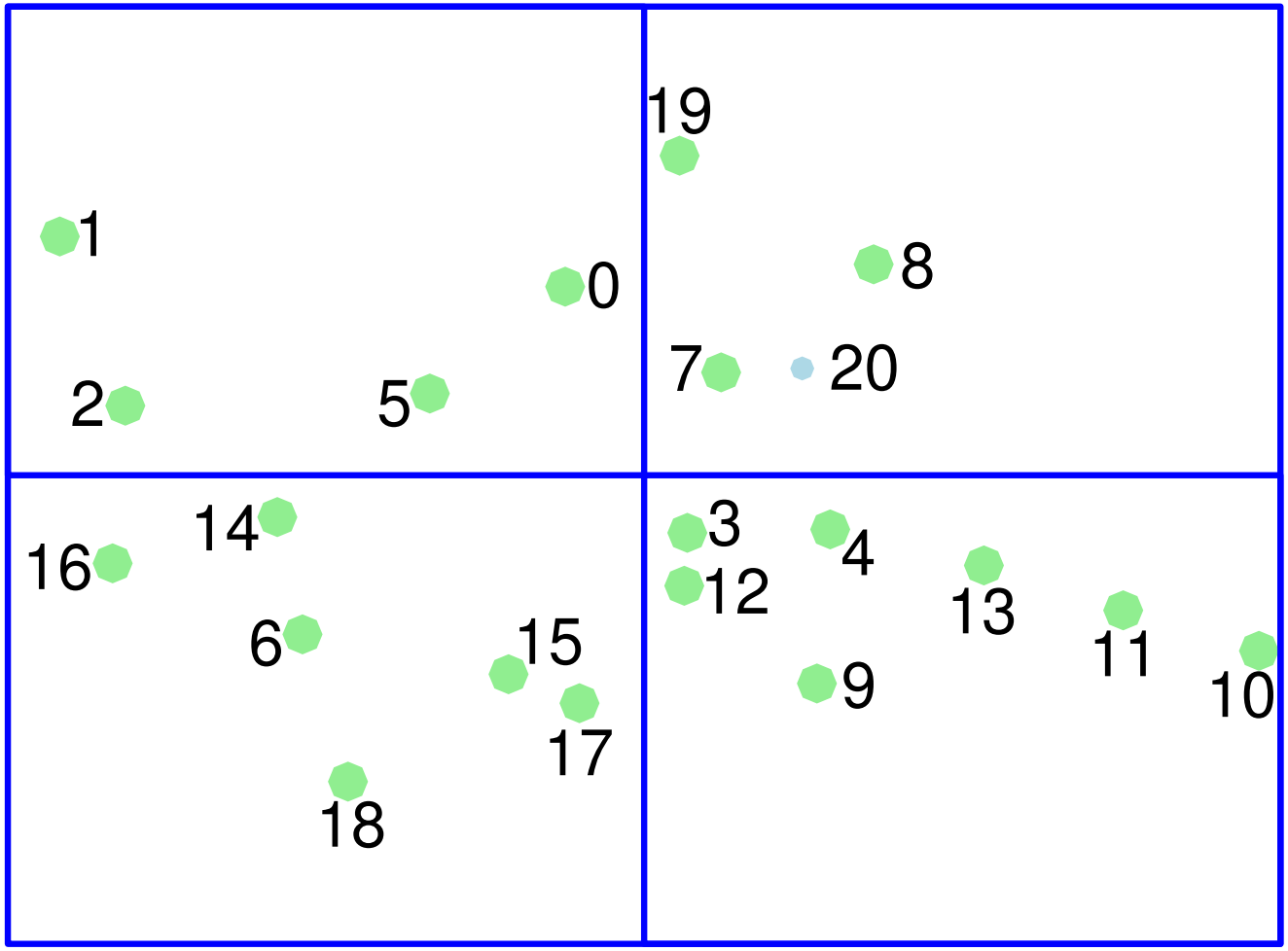
$Q_N = 20$; **level** 1.0 full **subdivide cells**

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

$Q_N = 20$; filling **level** 2.0

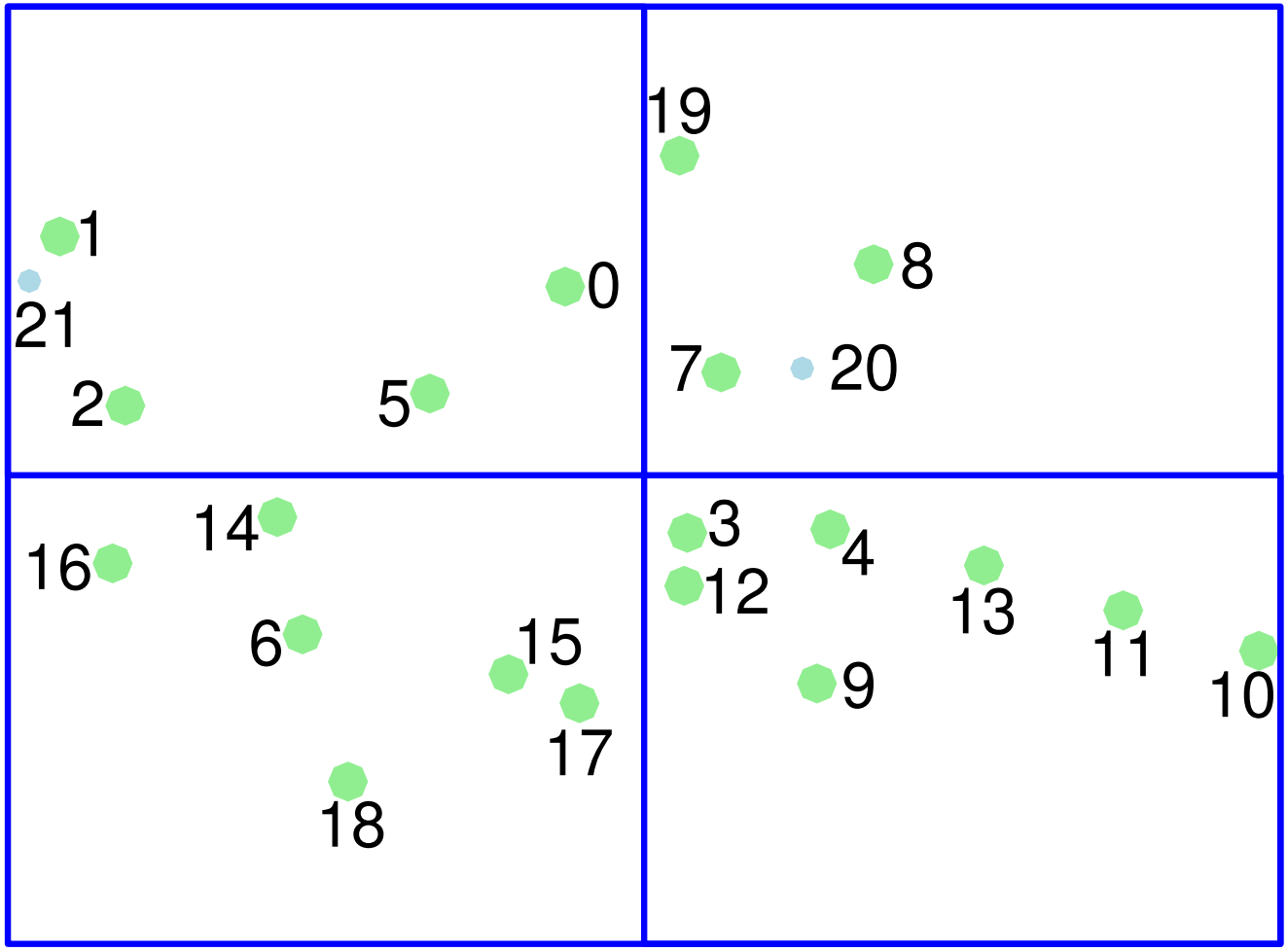
set $z(v)$ **= 2.0**

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

$Q_N = 20$; filling **level** 2.0

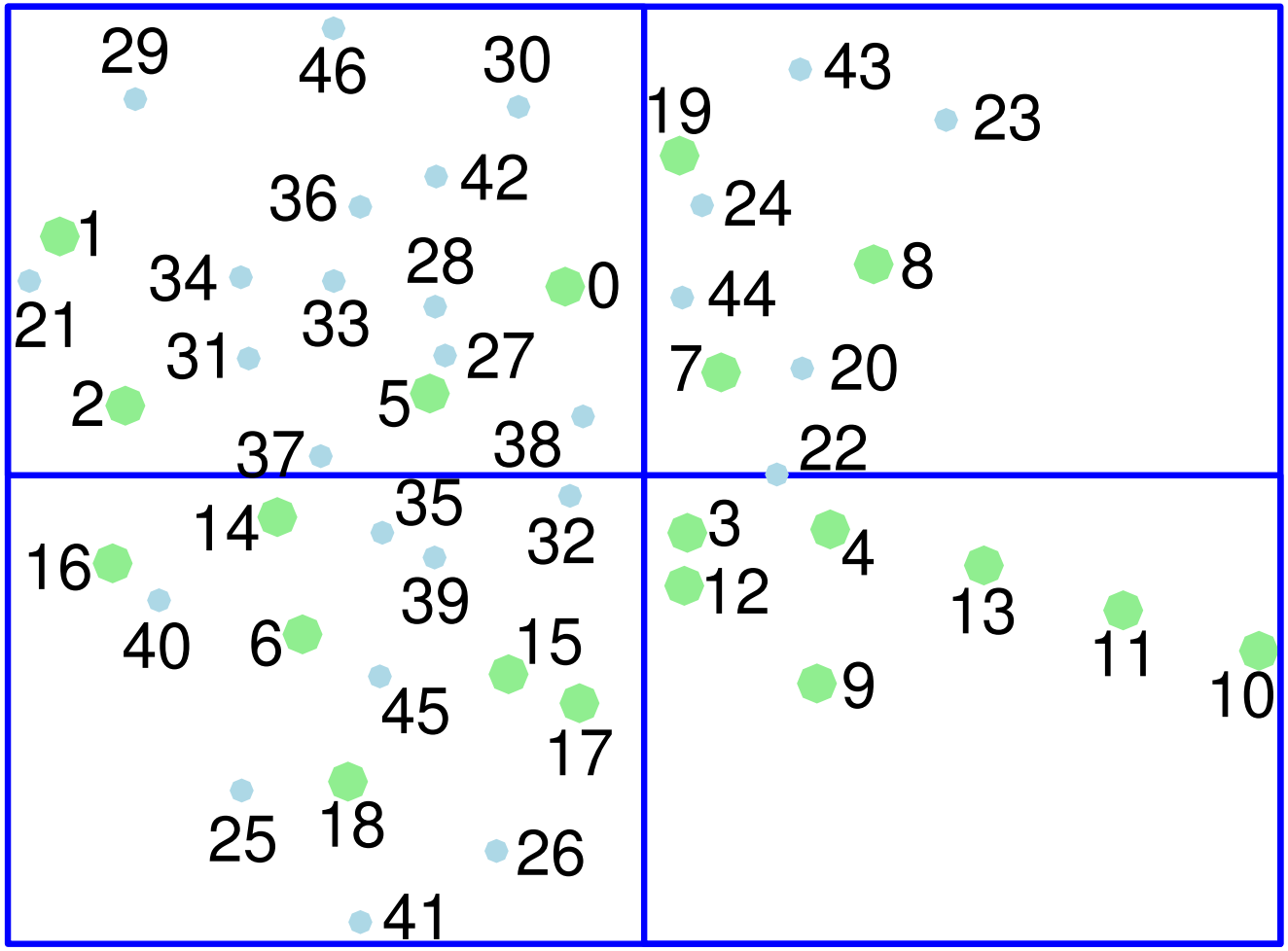
set $z(v)$ **= 2.0**

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

$Q_N = 20$; filling **level** 2.0

set $z(v)$ **= 2.0**

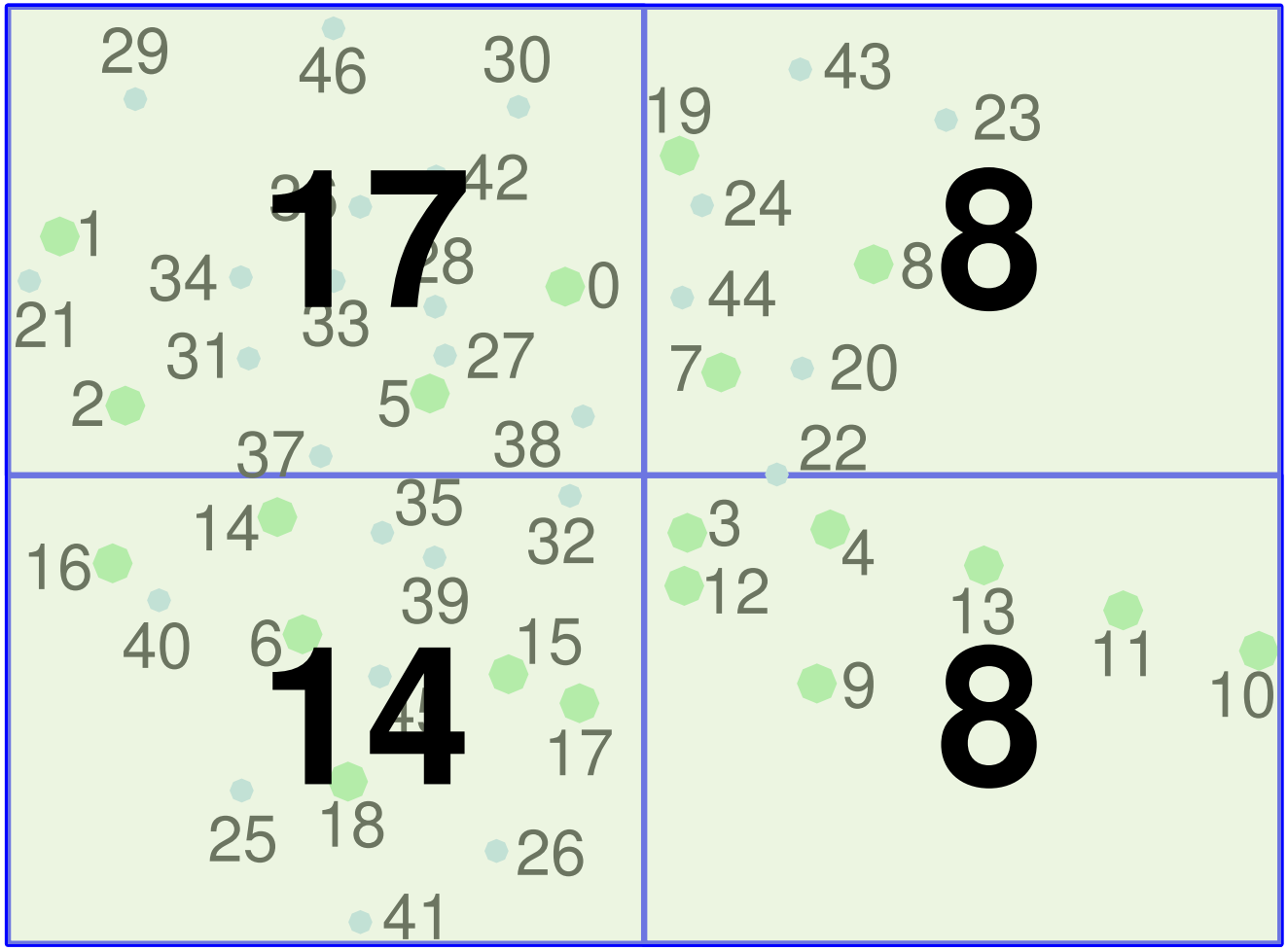
**all nodes added**

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

$Q_N = 20$; filling **level** 2.0

set $z(v)$ **= 2.0**

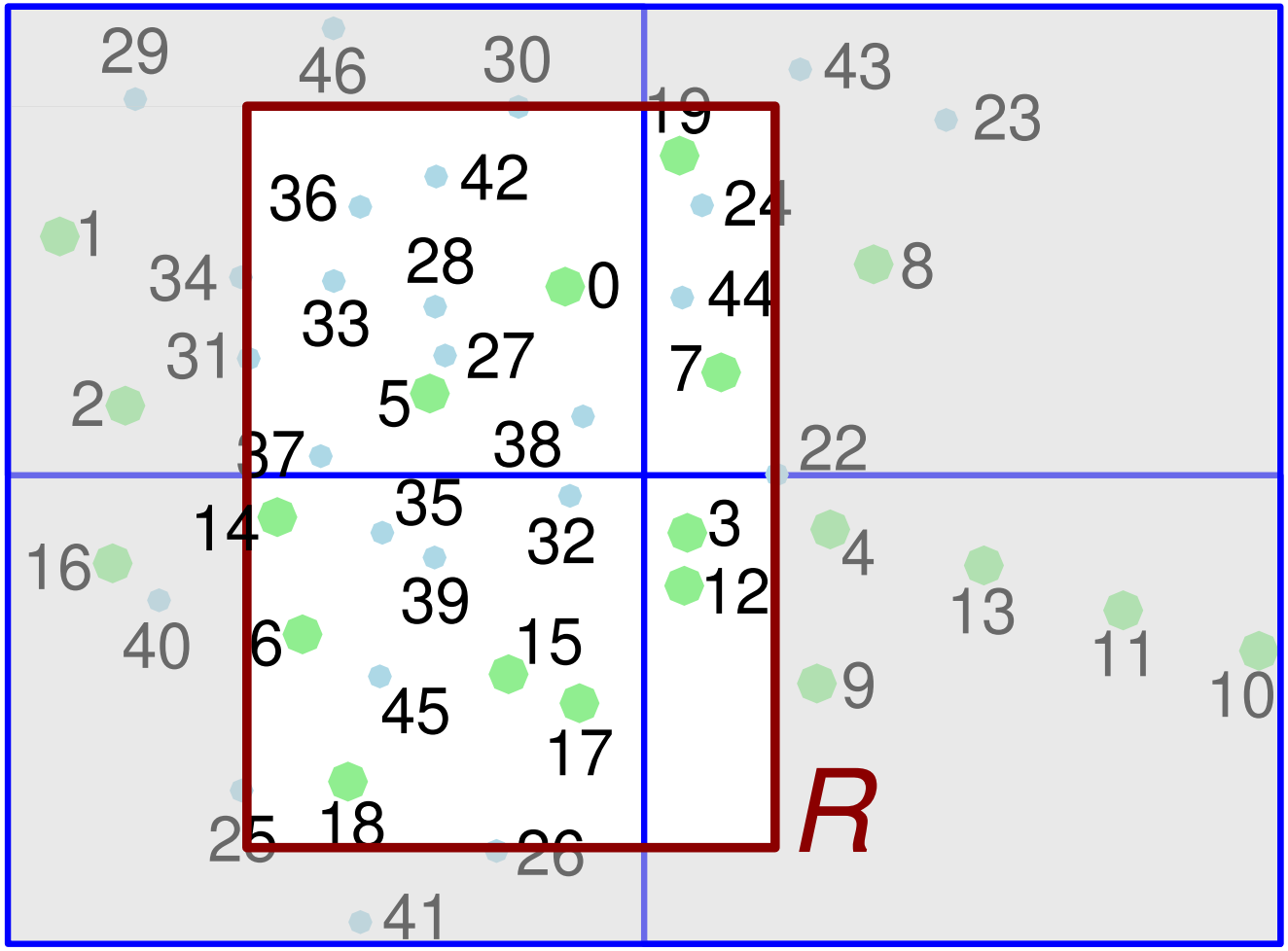
**all nodes added**

# Method description: **zoom level** selection

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

$Q_N = 20$;
view rectangle ***R*** has **zoom level**

$$z_R = \min\left\{\frac{w_{\text{total}}}{w_R}, \frac{h_{\text{total}}}{h_R}\right\} \approx 1.3$$

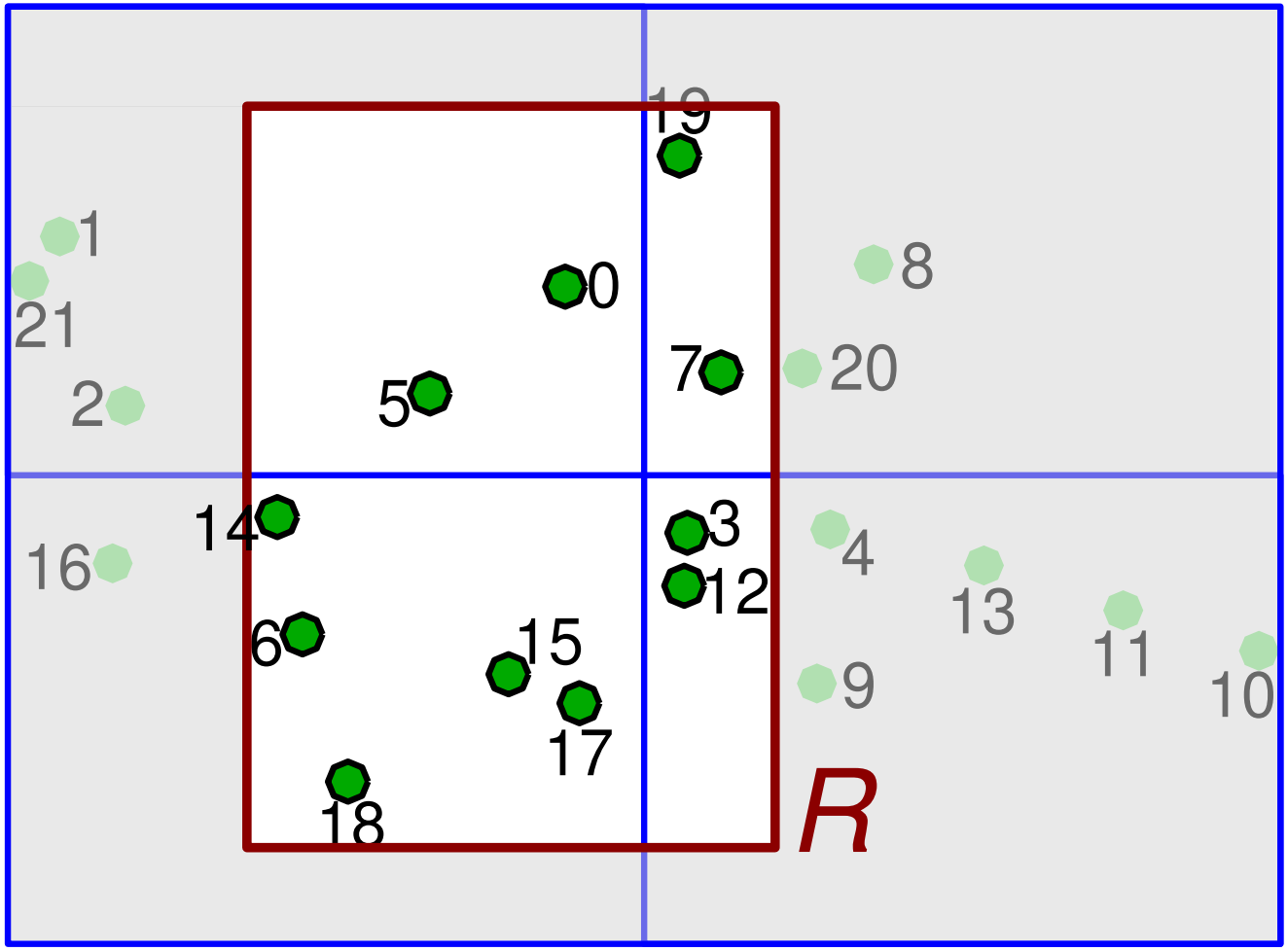
**show** $v$ **iff** $z(v) \leq z_R$

# Method description: **zoom level** assignment

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph with no edges (for presentation)

$Q_N = 20$;
view rectangle ***R***
has **zoom level**
$z_R = \min\{\frac{w_{\text{total}}}{w_R}, \frac{h_{\text{total}}}{h_R}\}$
$\approx 1.3$

**show** $v$ **iff** $z(v) \leq z_R$

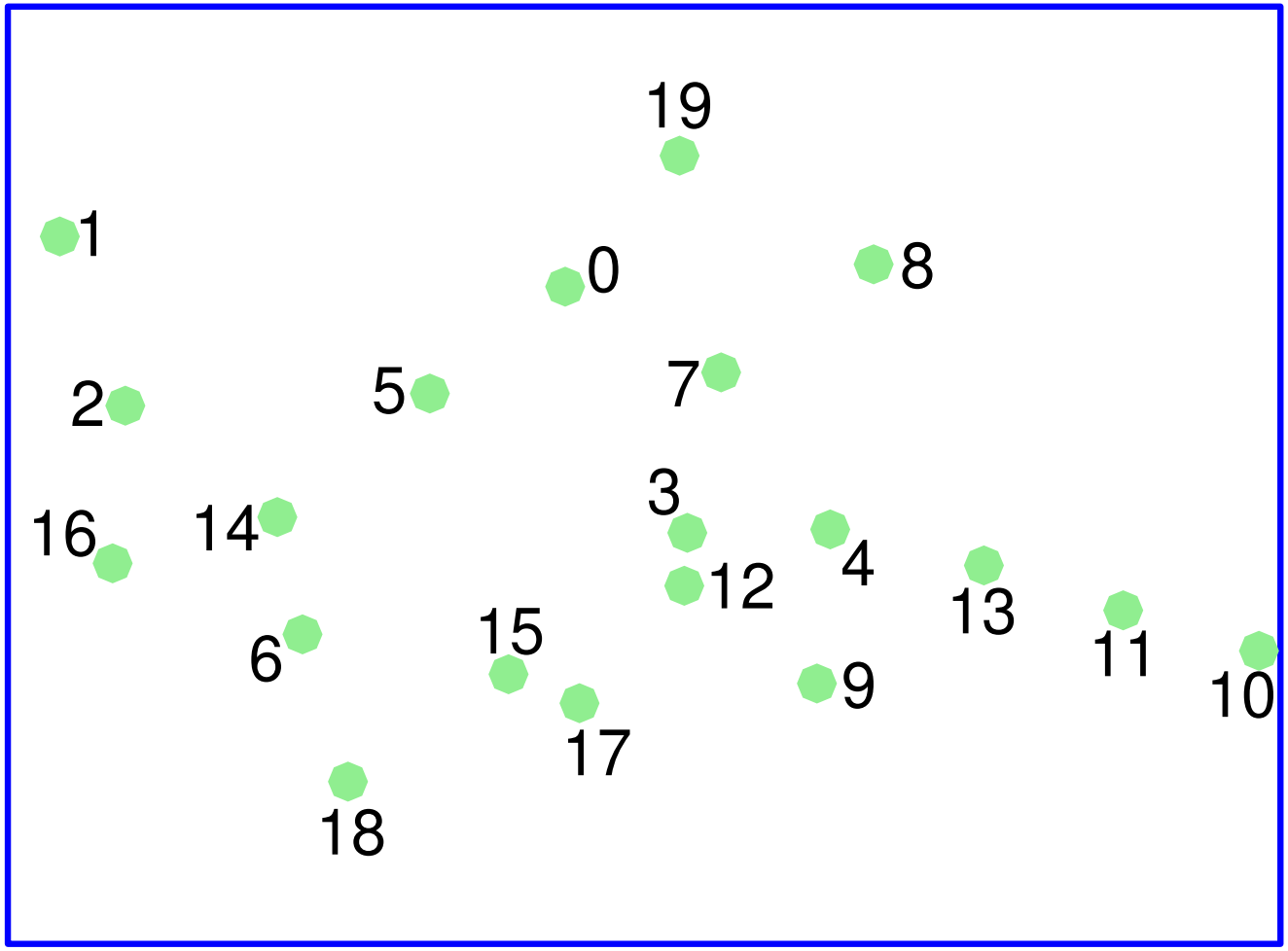
**at most** $4Q_N$ visible

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph **with edges**

$Q_N = 20$, $Q_R = 45$

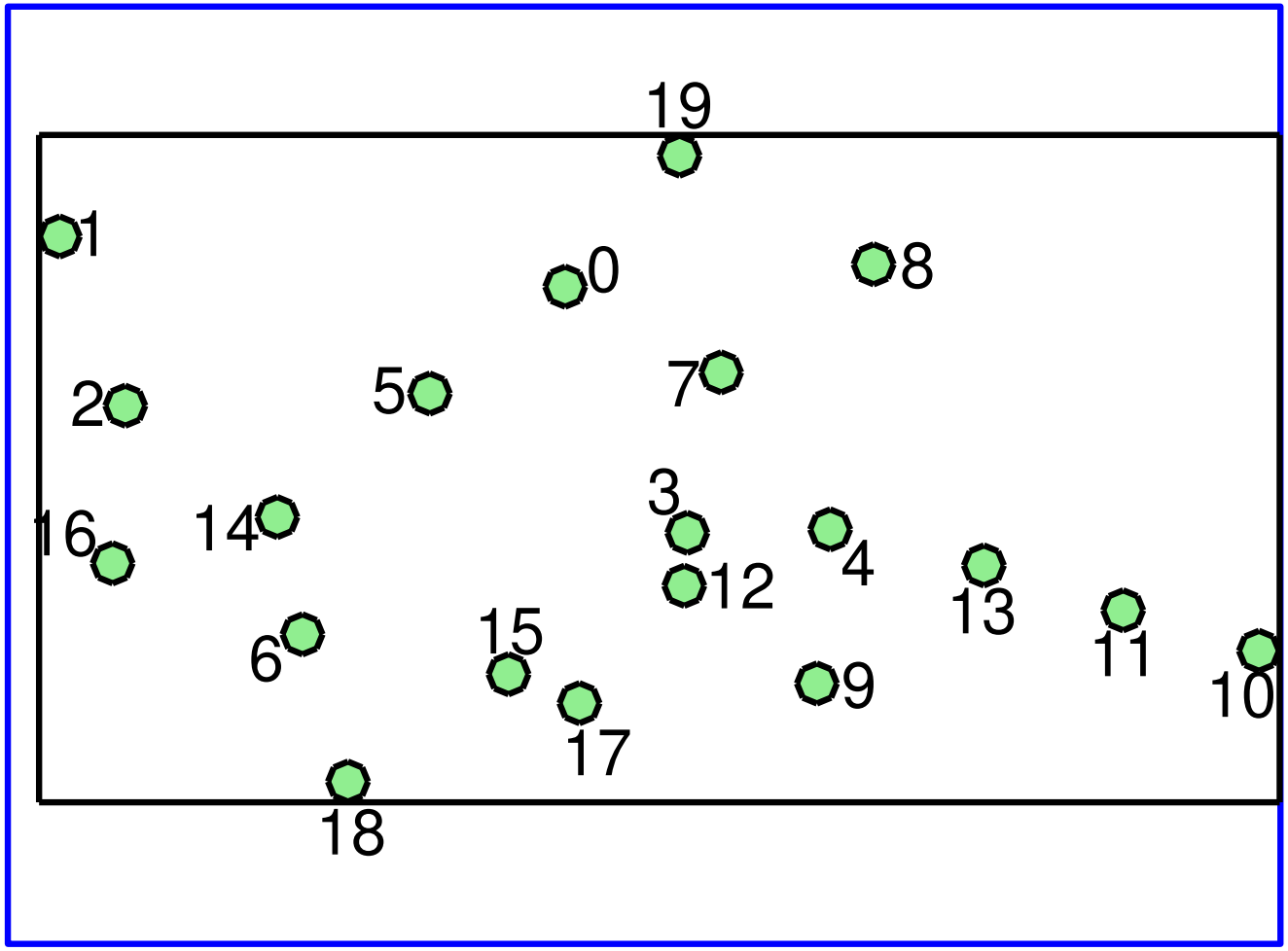
filling **level** 1.0

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

use as input for mesh generator

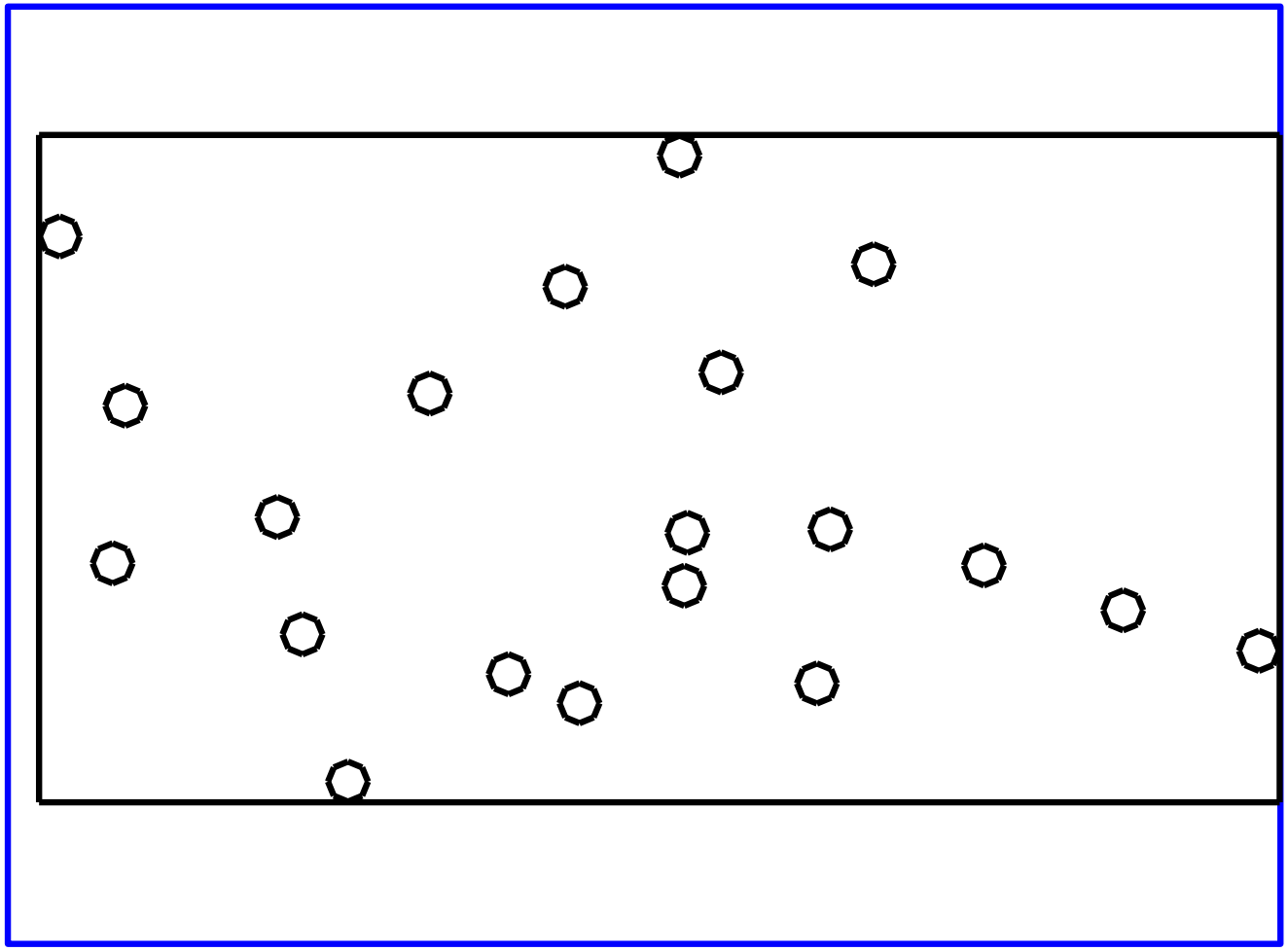
***triangle*** [J. R. Shewchuk]

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**



graph **with edges**

$Q_N = 20$, $Q_R = 45$

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use as input for mesh generator

***triangle*** [J. R. Shewchuk]

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

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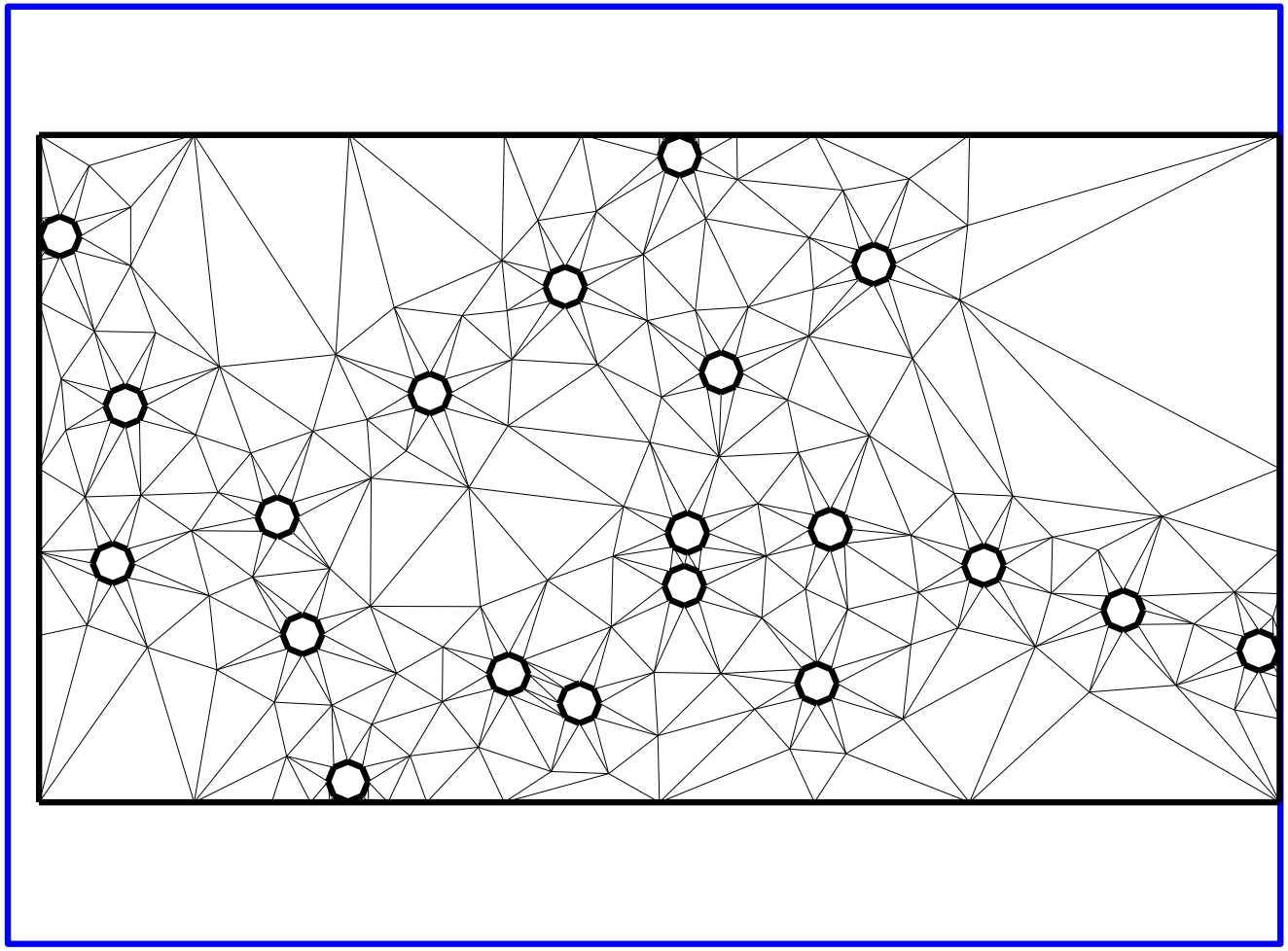

graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

use as input for mesh generator

***triangle*** [J. R. Shewchuk]

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

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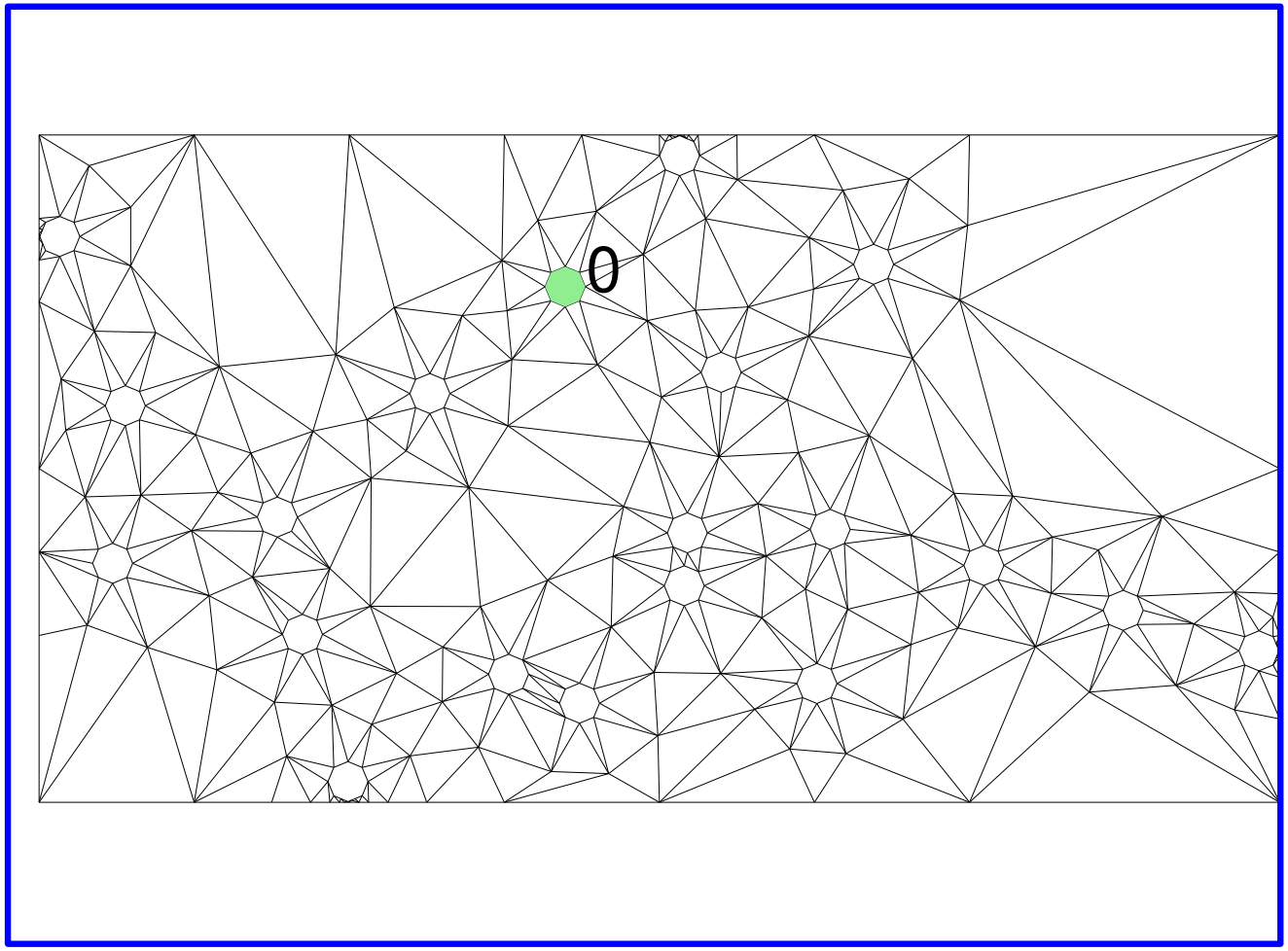


graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

use as input for mesh generator

***triangle*** [J. R. Shewchuk]

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

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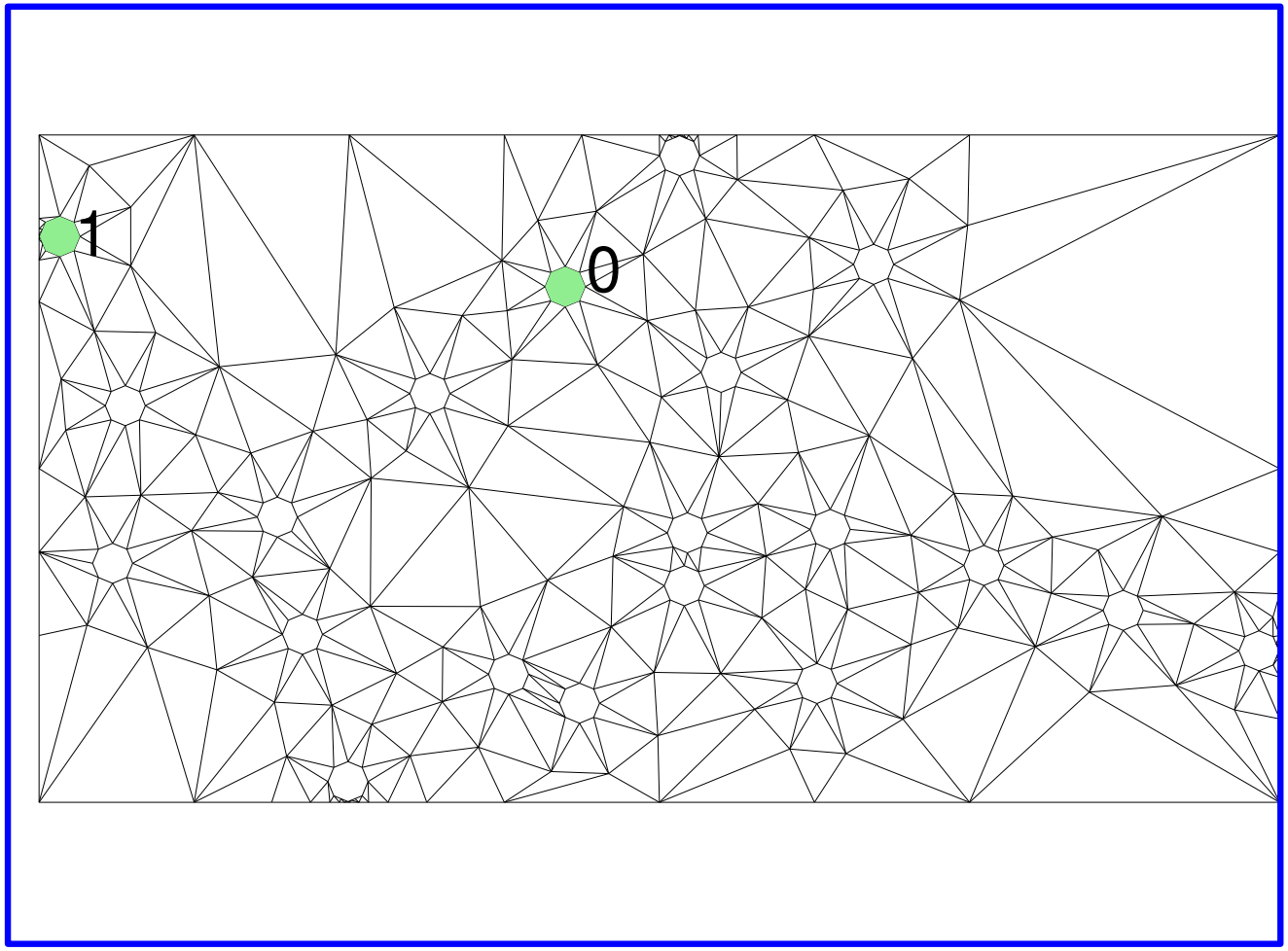


graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

use as input for mesh generator

***triangle*** [J. R. Shewchuk]

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

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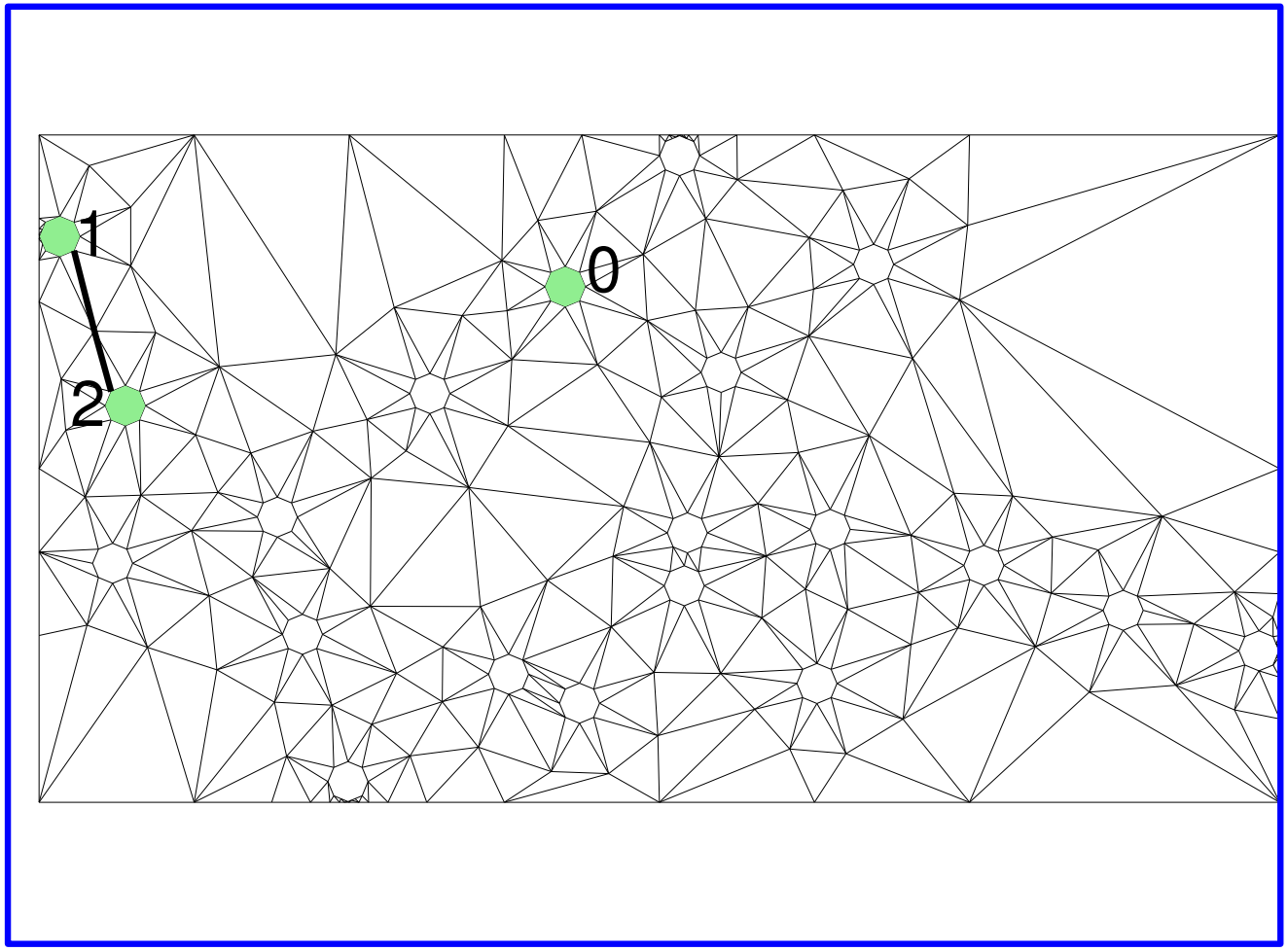


graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

use as input for mesh generator

***triangle*** [J. R. Shewchuk]

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

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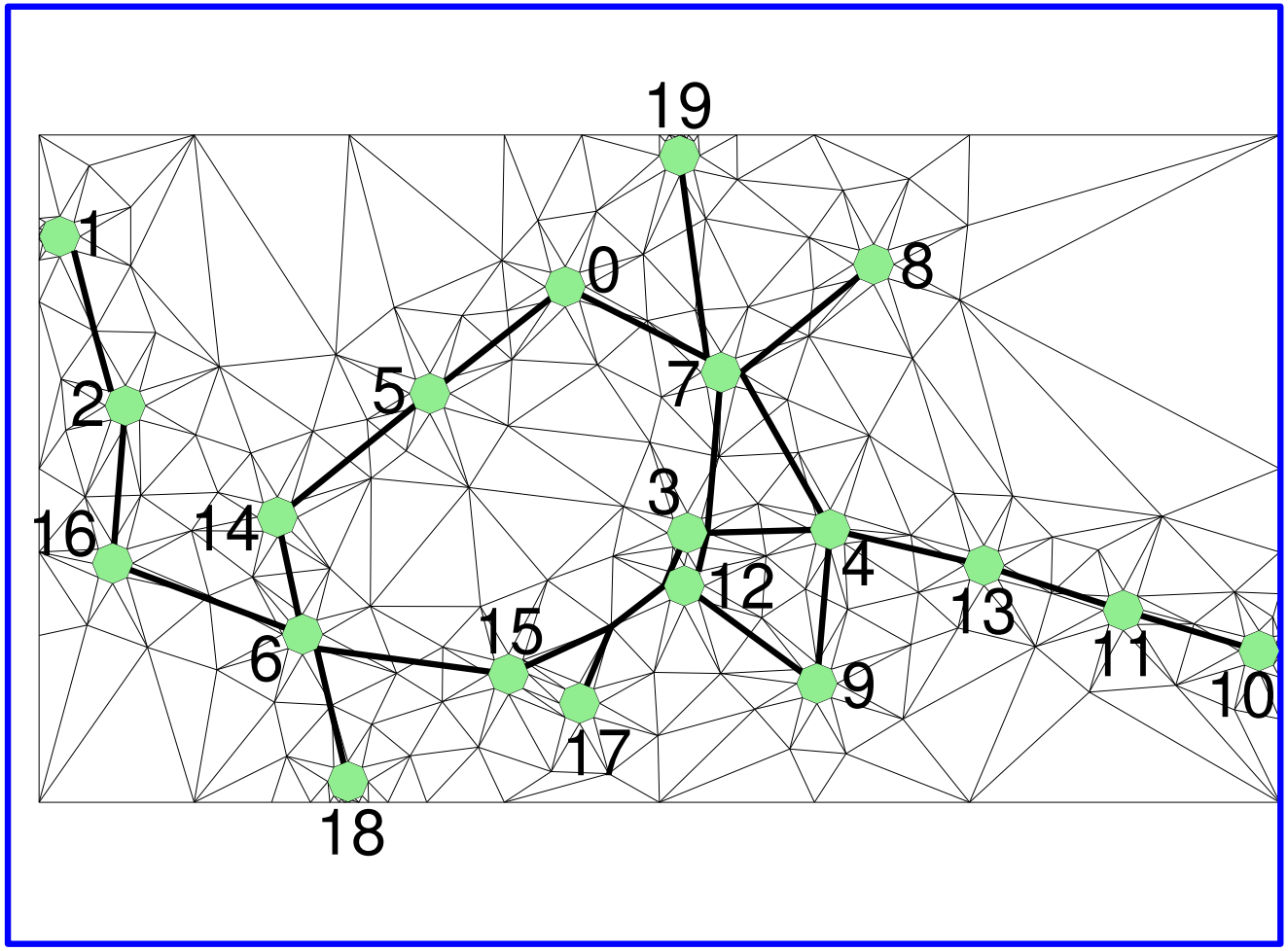


graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

use as input for mesh generator

***triangle*** [J. R. Shewchuk]

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

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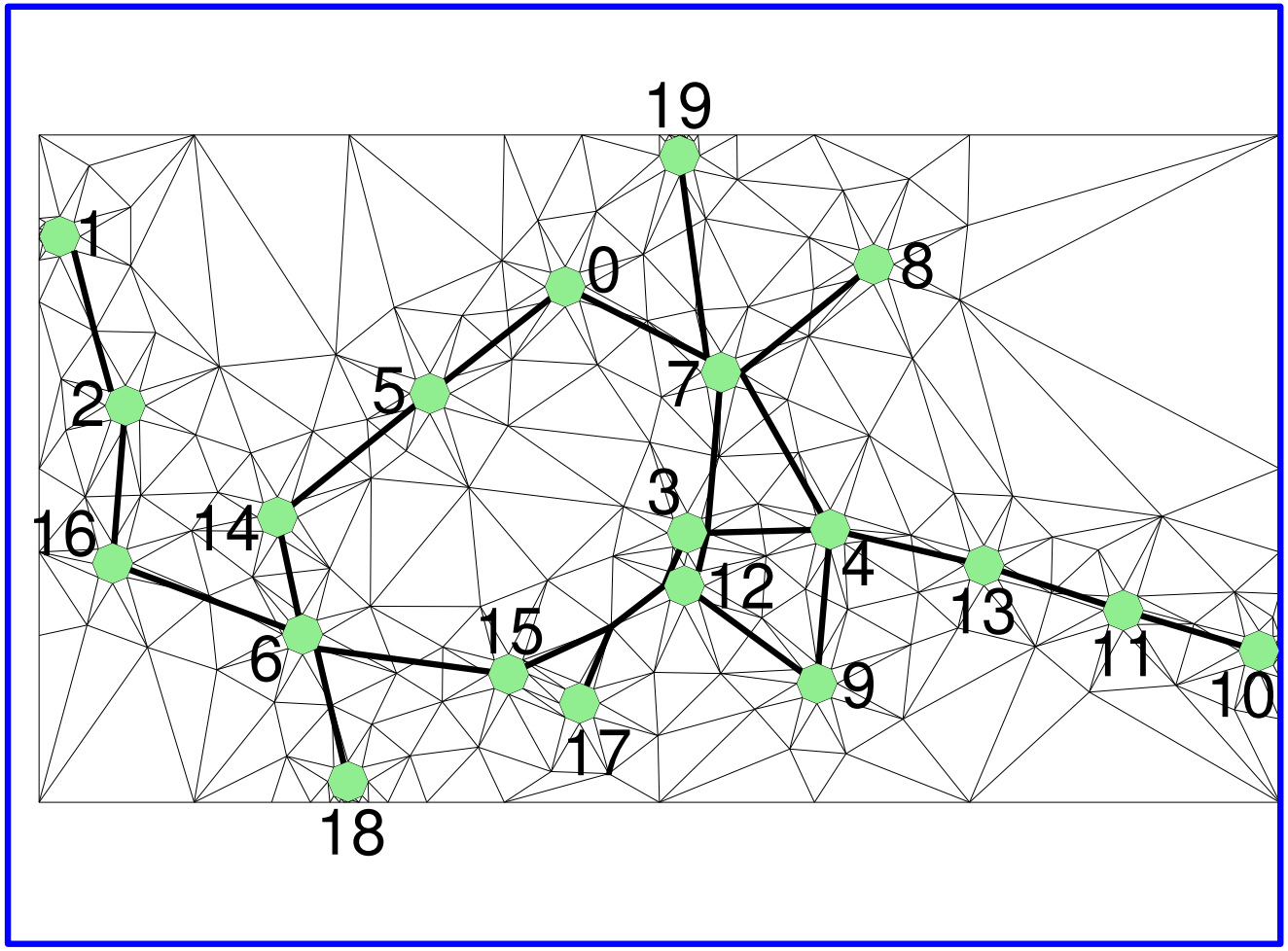



graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

added nodes 0 . . . 19

**all edges in between**

per cell: $\leq$ **20 nodes**,

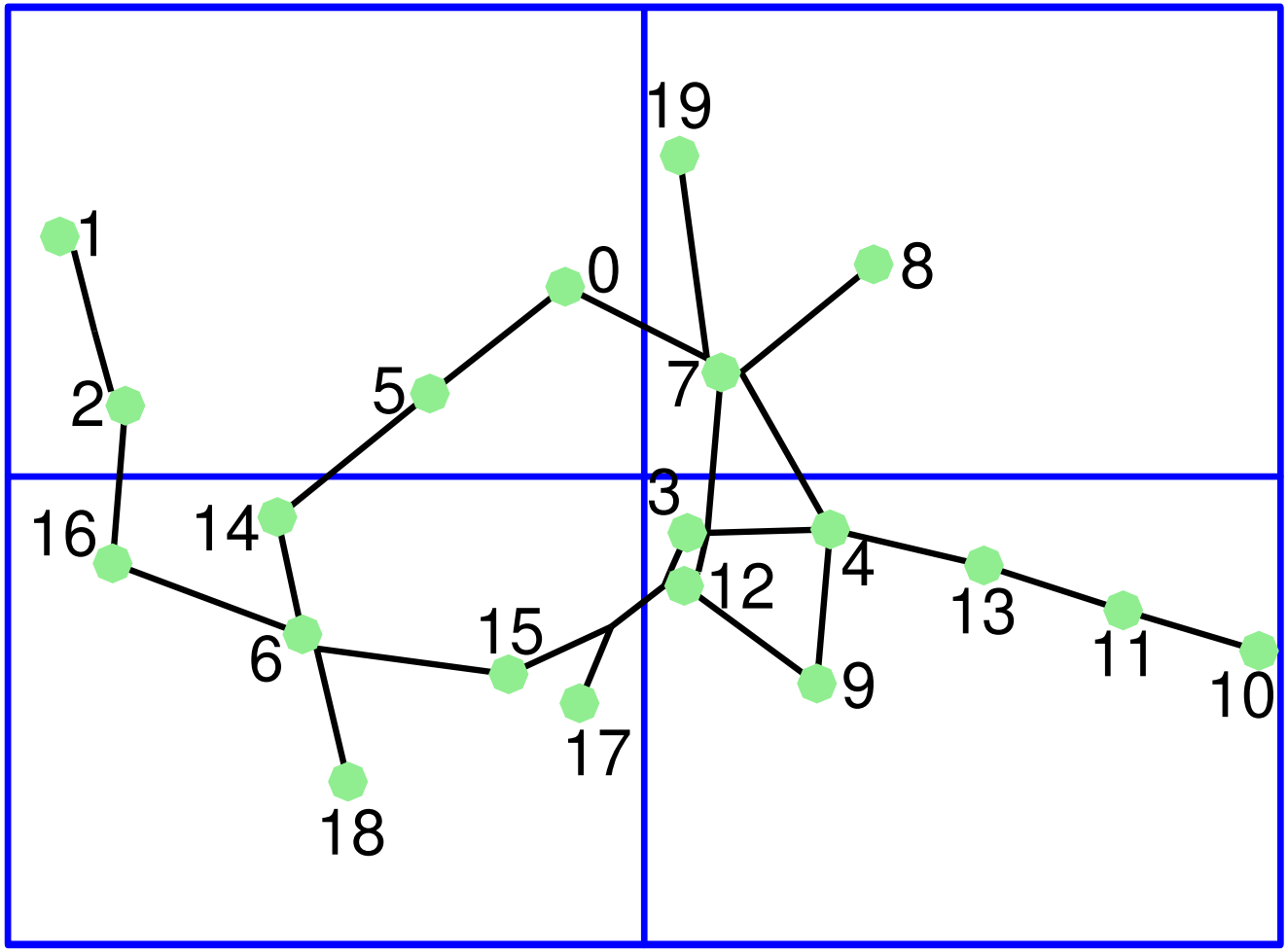
$\leq$ **45 rails**

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 1.0

added nodes 0 . . . 19

**all edges in between**

**subdivide cells**

per cell: $\leq$ **20 nodes**,

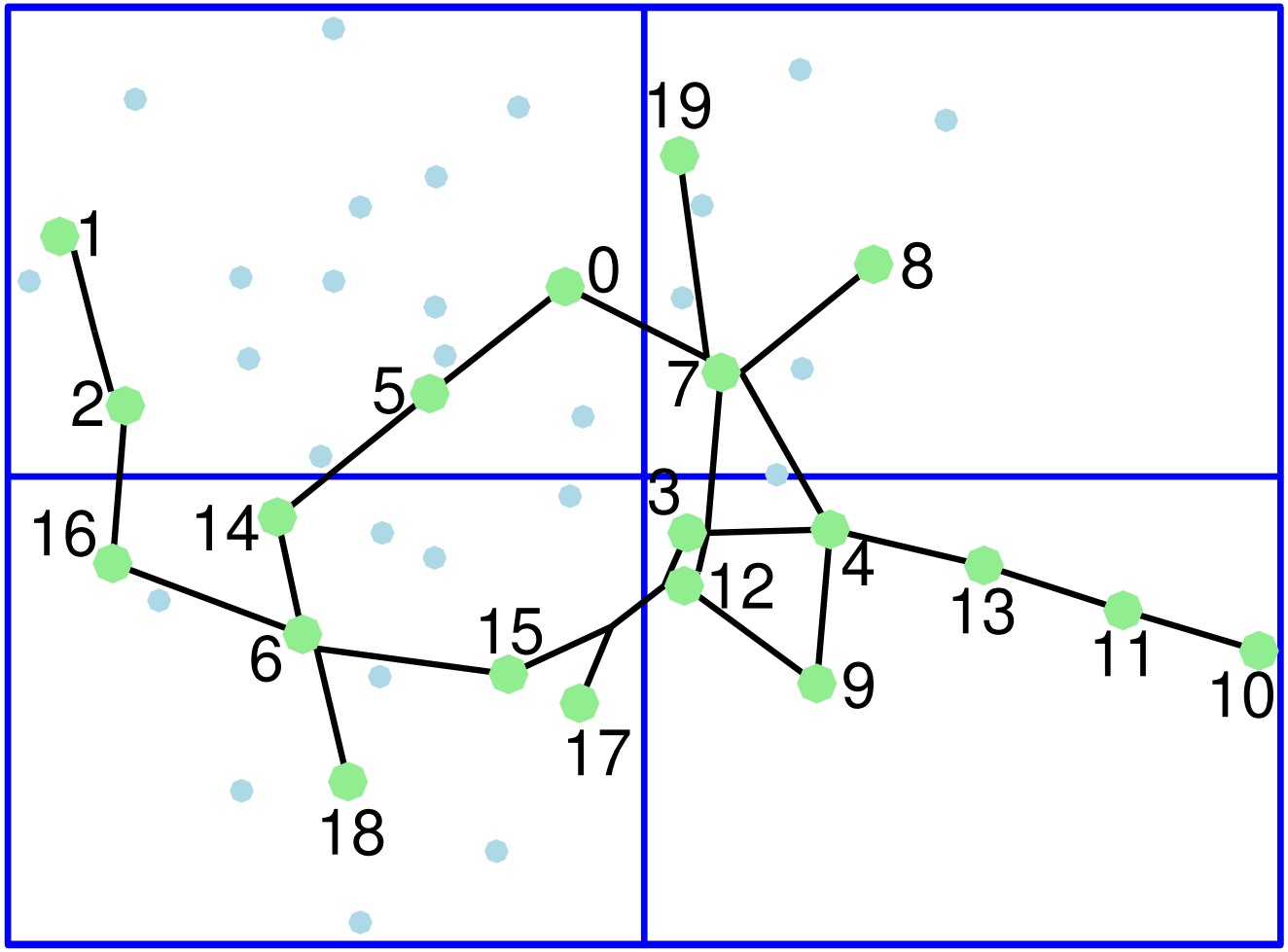
$\leq$ **45 rails**

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 2.0

added nodes 20 . . . 46

**subdivide cells**

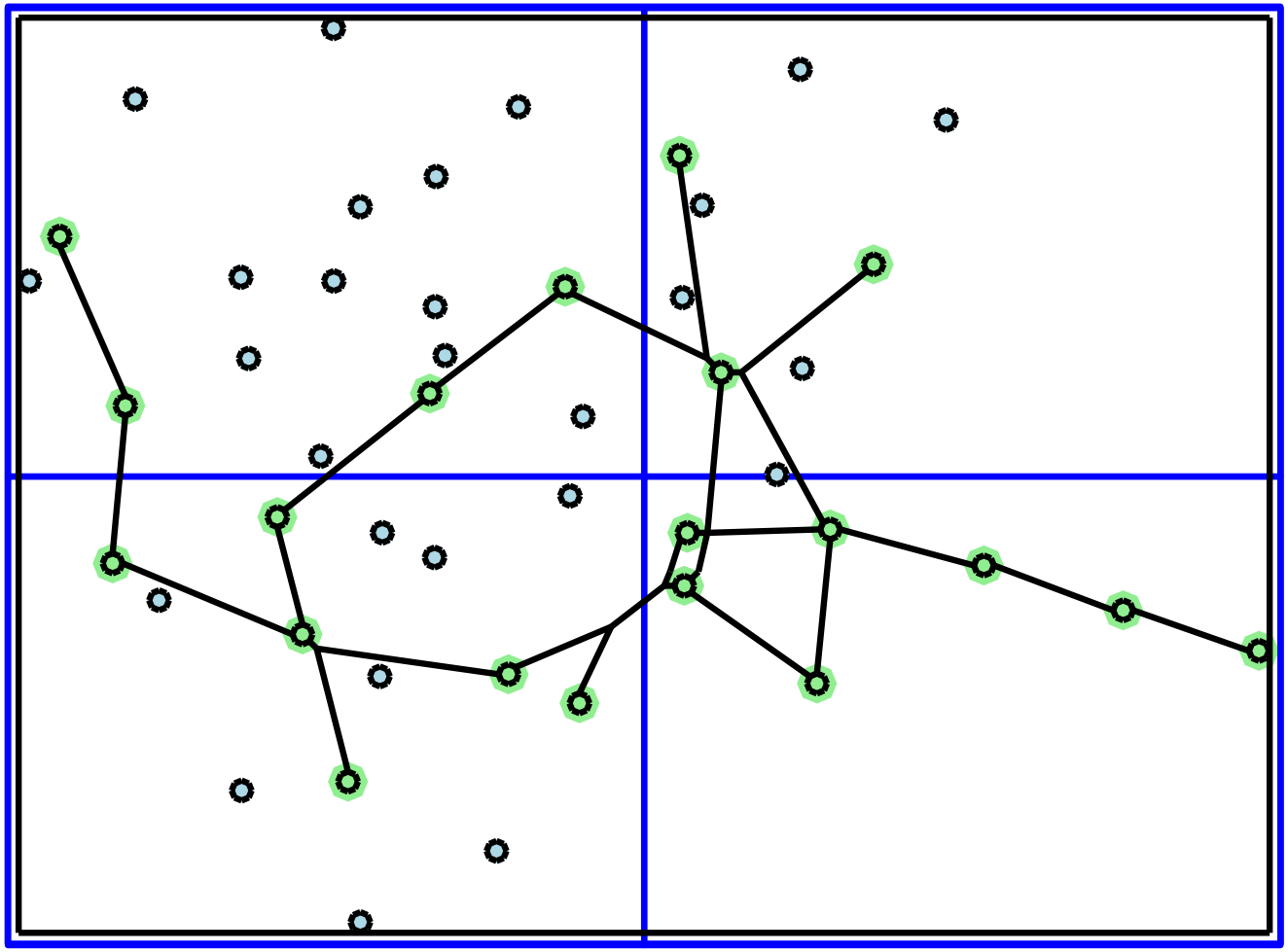
per cell: $\leq$ **20 nodes**,
$\leq$ **45 rails**

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**



graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 2.0

added nodes 20 . . . 46

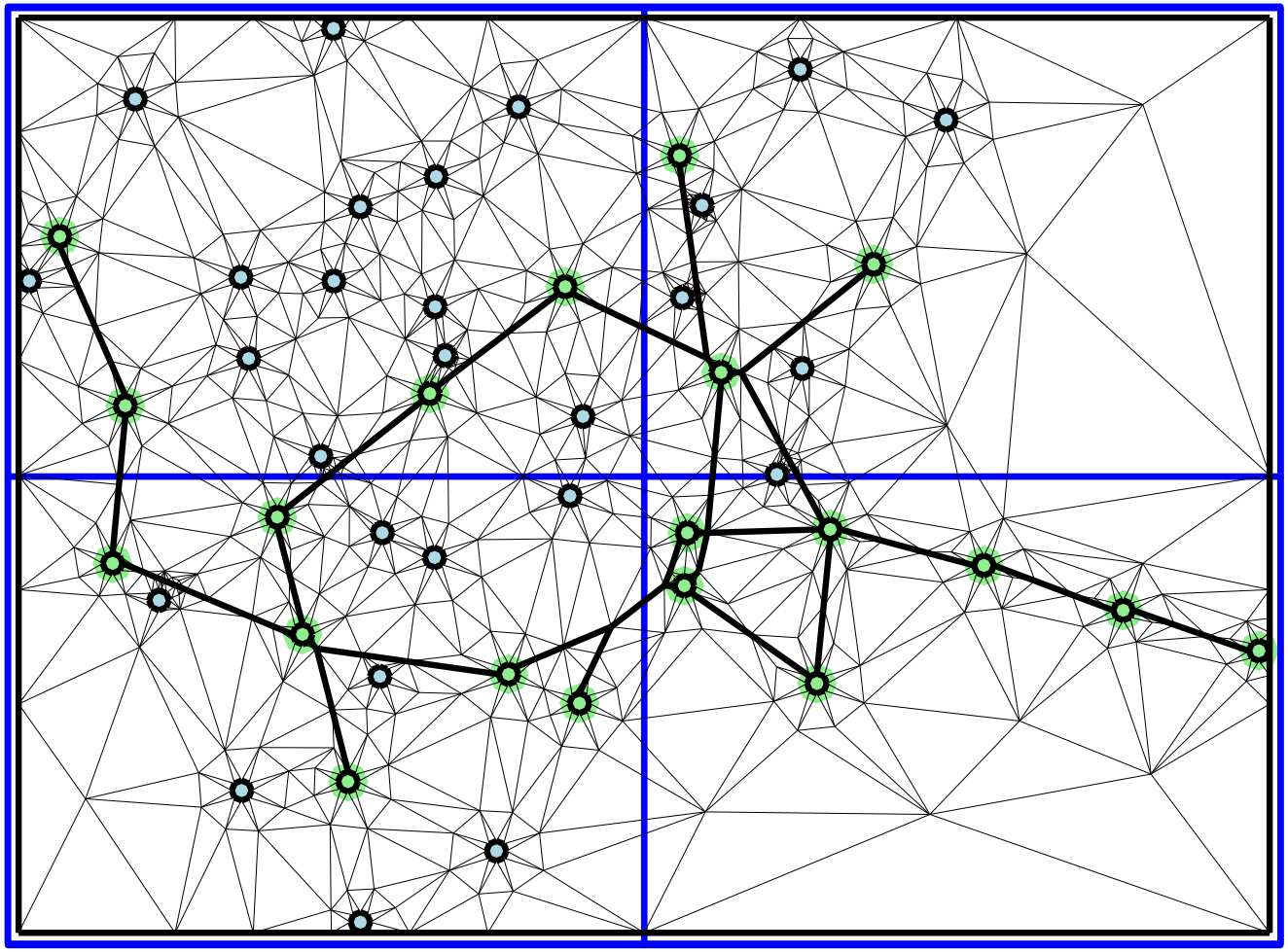
use **added nodes** and **old rails** as input

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**



graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 2.0

added nodes 20 . . . 46

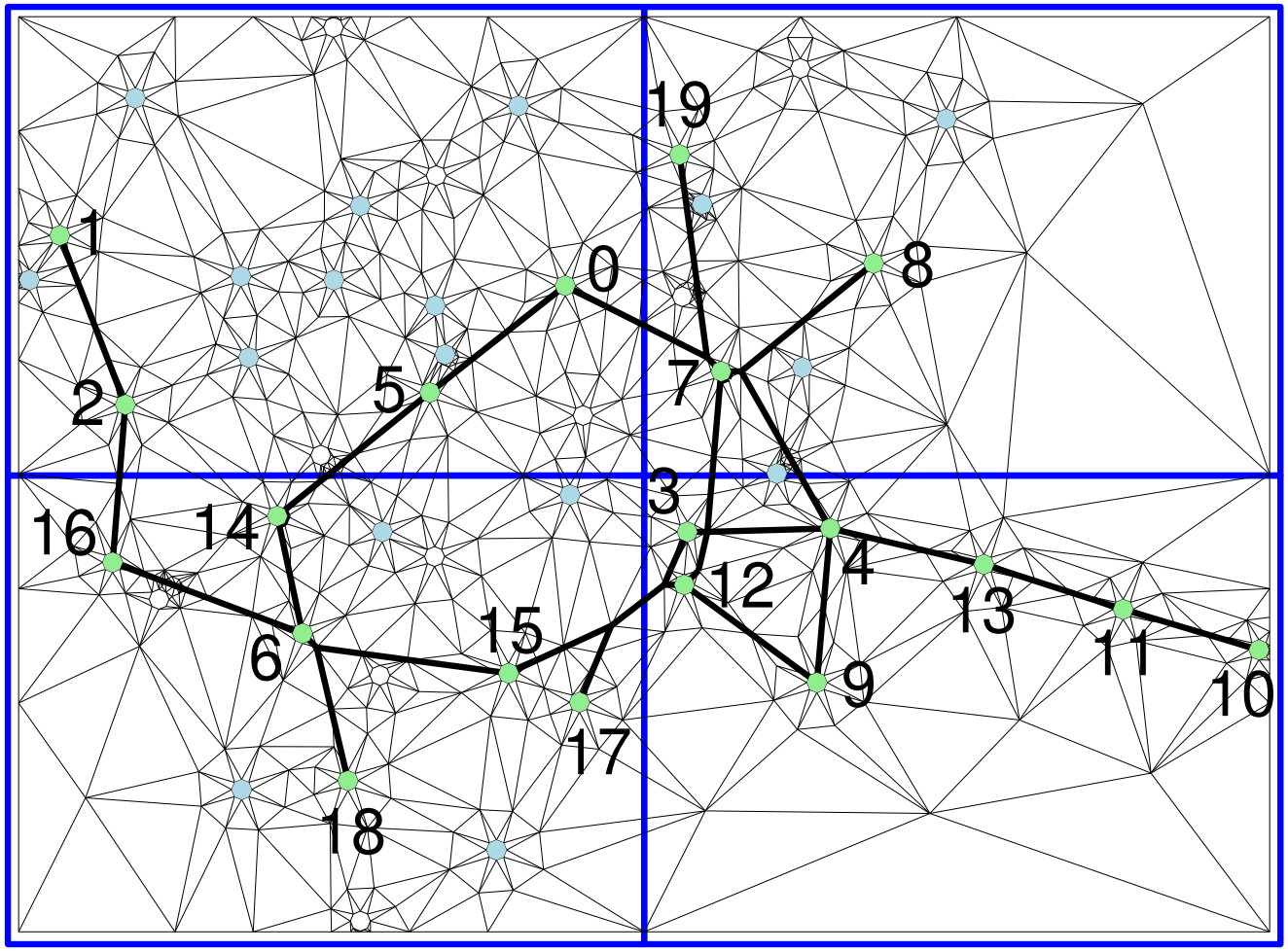
use **added nodes**
and **old rails**
as input

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 2.0

added nodes 0 . . . 36

**all edges in between**

per cell: $\leq$ **20 nodes**,

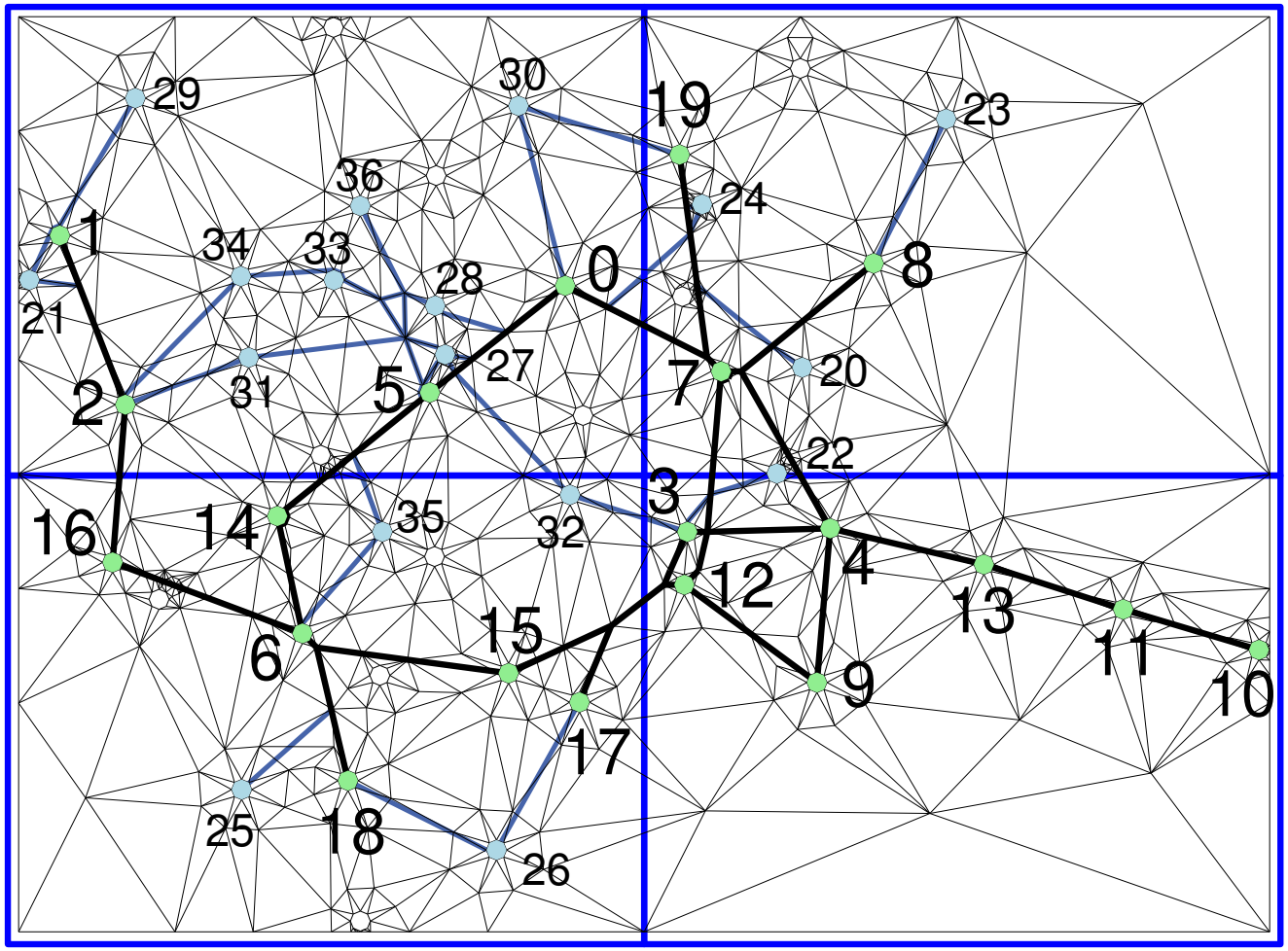
$\leq$ **45 rails**

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

③ preserve **mental map** of the user ④ limit **clutter** and **complexity**

maintain **node quota** $Q_N$ and **rail quota** $Q_R$ in each **cell**




graph **with edges**

$Q_N = 20$, $Q_R = 45$

filling **level** 2.0

added nodes 0 . . . 36

**all edges in between**

per cell: $\leq$ **20 nodes**,

$\leq$ **45 rails**

# Method description: **zoom level** assignment with **rails**

① no restriction on input graphs ② overview through **zoom** and **pan**

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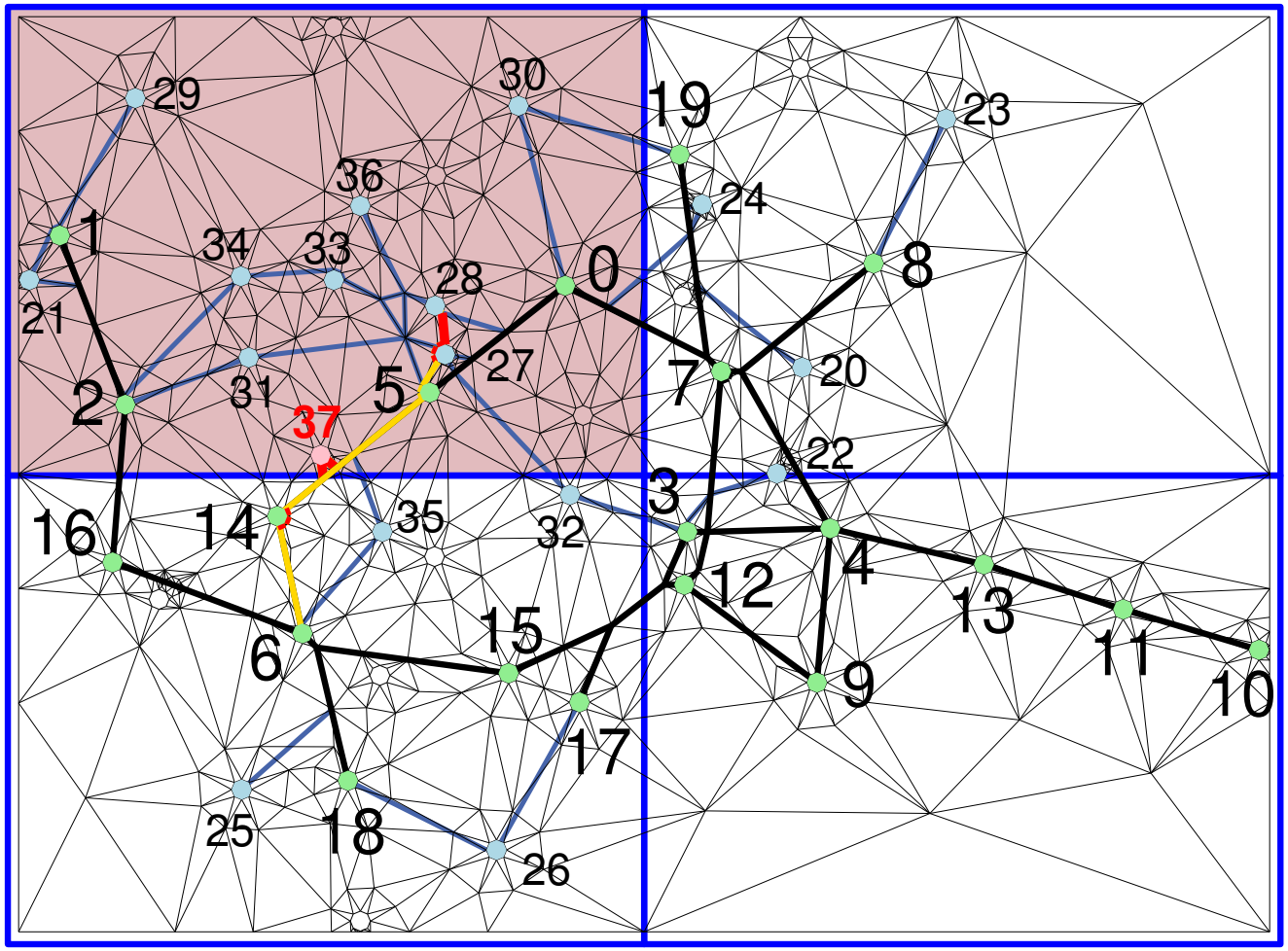


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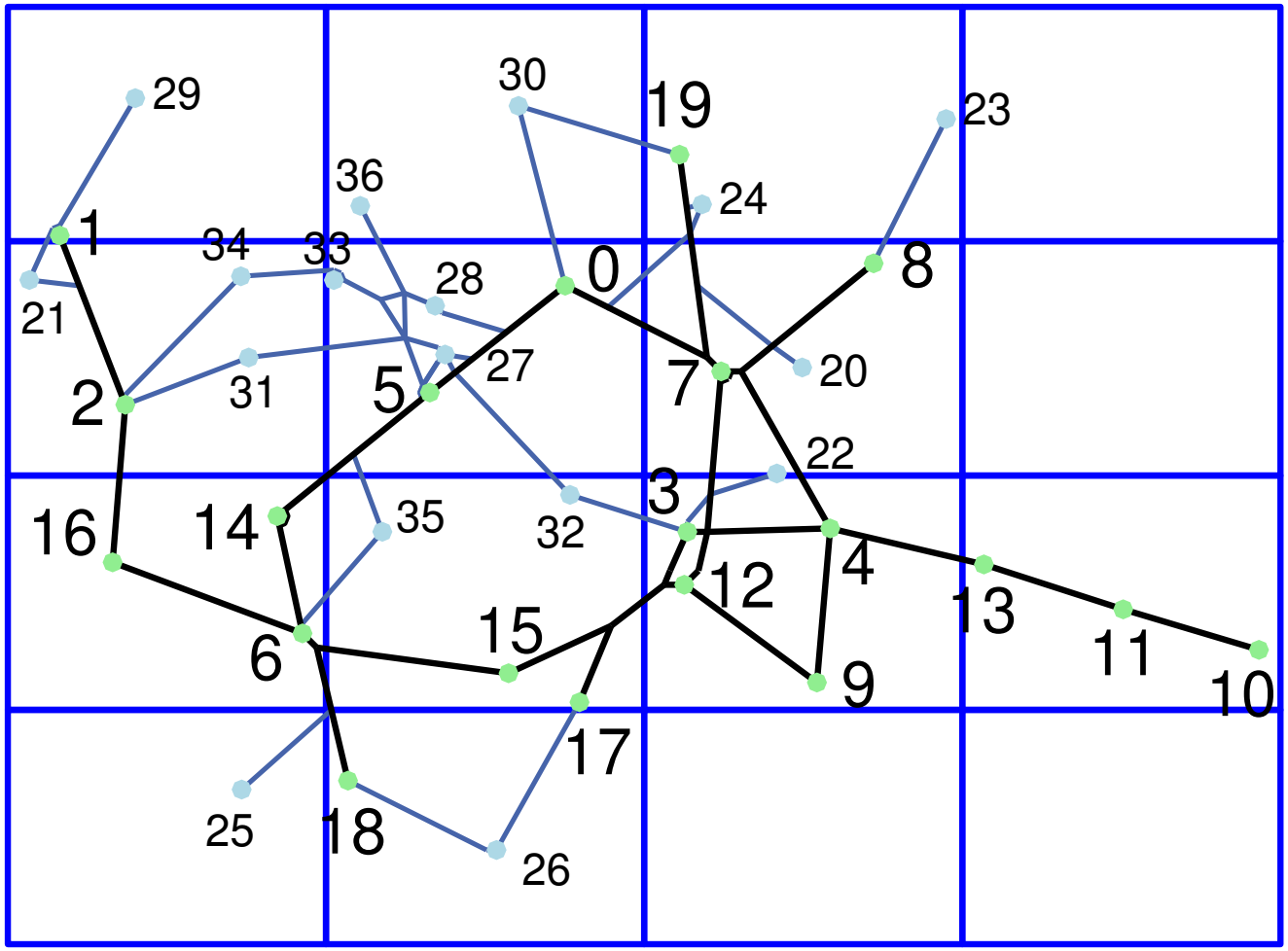


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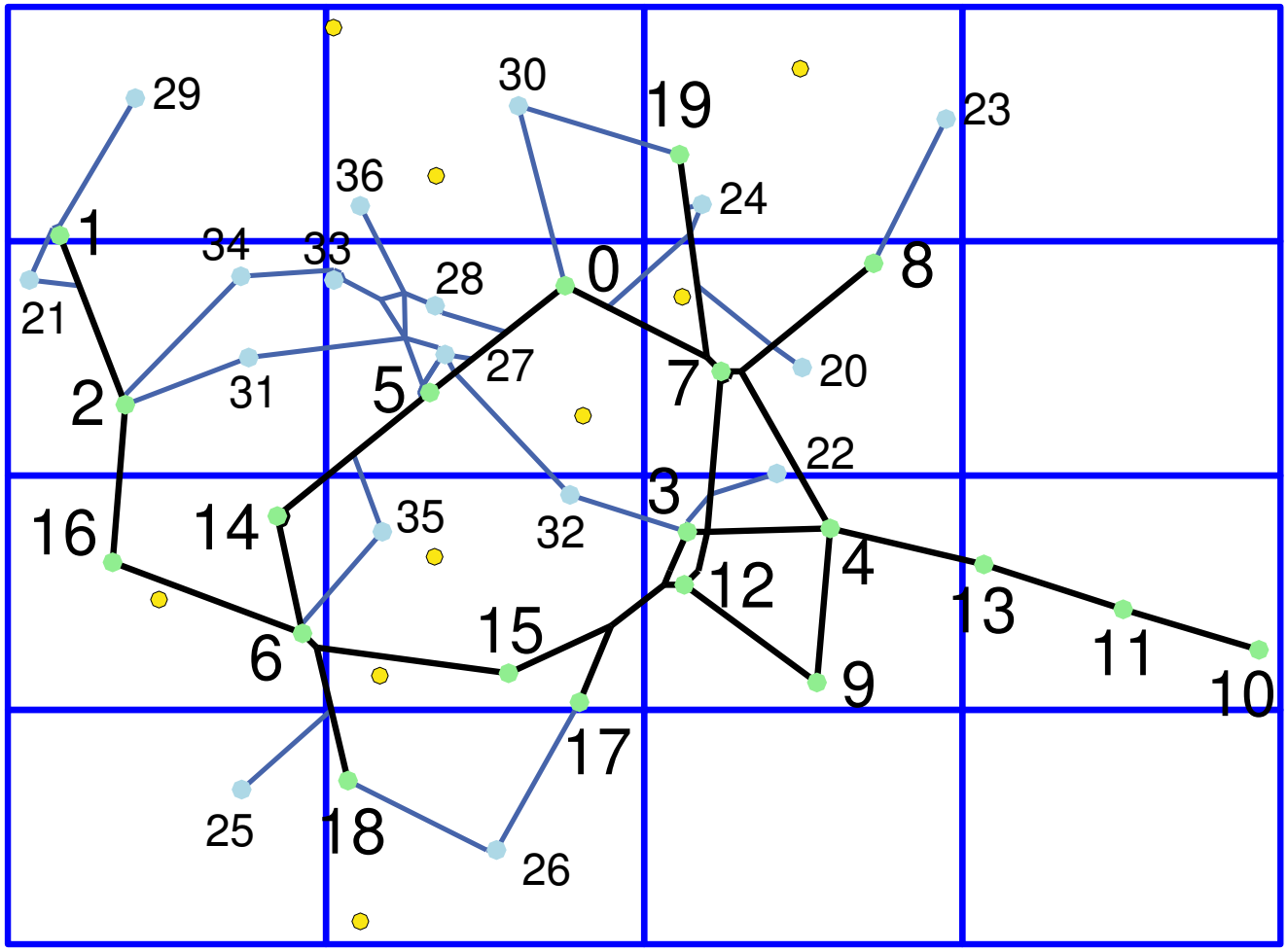


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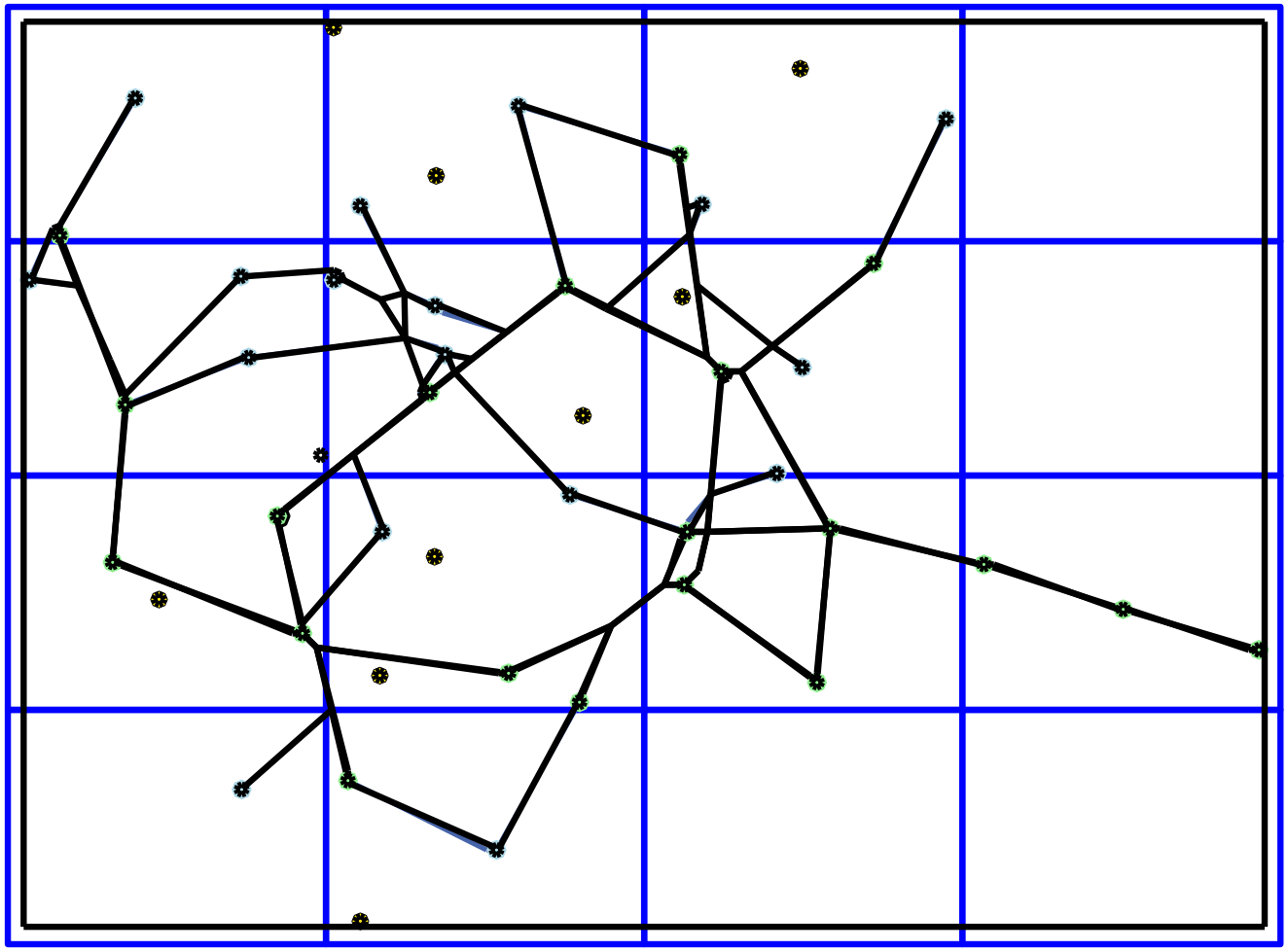

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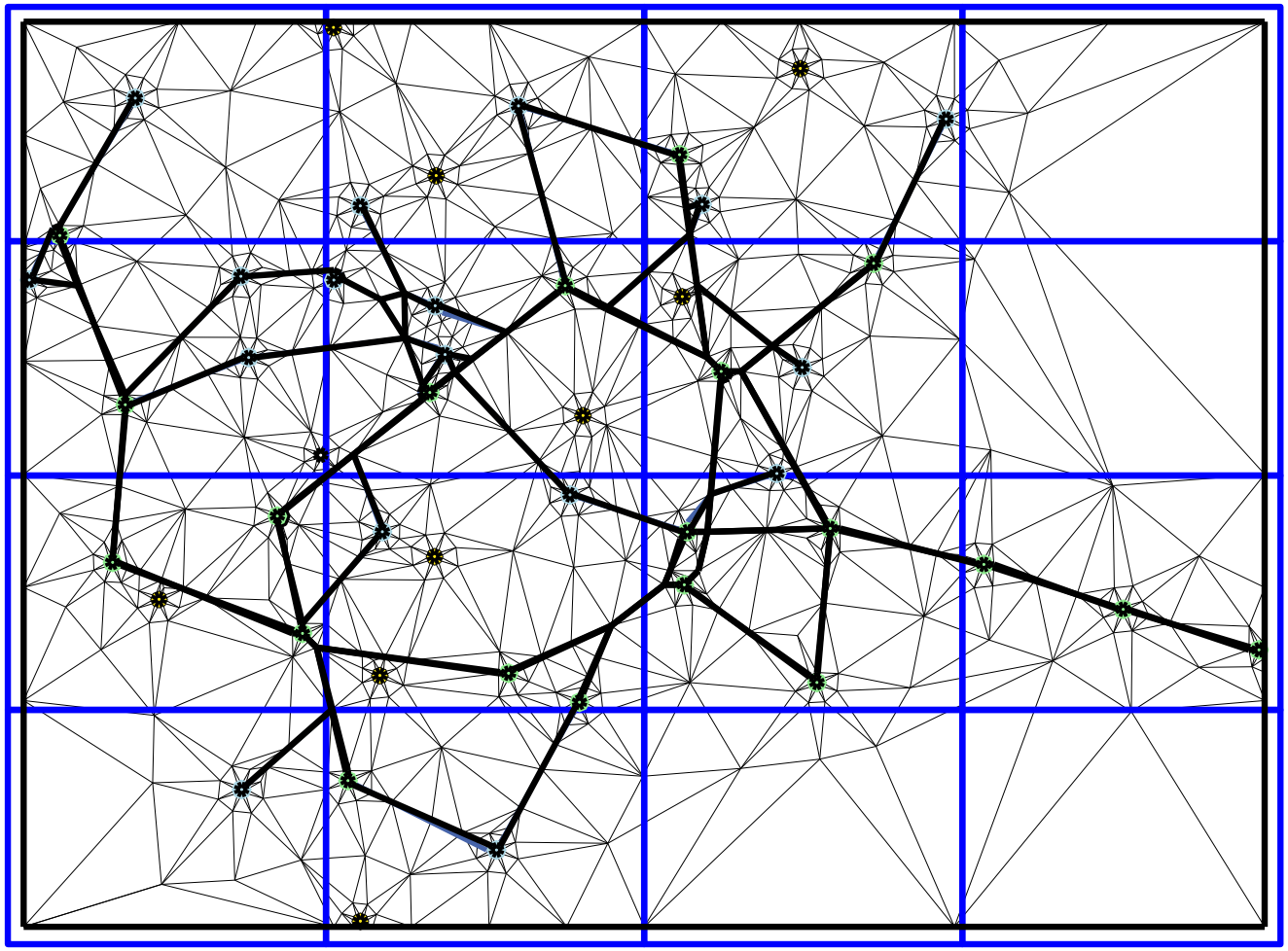

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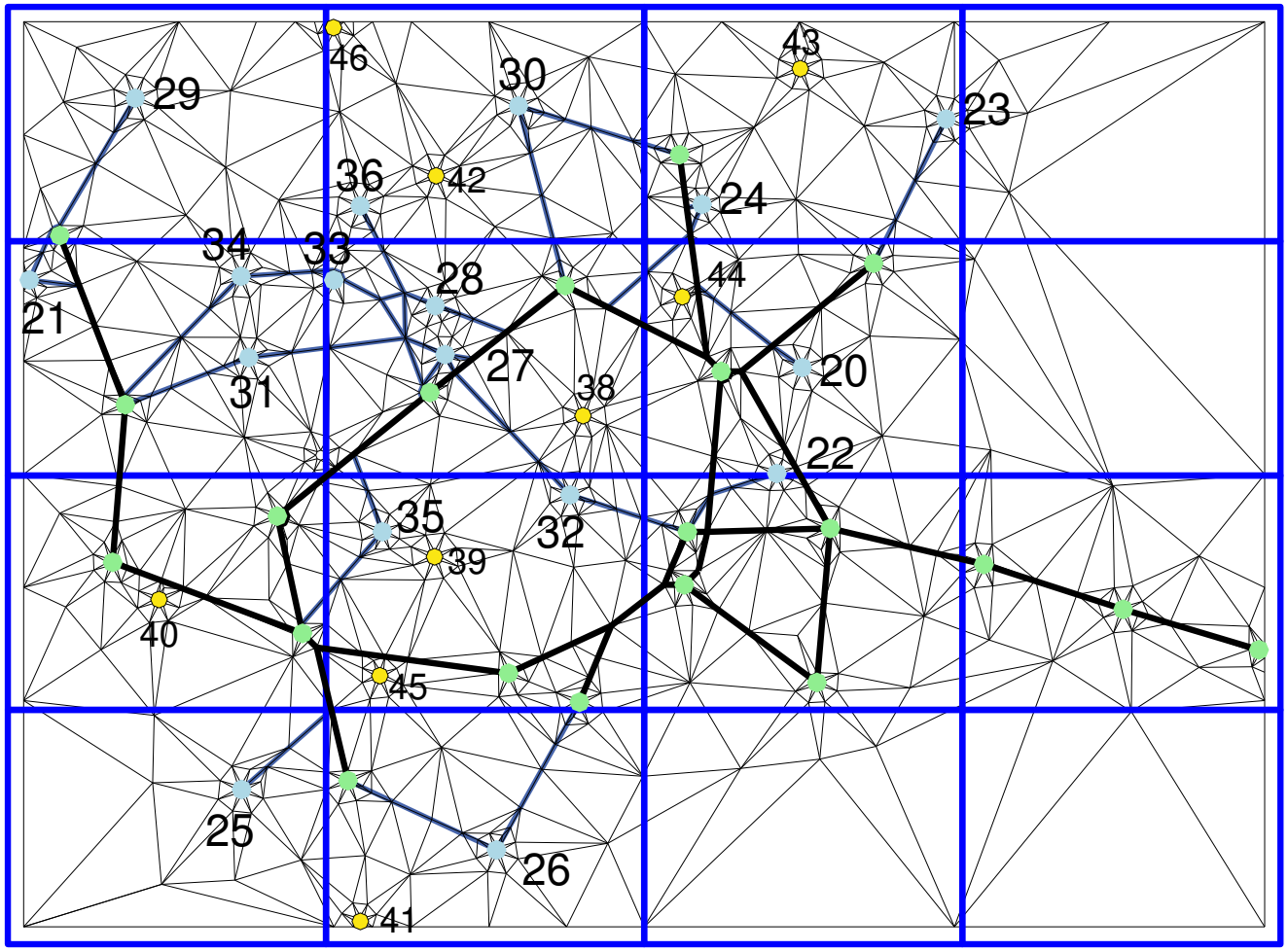


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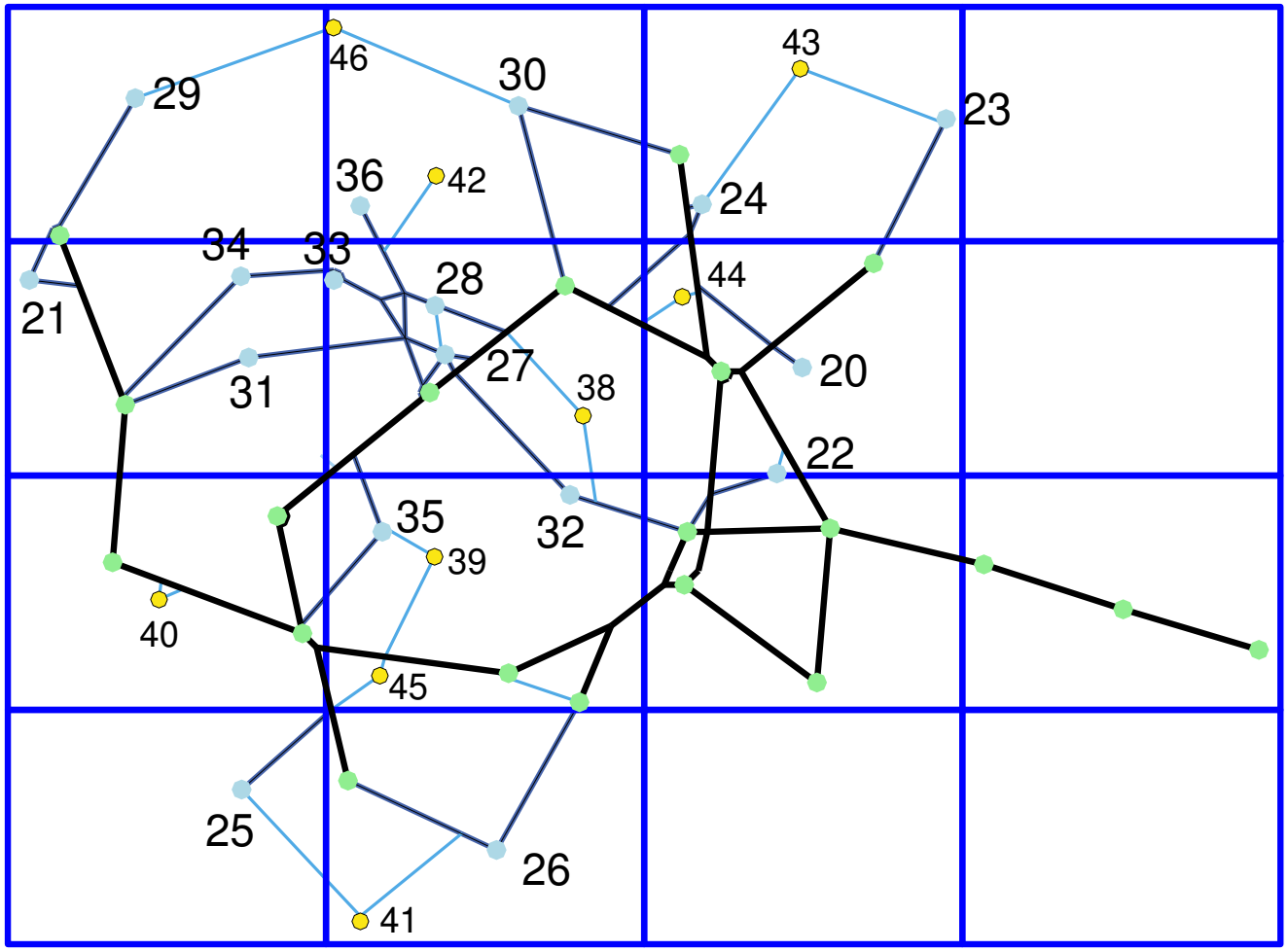


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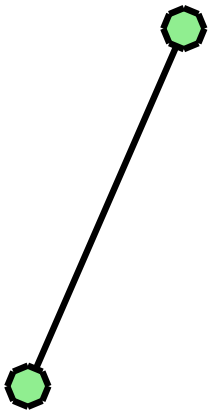
# More details

remove overlaps



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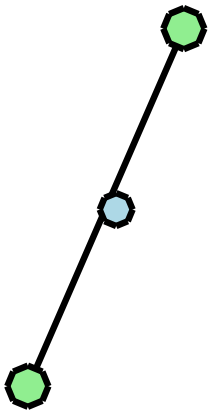

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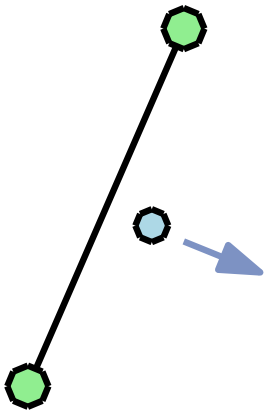

# More details

remove overlaps

pre-rendered bitmap tiles for orientation

# More details

remove overlaps

pre-rendered bitmap tiles for orientation

node labeling

# More details

remove overlaps

pre-rendered bitmap tiles for orientation

node labeling

interactions

# More details: see paper

remove overlaps

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# Conclusion

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- provide a familiar browsing experience
- preserve mental map
- bounds on number of visible objects
- scalability, reduced clutter

part of **MSAGL**, available at
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## Future work

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ask **Debajyoti Mondal**
and **Lev Nachmanson**