Julius-Maximilians-UNIVERSITÄT WÜRZBURG

Chair for INFORMATICS I
Efficient Algorithms and Knowledge-Based Systems

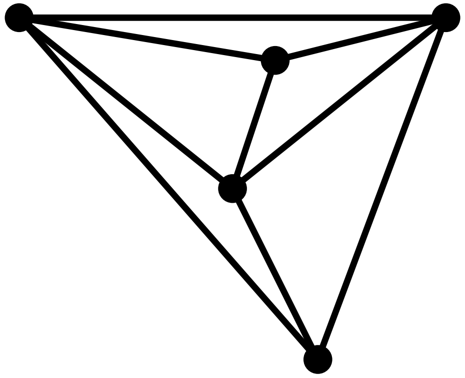
Institute for Informatics

Compact Drawings of 1-Planar Graphs with Right-Angle Crossings and Few Bends

Steven Chaplick, Fabian Lipp,
Alexander Wolff, and **Johannes Zink**

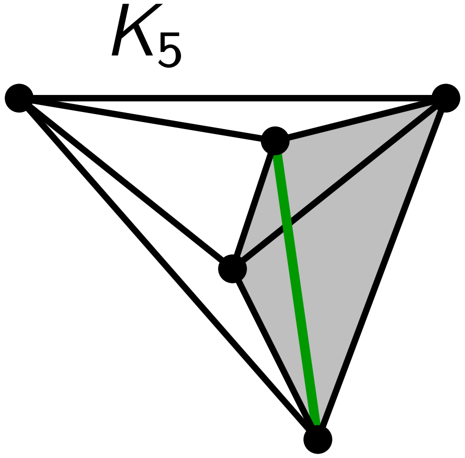
Introduction: Beyond-Planar Graphs

Types of drawings:



Planar: No crossings

Introduction: Beyond-Planar Graphs



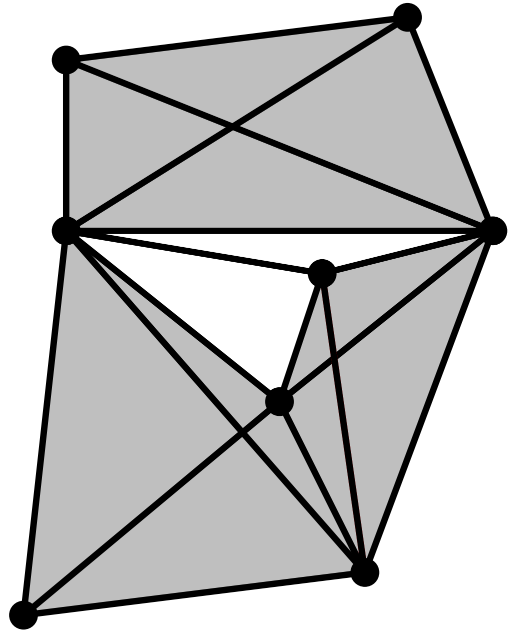
Types of drawings:

1-Planar: ≤ 1 crossings per edge

Planar: No crossings

Introduction: Beyond-Planar Graphs

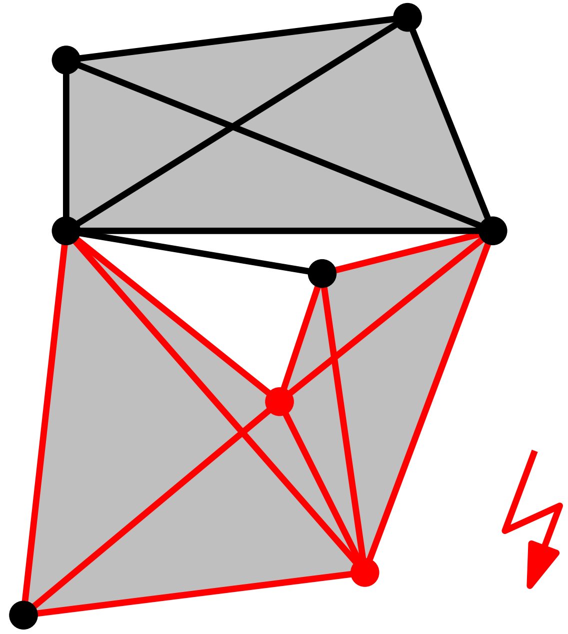
Types of drawings:



1-Planar: ≤ 1 crossings per edge

Planar: No crossings

Introduction: Beyond-Planar Graphs



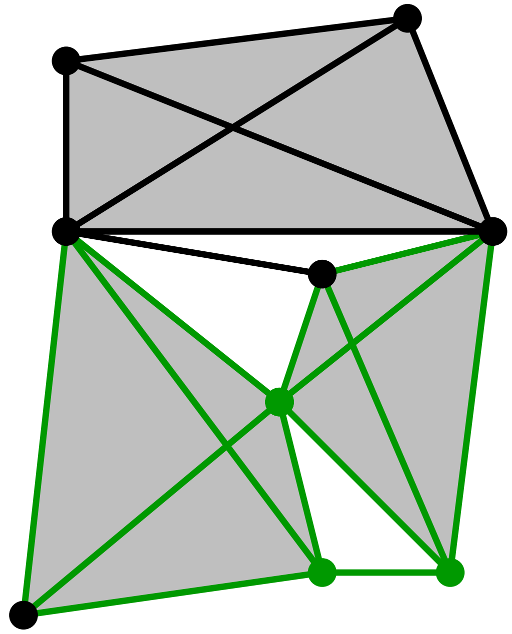
Types of drawings:

1-Planar: ≤ 1 crossings per edge

NIC-Planar: Two crossings share ≤ 1 vertices

Planar: No crossings

Introduction: Beyond-Planar Graphs



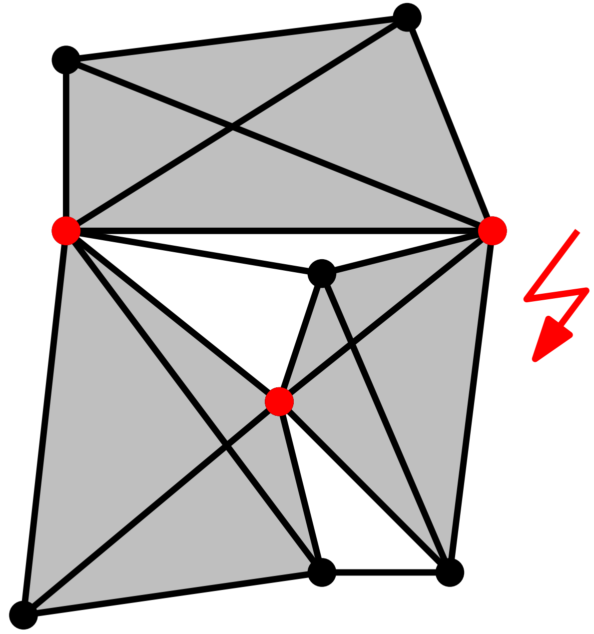
Types of drawings:

1-Planar: ≤ 1 crossings per edge

NIC-Planar: Two crossings share ≤ 1 vertices

Planar: No crossings

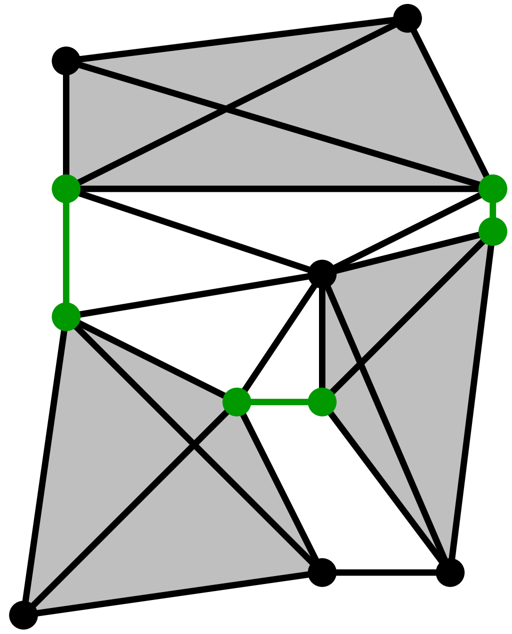
Introduction: Beyond-Planar Graphs



Types of drawings:

1-Planar:	≤ 1 crossings per edge
NIC-Planar:	Two crossings share ≤ 1 vertices
IC-Planar:	Two crossings share no vertices
Planar:	No crossings

Introduction: Beyond-Planar Graphs



Types of drawings:

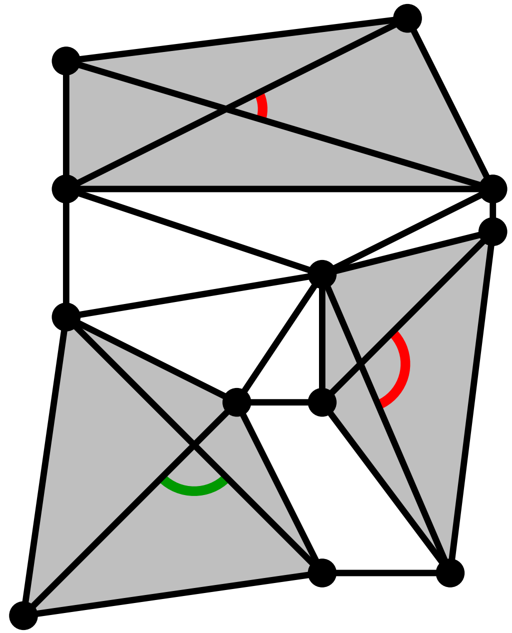
1-Planar: ≤ 1 crossings per edge

NIC-Planar: Two crossings share ≤ 1 vertices

IC-Planar: Two crossings share no vertices

Planar: No crossings

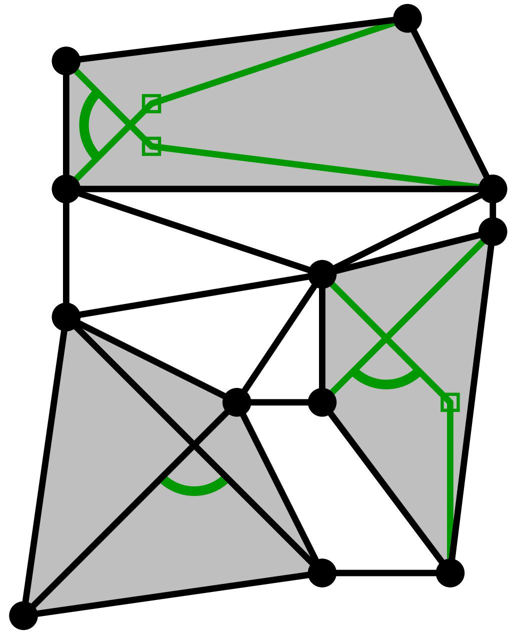
Introduction: Beyond-Planar Graphs



Types of drawings:

1-Planar:	≤ 1 crossings per edge
NIC-Planar:	Two crossings share ≤ 1 vertices
IC-Planar:	Two crossings share no vertices
Planar:	No crossings
RAC:	Right angle crossings

Introduction: Beyond-Planar Graphs

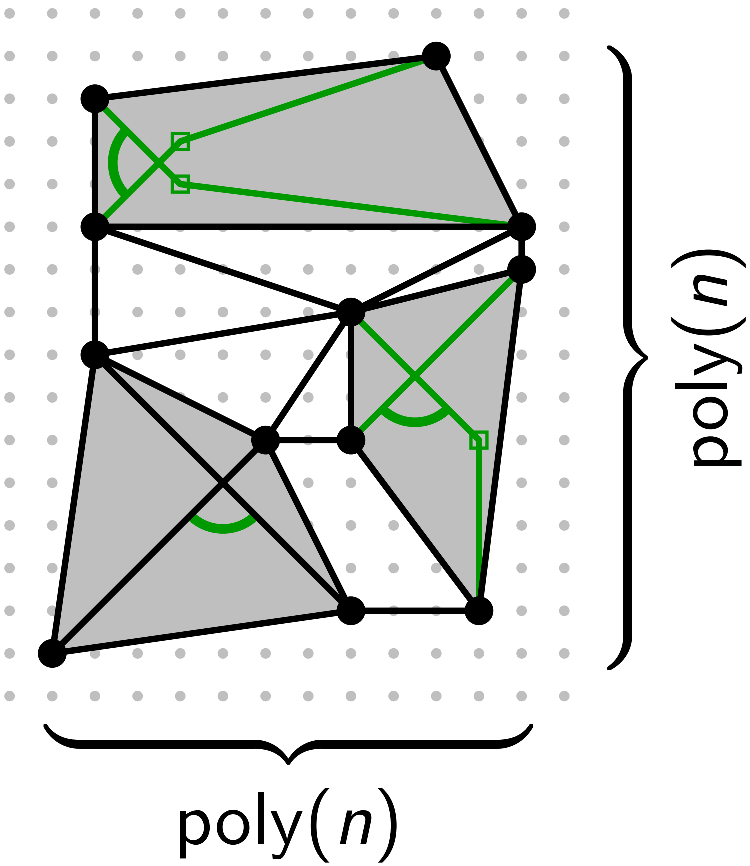


Types of drawings:

1-Planar:	≤ 1 crossings per edge
NIC-Planar:	Two crossings share ≤ 1 vertices
IC-Planar:	Two crossings share no vertices
Planar:	No crossings
RAC:	Right angle crossings

RAC$_k$: with $\leq k$ bends per edge
RAC$_0$: with straight-line edges

Introduction: Beyond-Planar Graphs



Types of drawings:

1-Planar: ≤ 1 crossings per edge

NIC-Planar: Two crossings share ≤ 1 vertices

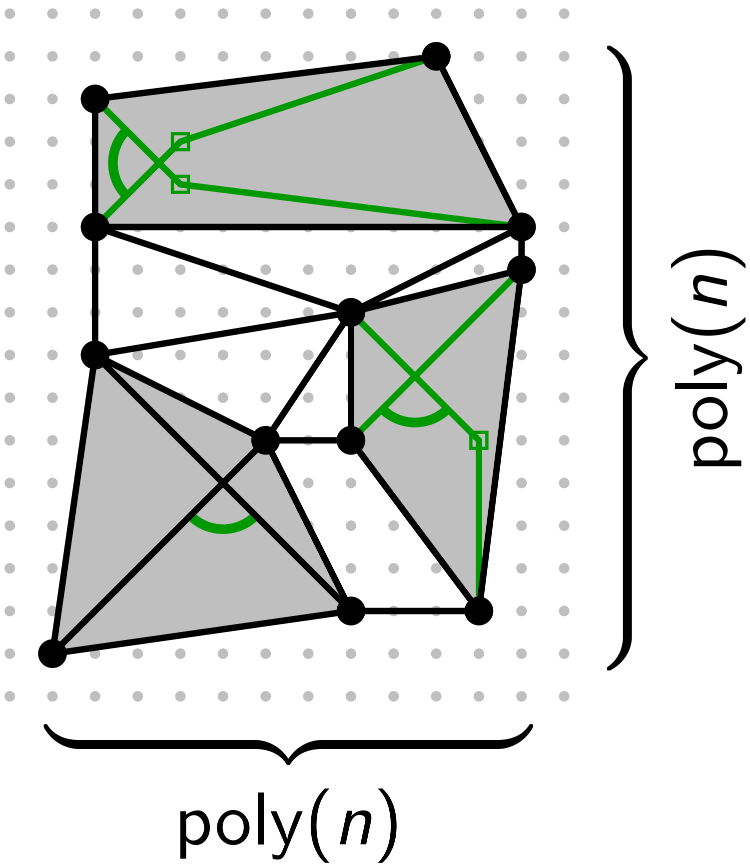
IC-Planar: Two crossings share no vertices

Planar: No crossings

RAC: Right angle crossings

RAC$_k$: with $\leq k$ bends per edge
RAC$_0$: with straight-line edges
RAC$^{\text{poly}}$: in polynomial area

Introduction: Beyond-Planar Graphs



Types of drawings:

1-Planar: ≤ 1 crossings per edge

$\cup\!\mid$

NIC-Planar: Two crossings share ≤ 1 vertices

$\cup\!\mid$

IC-Planar: Two crossings share no vertices

$\cup\!\mid$

Planar: No crossings

RAC: Right angle crossings

RAC$_k$: with $\leq k$ bends per edge
RAC$_0$: with straight-line edges
RAC$^{\text{poly}}$: in polynomial area

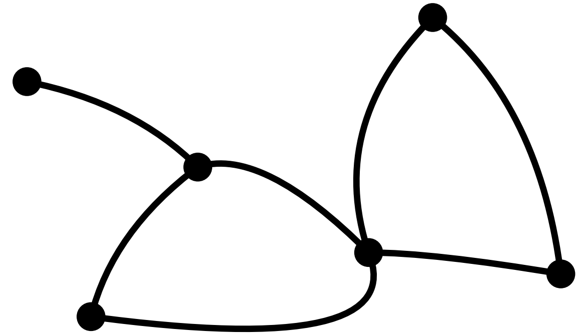
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

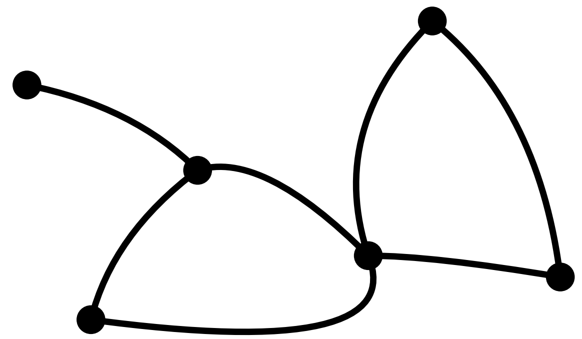


Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.

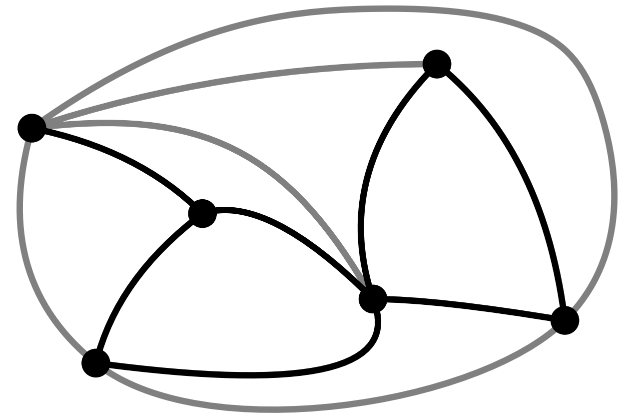


Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.

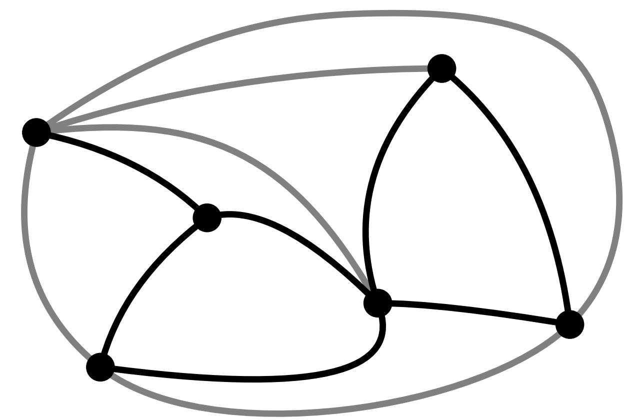


Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \dots, v_n$.

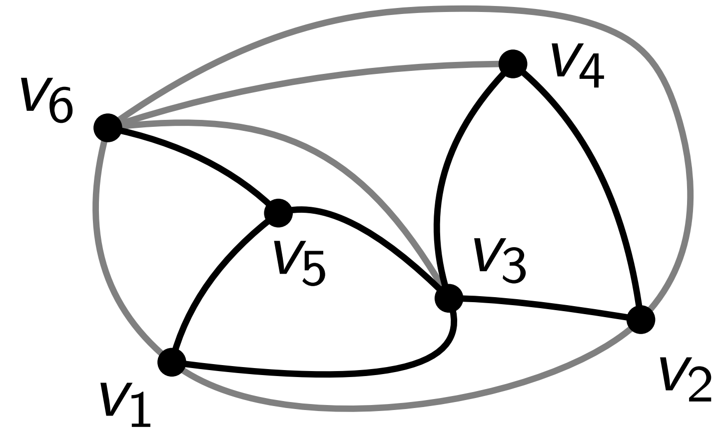


Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.

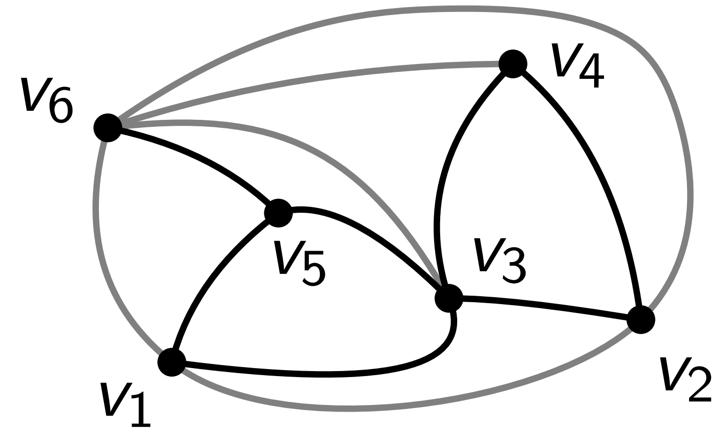


Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:

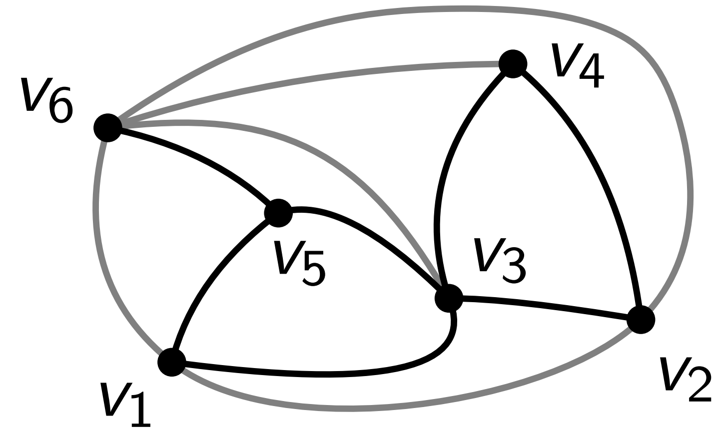


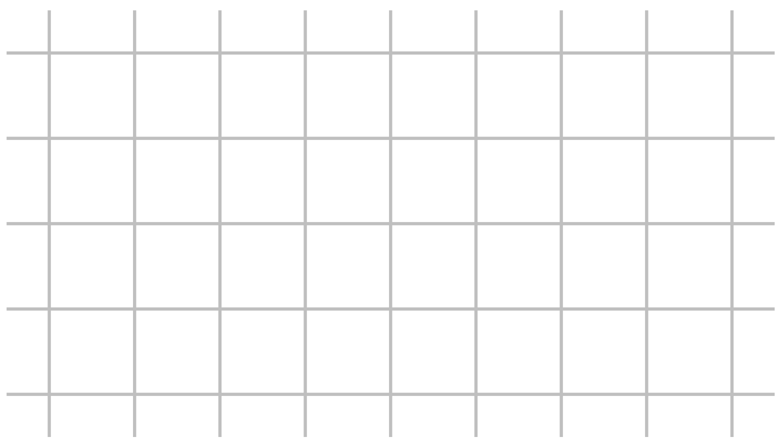
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.



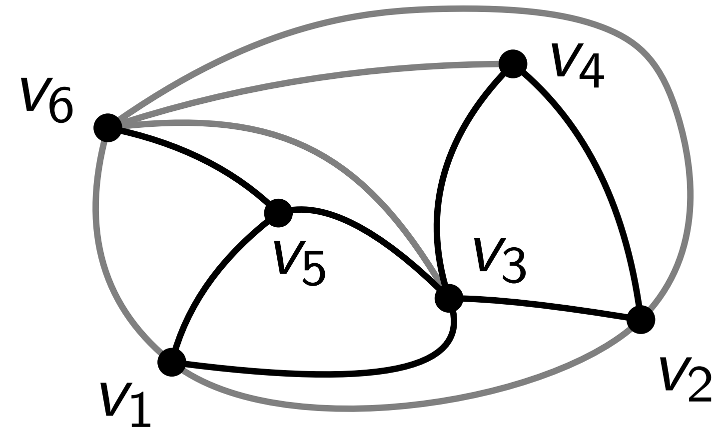


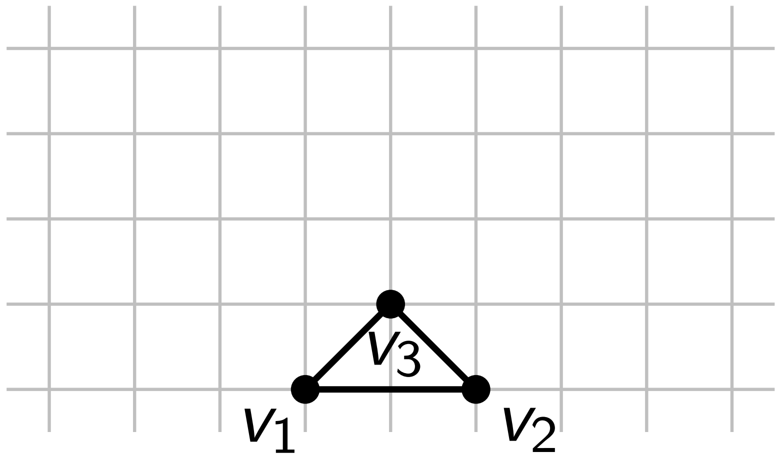
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.



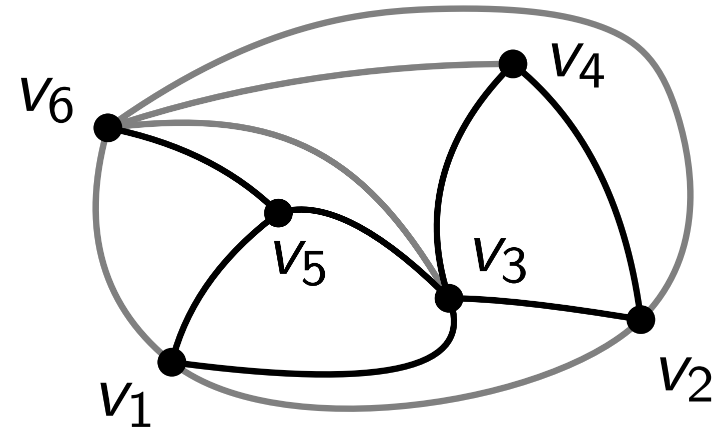


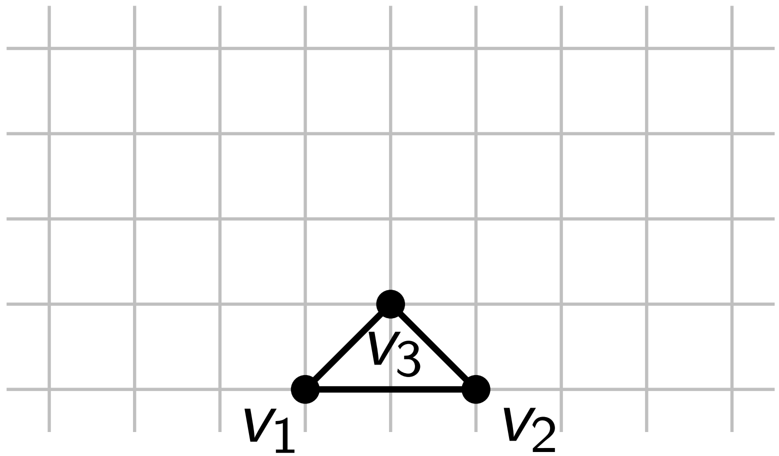
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.



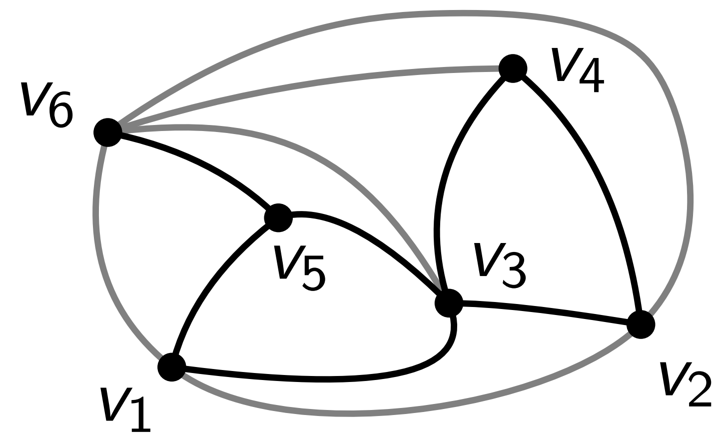


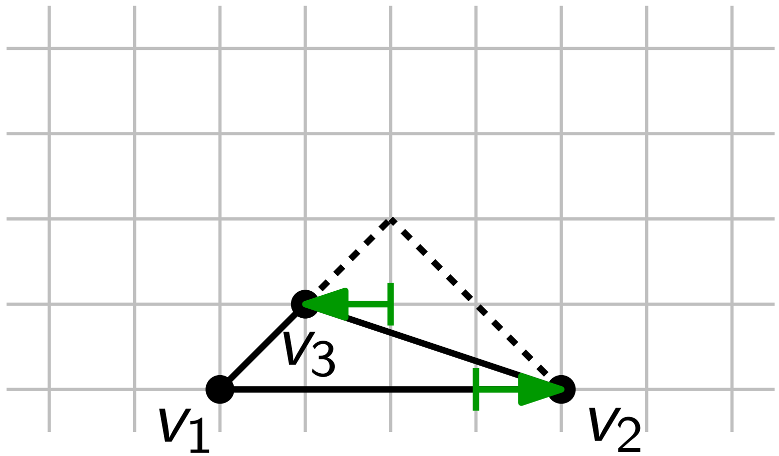
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.



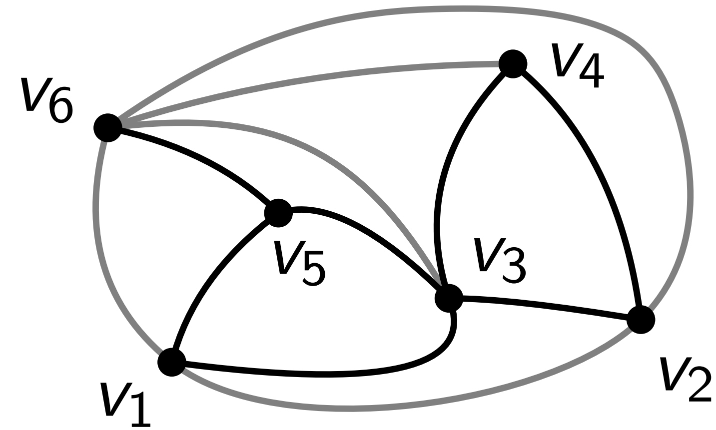


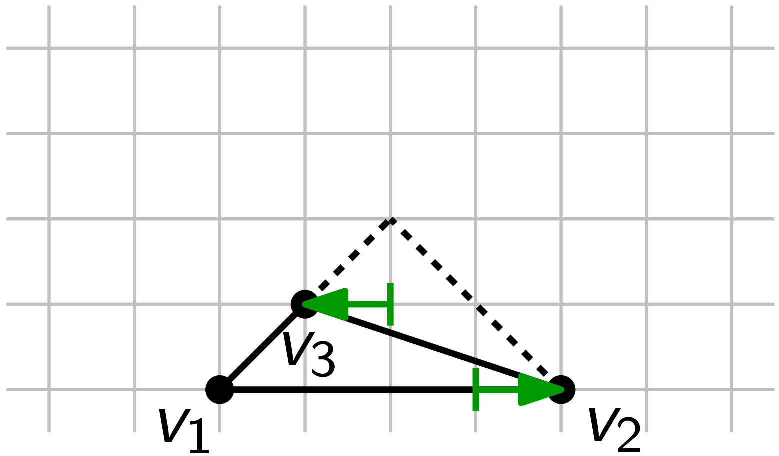
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.



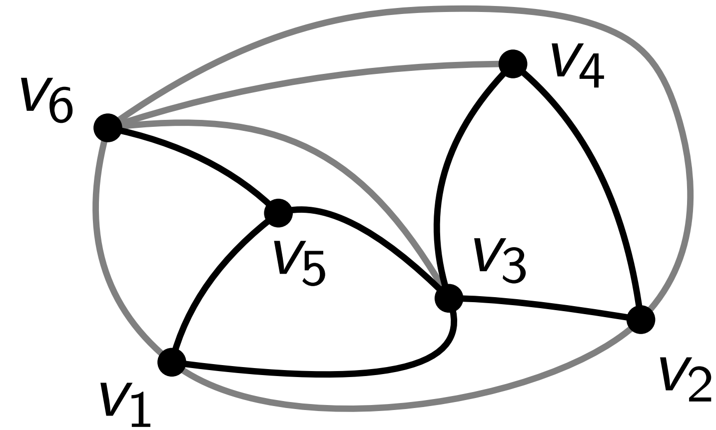


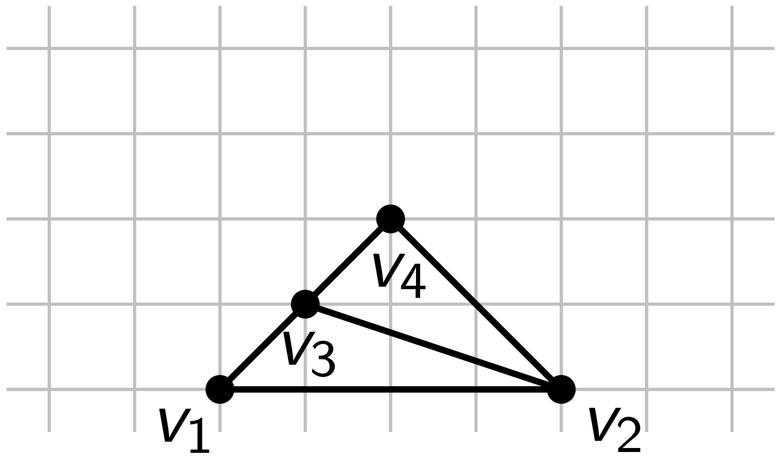
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.





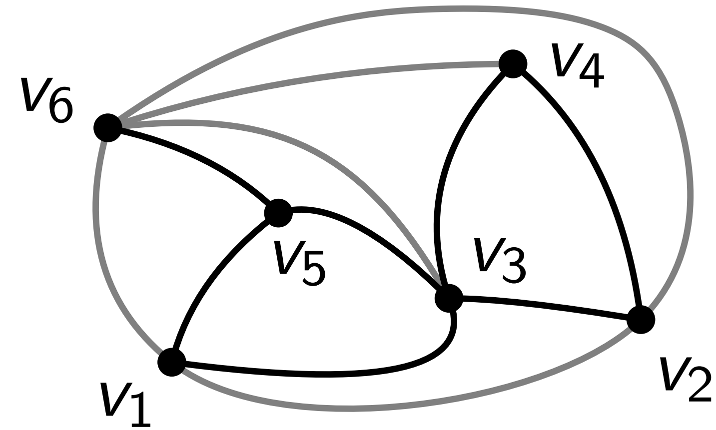
Introduction: The Shift Algorithm

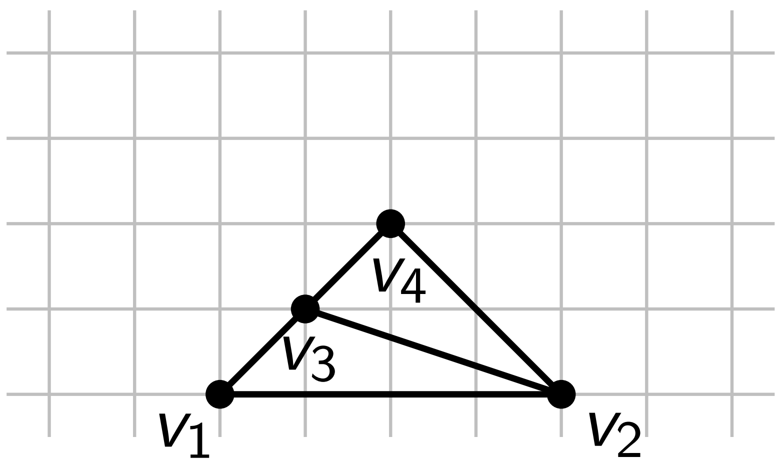
[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

  $\Rightarrow$ all slopes on outer face ± 1
  (except for $v_1 v_2$)





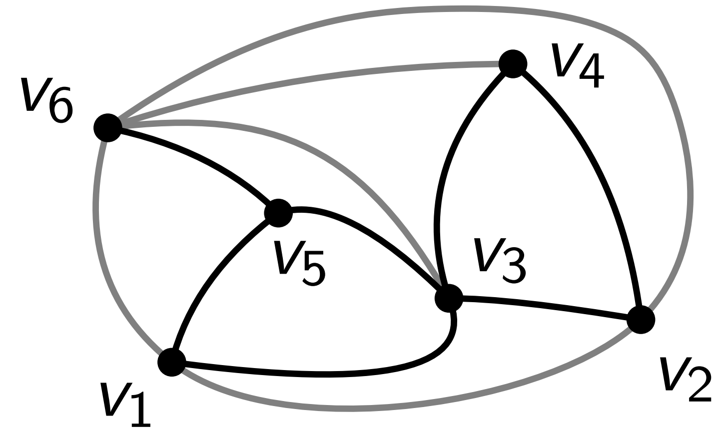
Introduction: The Shift Algorithm

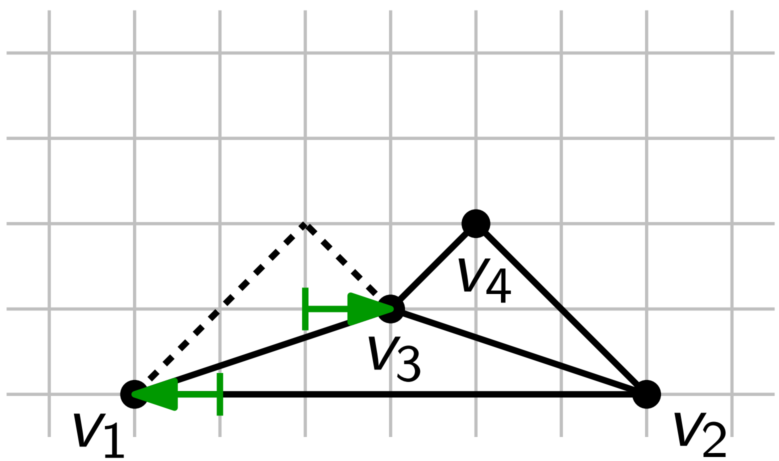
[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

  $\Rightarrow$ all slopes on outer face ± 1 (except for $v_1 v_2$)





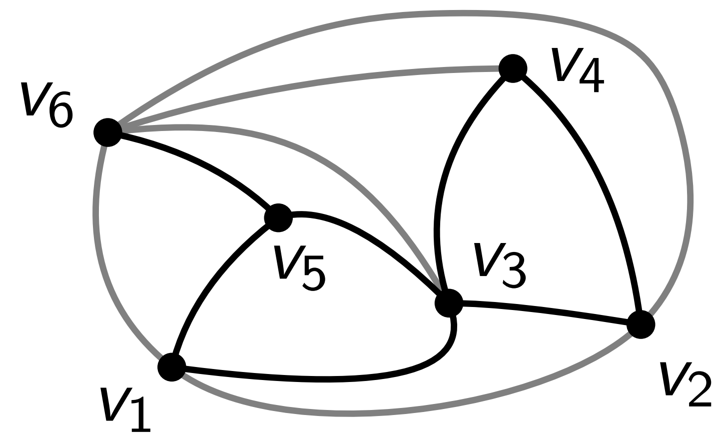
Introduction: The Shift Algorithm

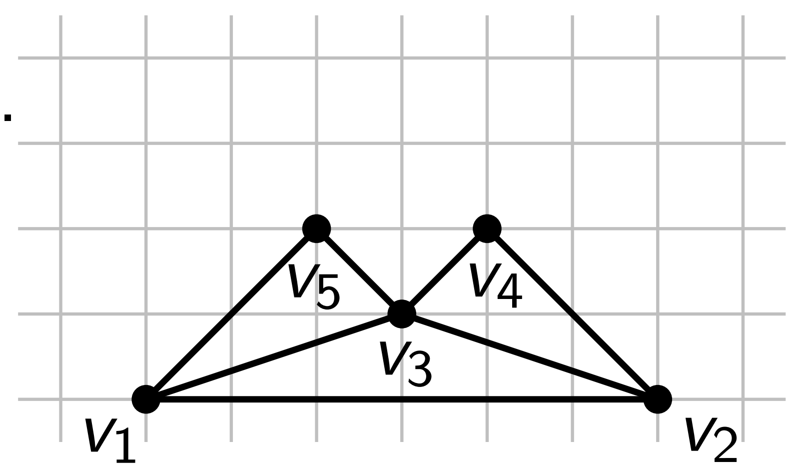
[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

  $\Rightarrow$ all slopes on outer face ± 1 (except for $v_1 v_2$)





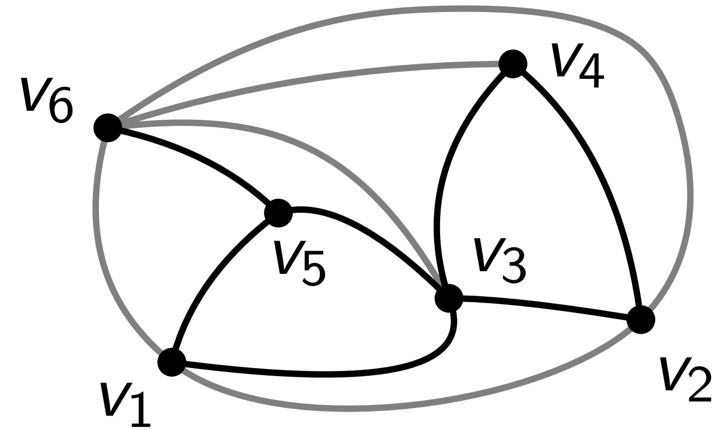
Introduction: The Shift Algorithm

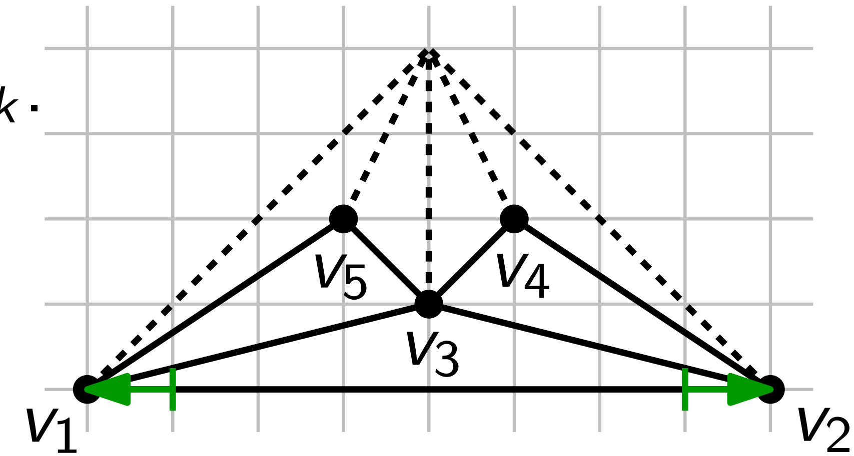
[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

$\Rightarrow$ all slopes on outer face ± 1
(except for $v_1 v_2$)





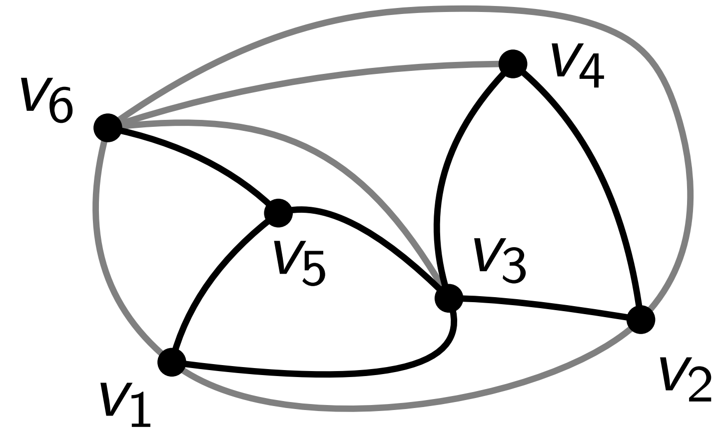
Introduction: The Shift Algorithm

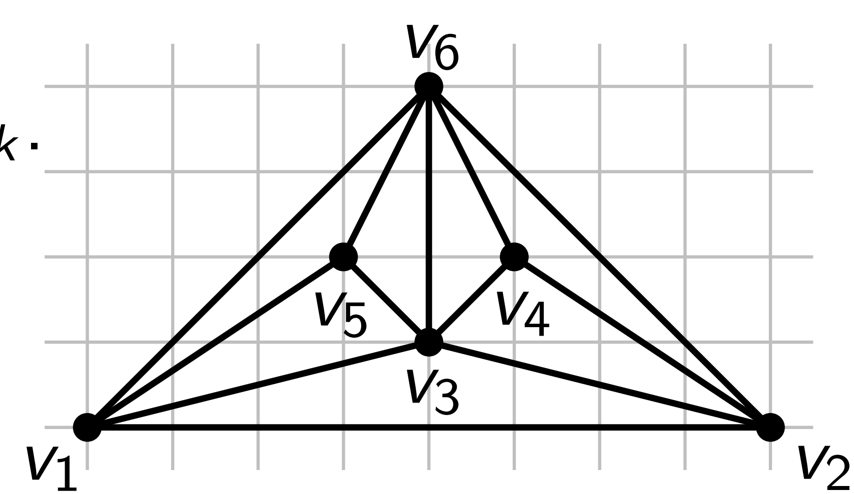
[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

  $\Rightarrow$ all slopes on outer face ± 1
  (except for $v_1 v_2$)





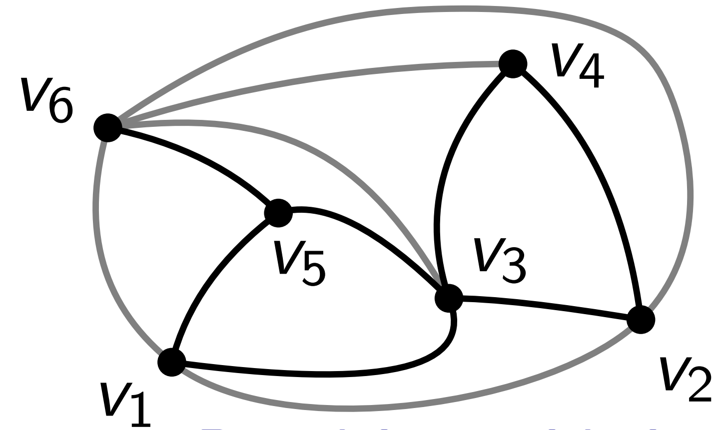
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

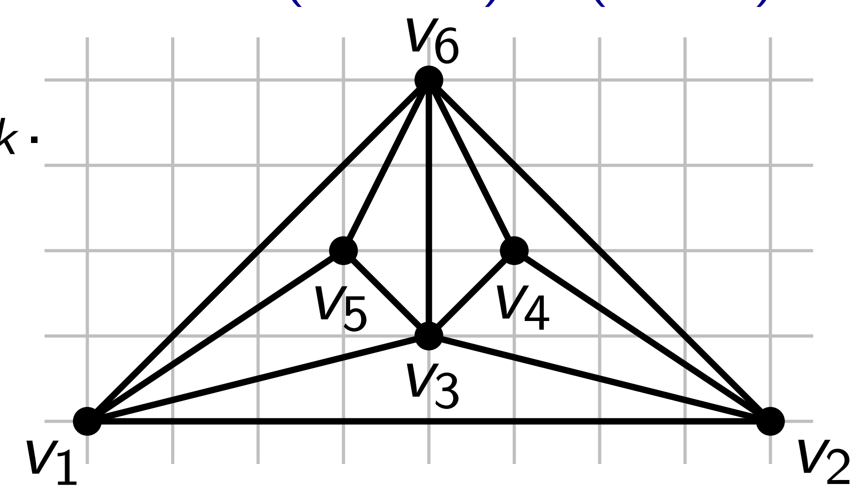
Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

  $\Rightarrow$ all slopes on outer face ± 1 (except for $v_1 v_2$)



Resulting grid size:
$(2n-4) \times (n-2)$



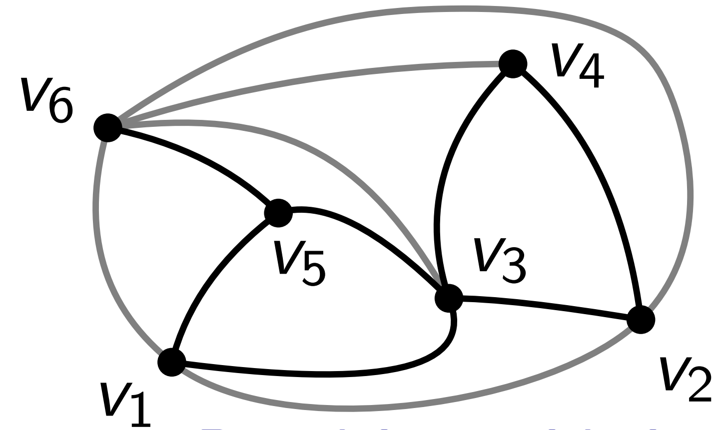
Introduction: The Shift Algorithm

[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

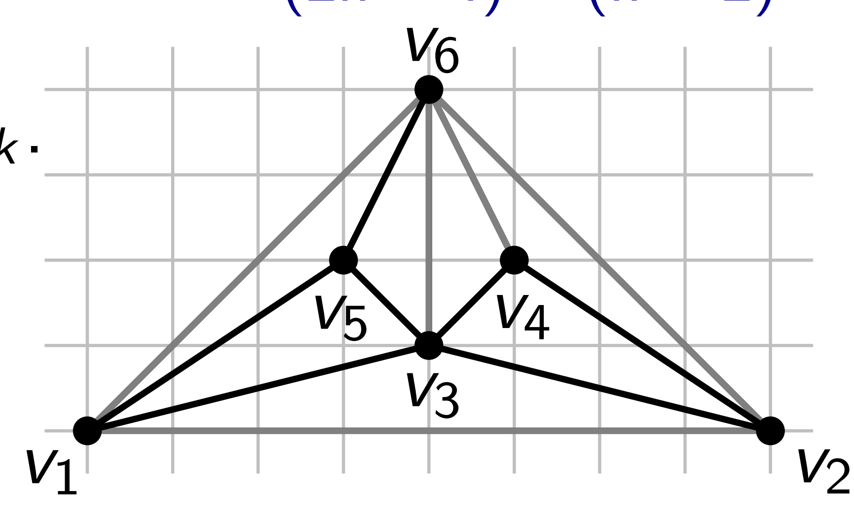
Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

  $\Rightarrow$ all slopes on outer face ± 1 (except for $v_1 v_2$)



Resulting grid size:
$(2n-4) \times (n-2)$

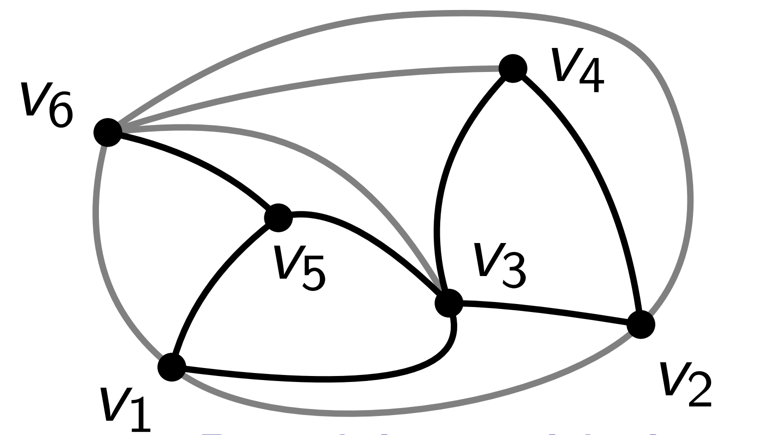


[de Fraysseix, Pach, and Pollack, 1990]
[Chrobak and Payne, 1995]

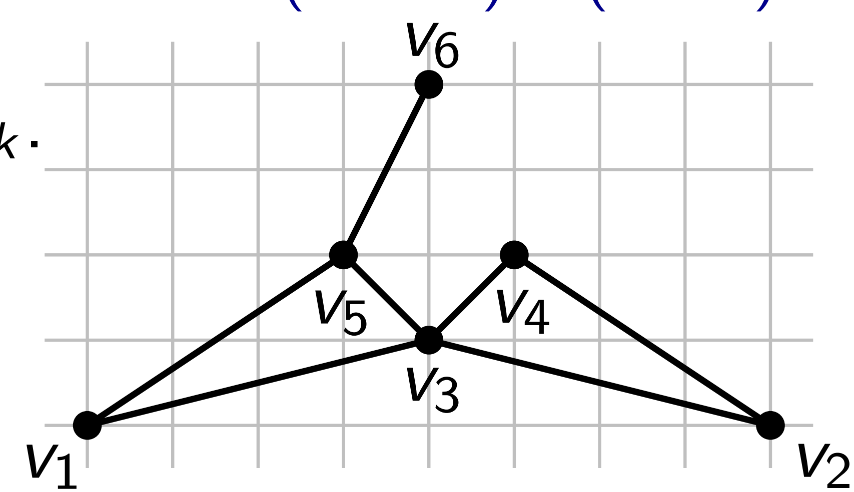
Idea:

- Triangulate given plane graph.
- Compute a canonical ordering of the vertices $v_1, v_2, \ldots, v_n$.
- Draw the graph:
  - Start with triangle v_1, v_2, v_3.
  - For v_k:
    Shift first & last neighbor of v_k.
  - Add v_k to the outer face.

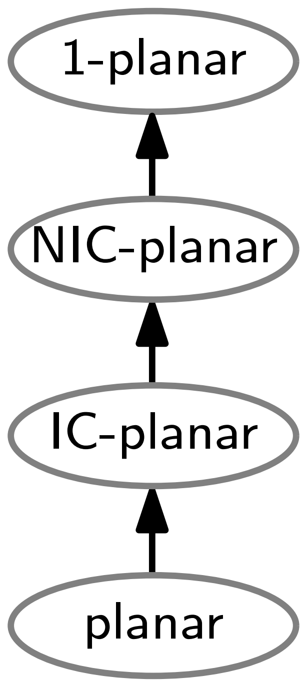
$\Rightarrow$ all slopes on outer face ± 1 (except for $v_1 v_2$)



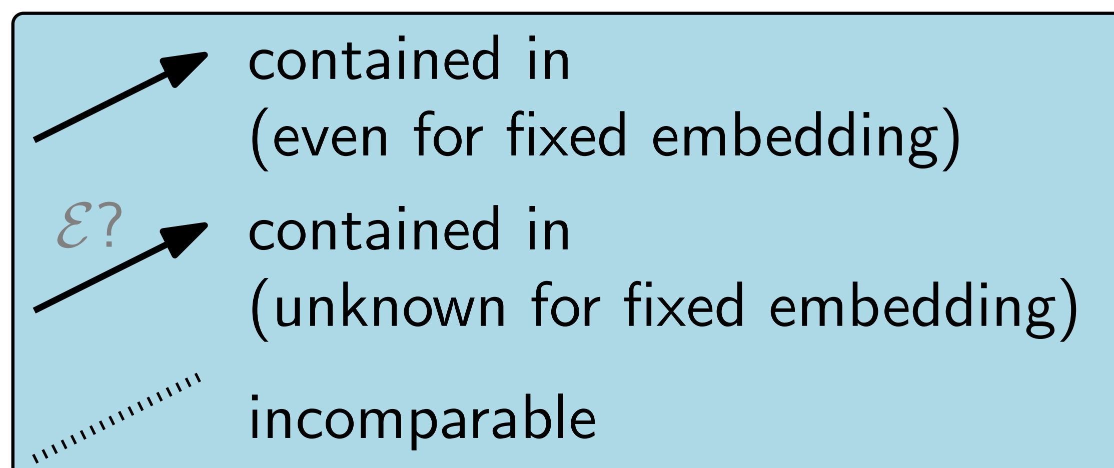
Resulting grid size:
$(2n-4) \times (n-2)$



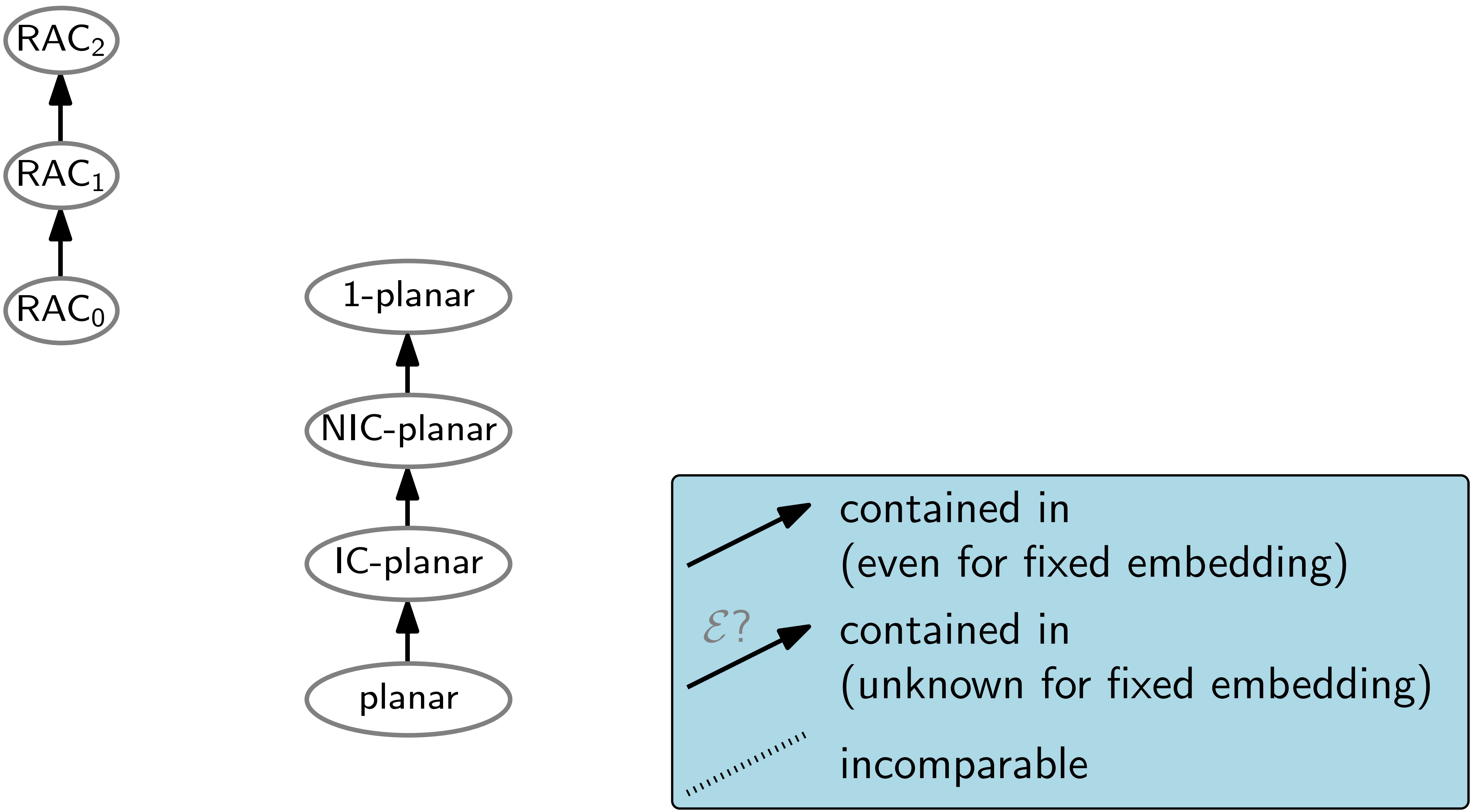
Introduction: Related Work



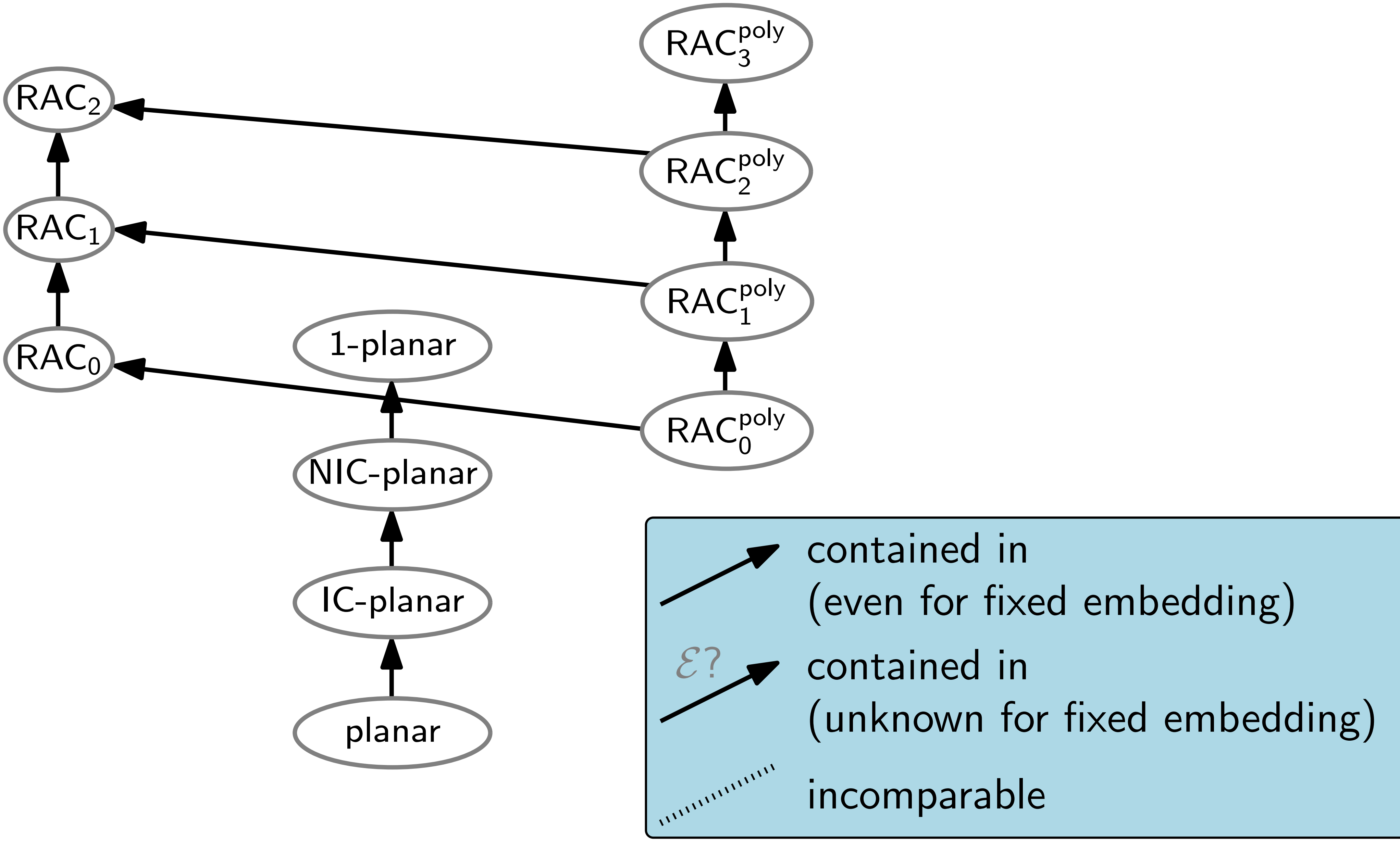
NIC-planar $= \{\text{graph } G \mid G \text{ has a NIC-planar drawing}\}$



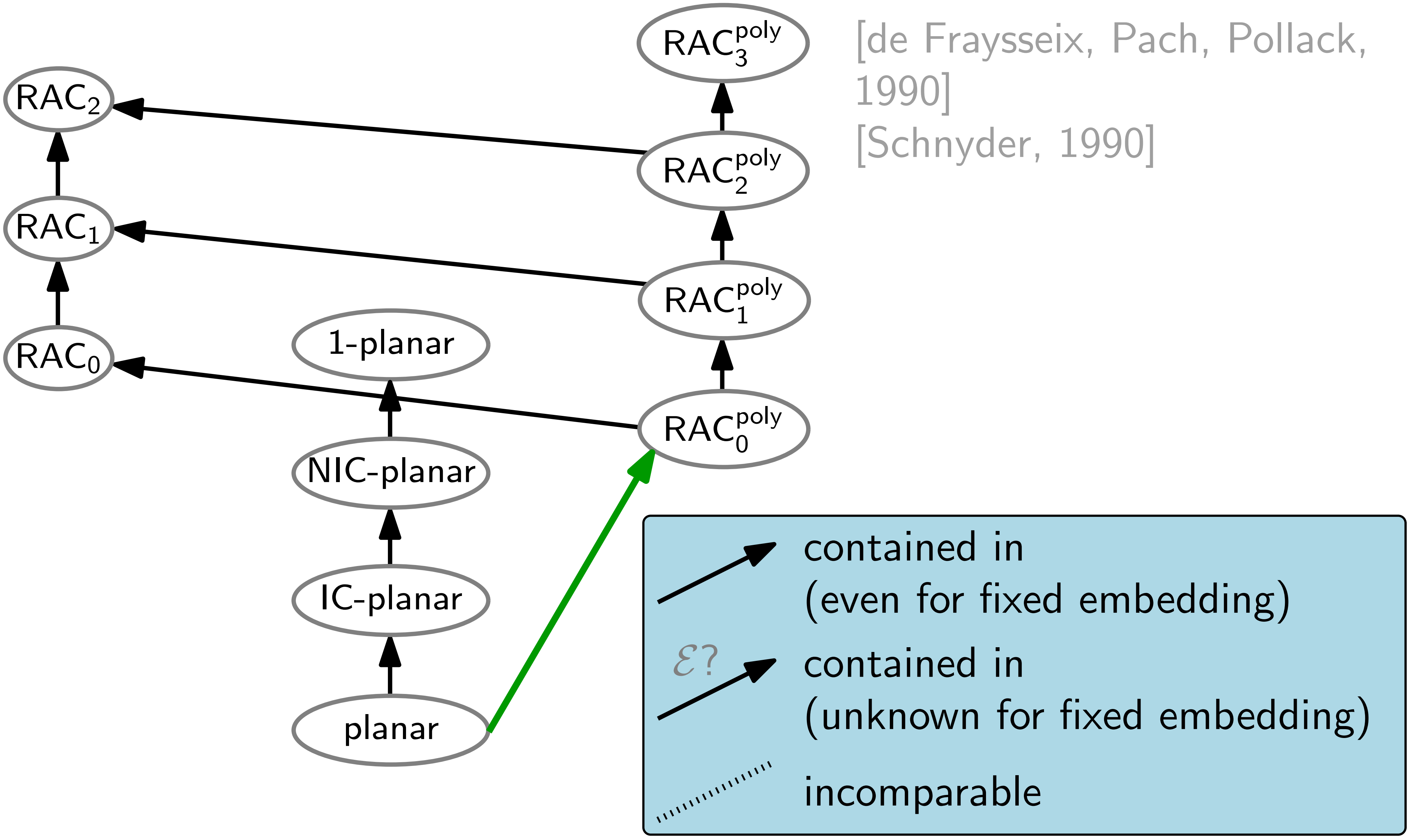
Introduction: Related Work



Introduction: Related Work

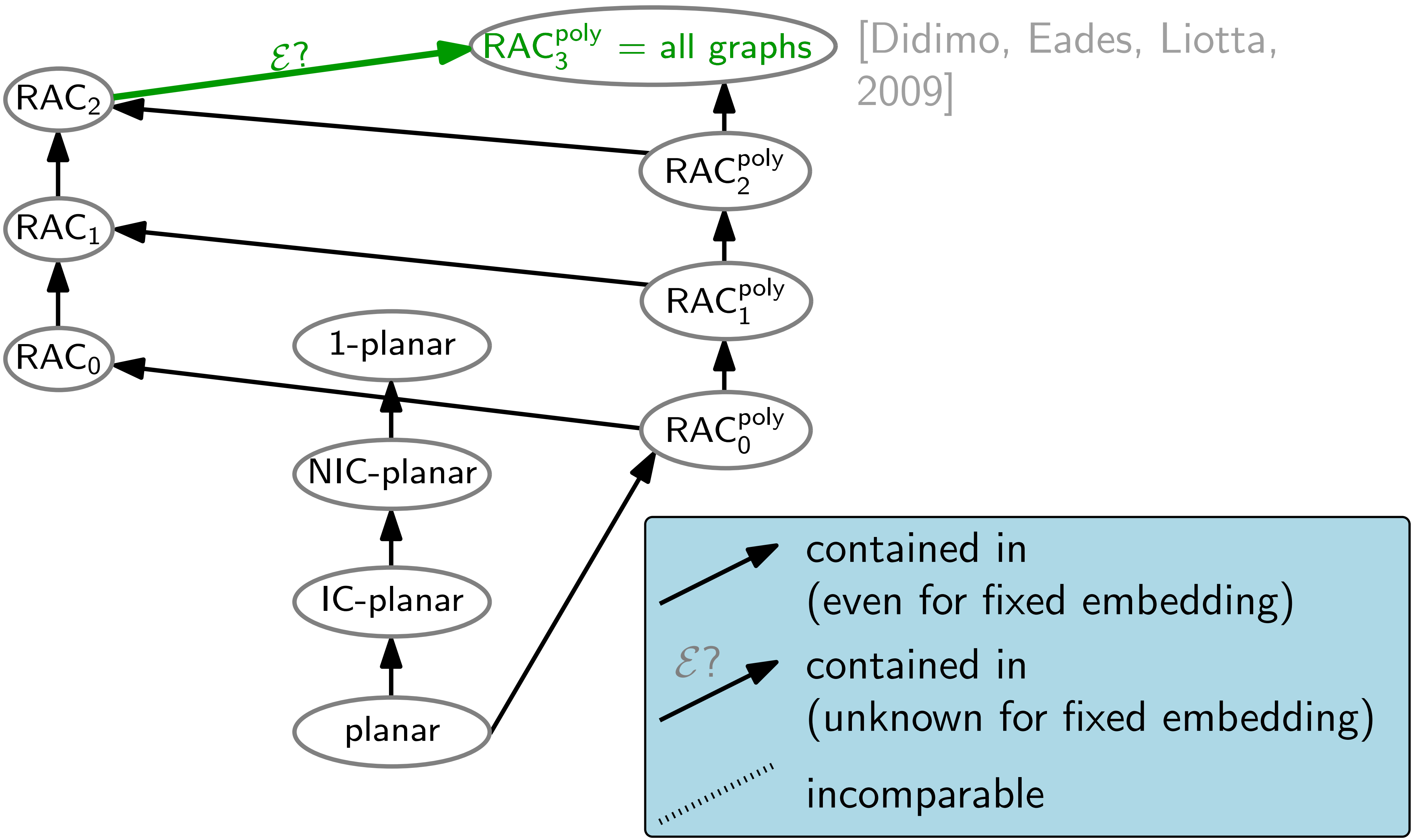


Introduction: Related Work



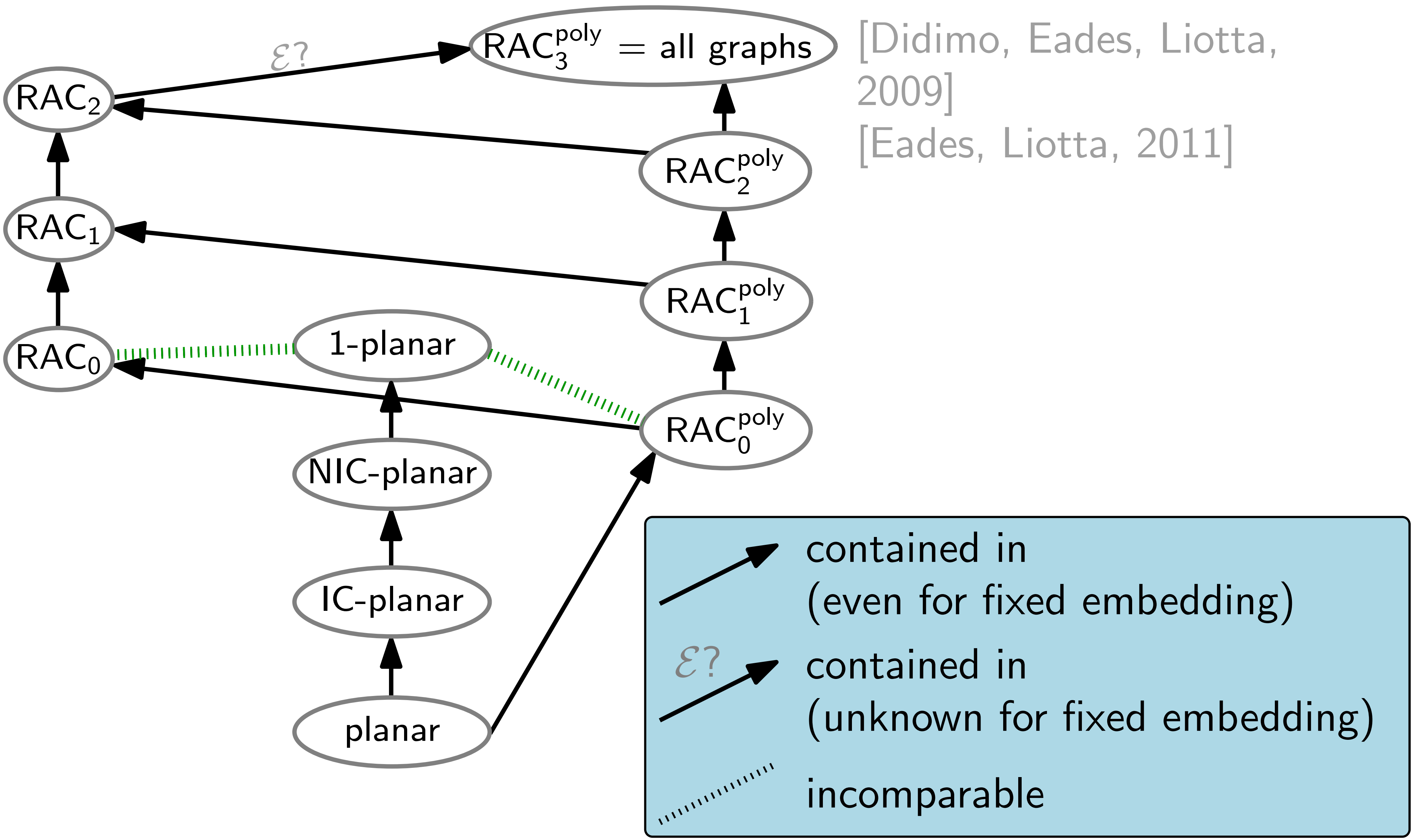
[de Fraysseix, Pach, Pollack, 1990]
[Schnyder, 1990]

Introduction: Related Work



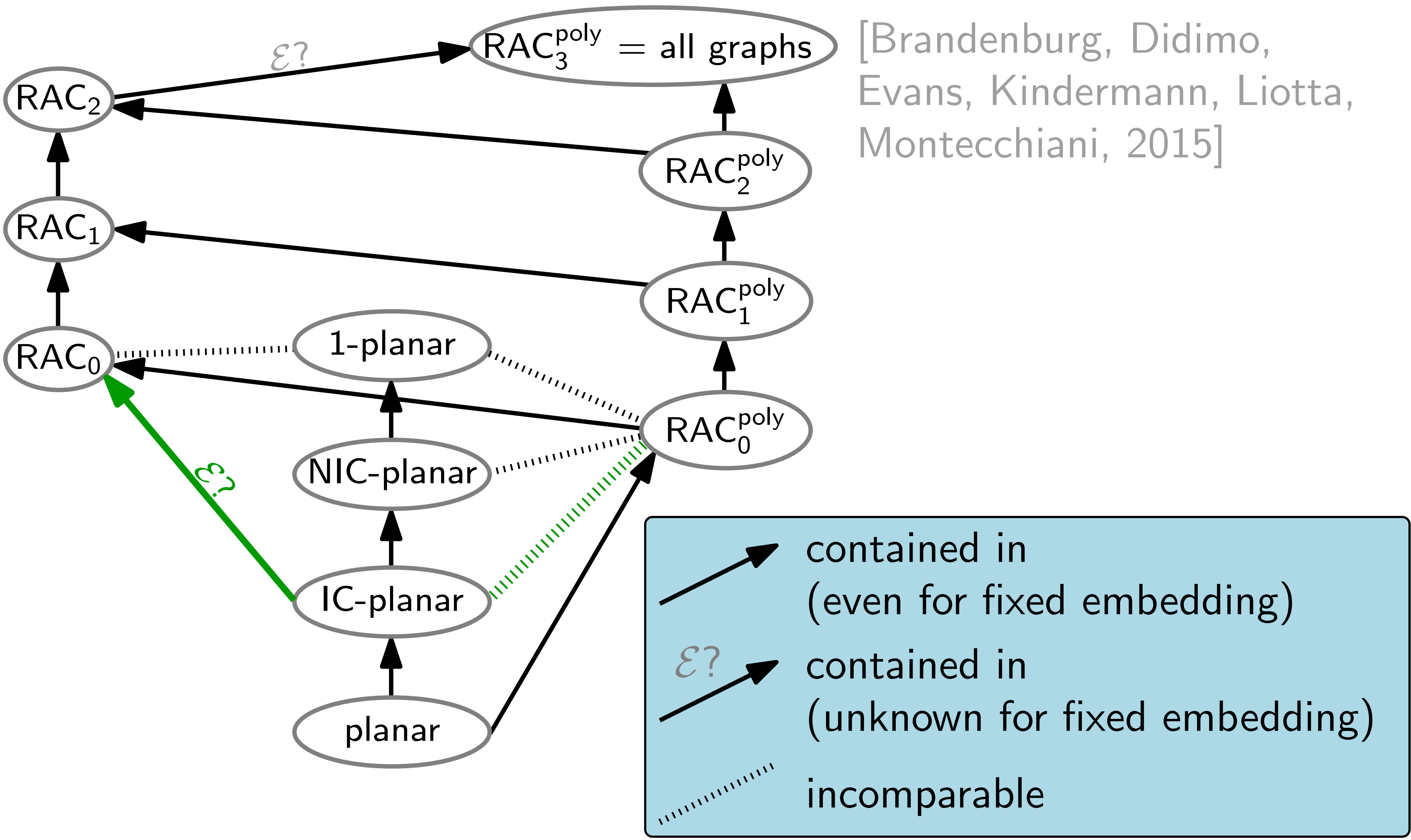
[Didimo, Eades, Liotta, 2009]

Introduction: Related Work



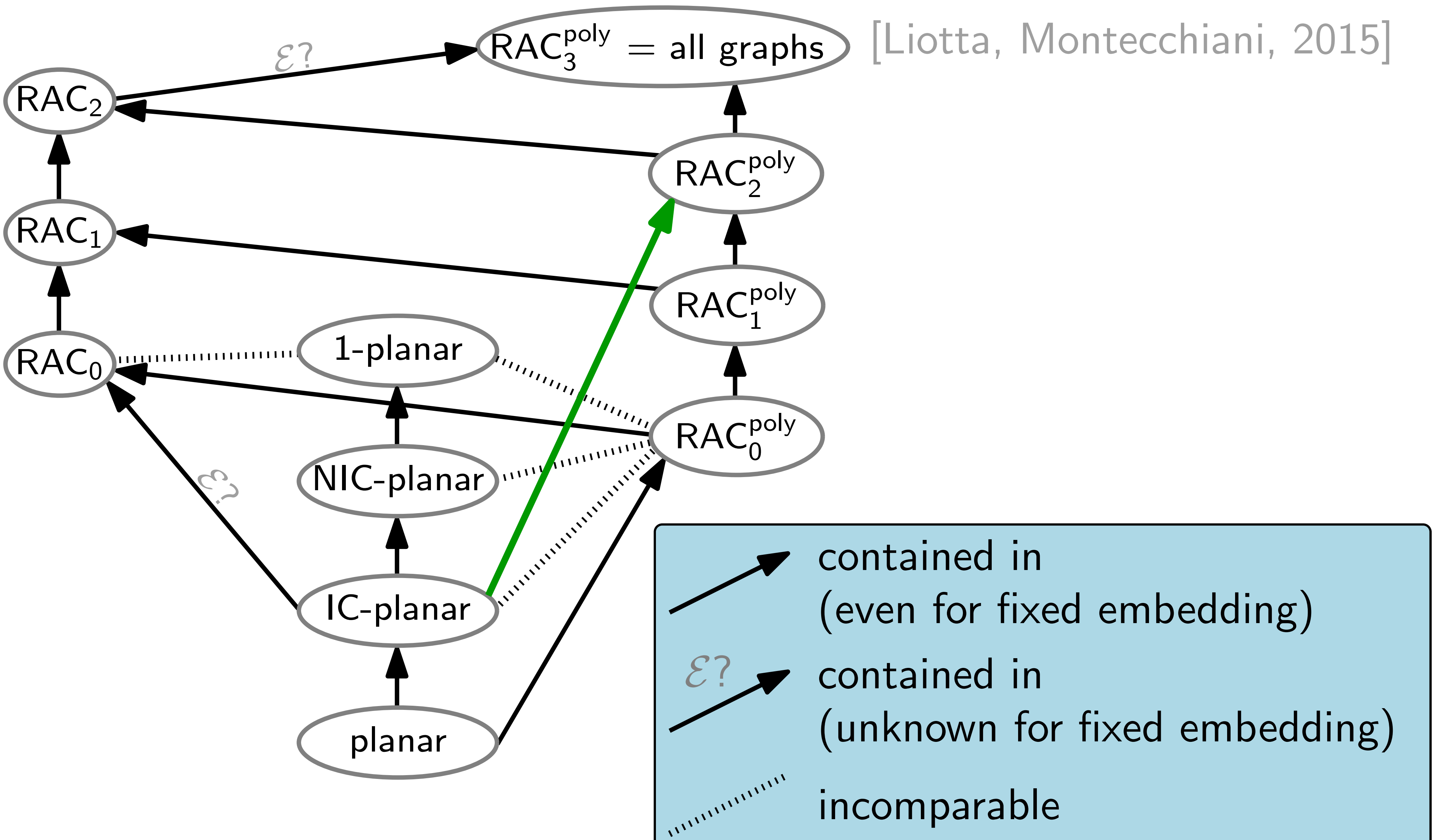
[Didimo, Eades, Liotta, 2009]
[Eades, Liotta, 2011]

Introduction: Related Work

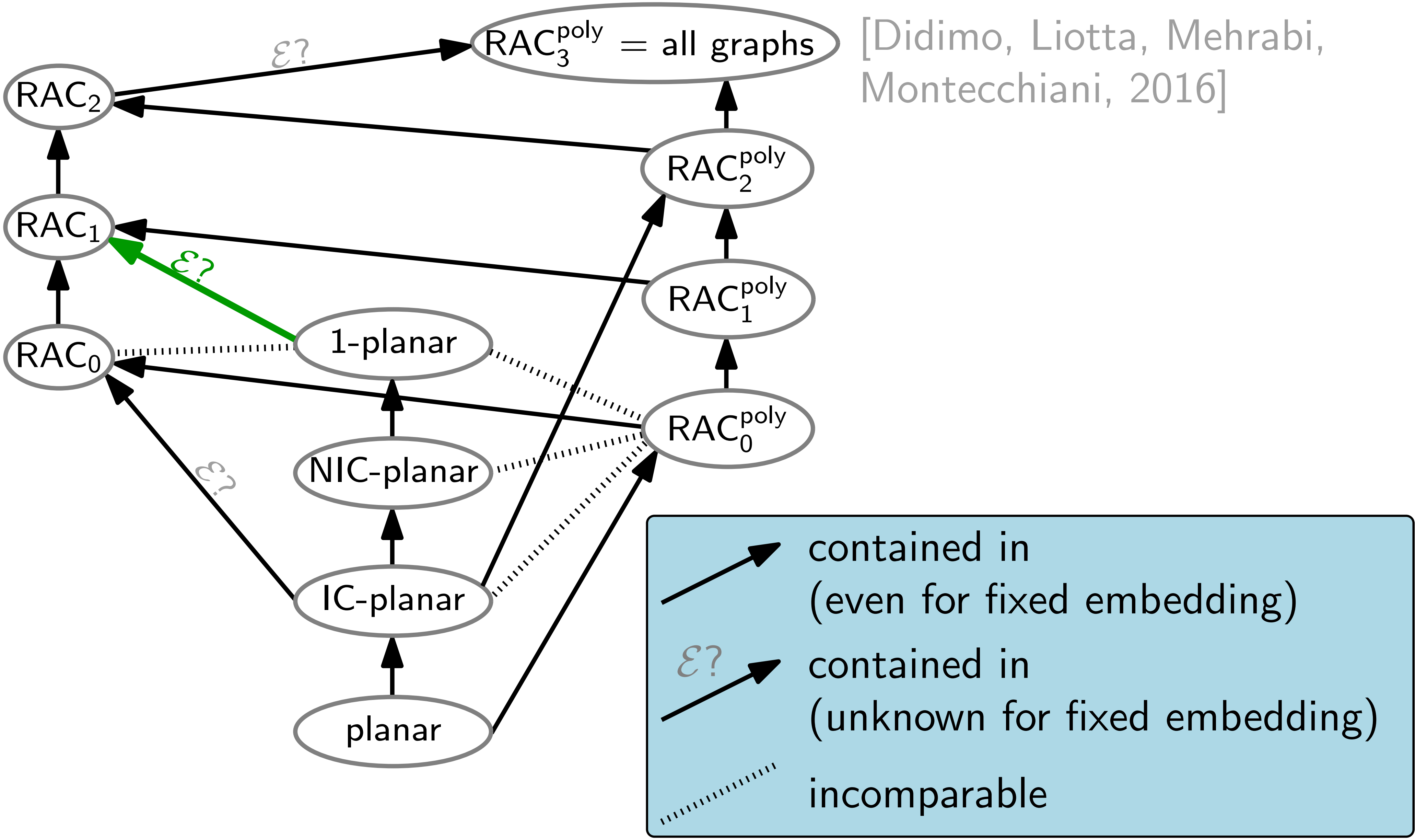


[Brandenburg, Didimo, Evans, Kindermann, Liotta, Montecchiani, 2015]

Introduction: Related Work

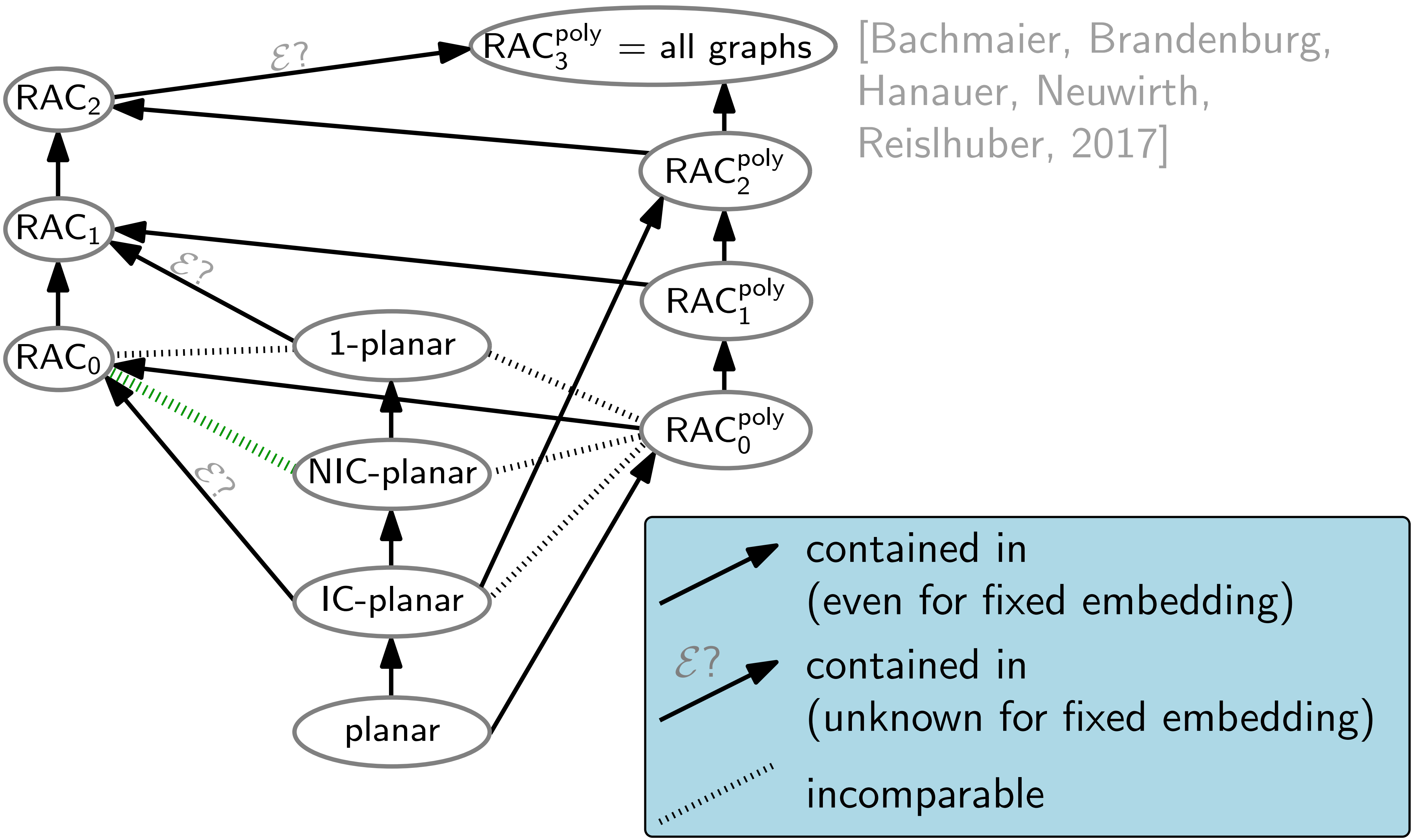


Introduction: Related Work



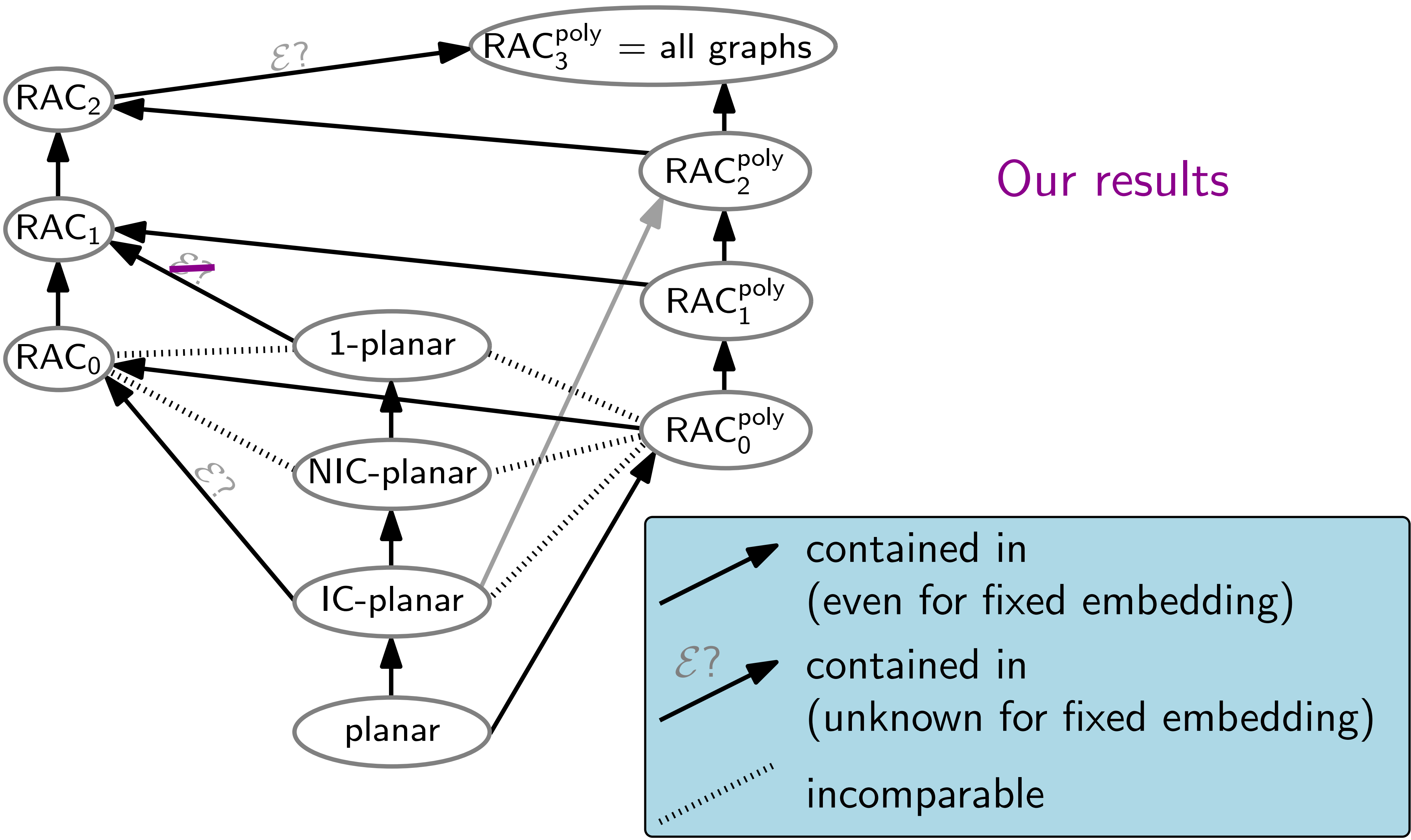
[Didimo, Liotta, Mehrabi, Montecchiani, 2016]

Introduction: Related Work



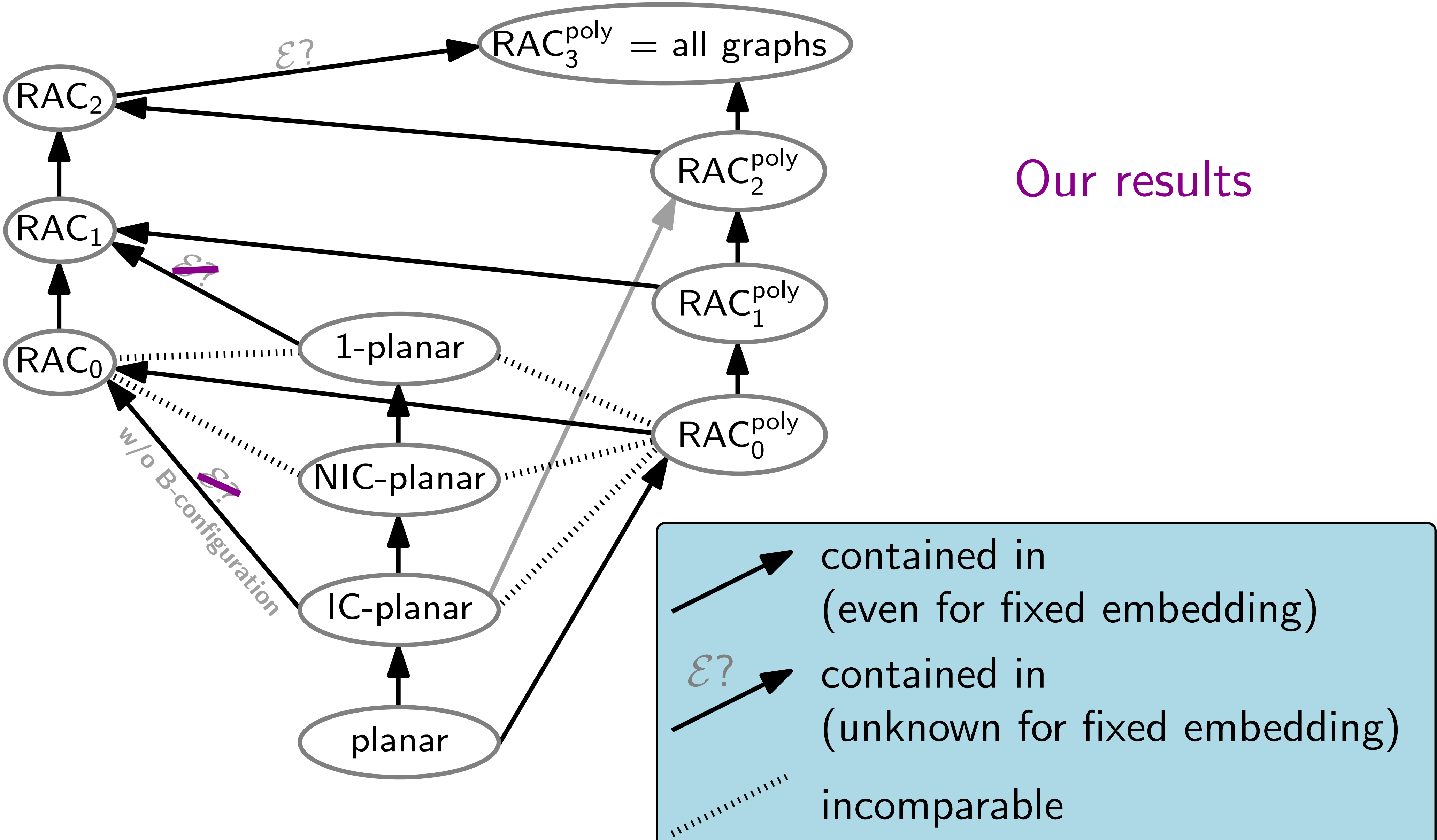
[Bachmaier, Brandenburg, Hanauer, Neuwirth, Reislhuber, 2017]

Introduction: Related Work



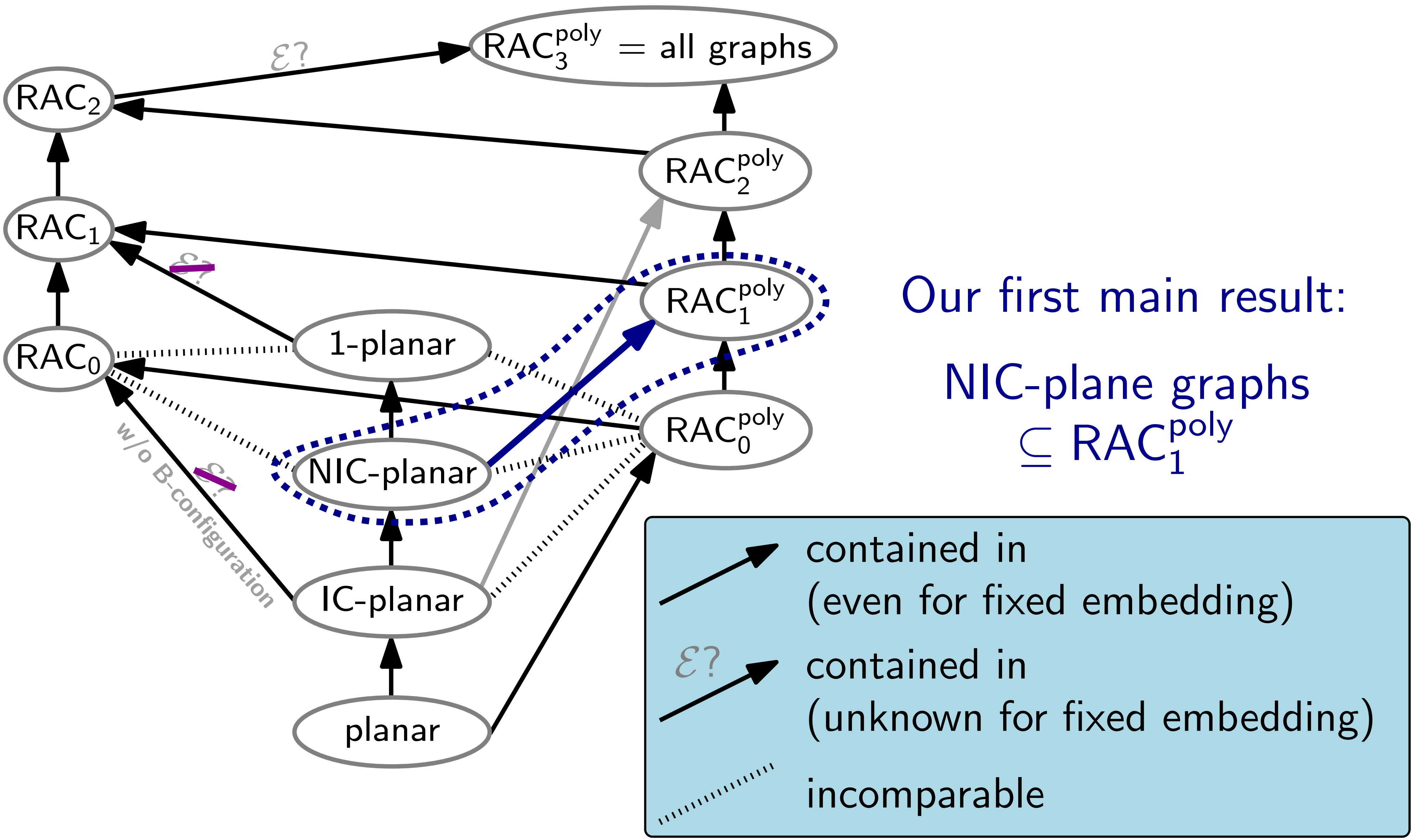
Our results

Introduction: Related Work



Our results

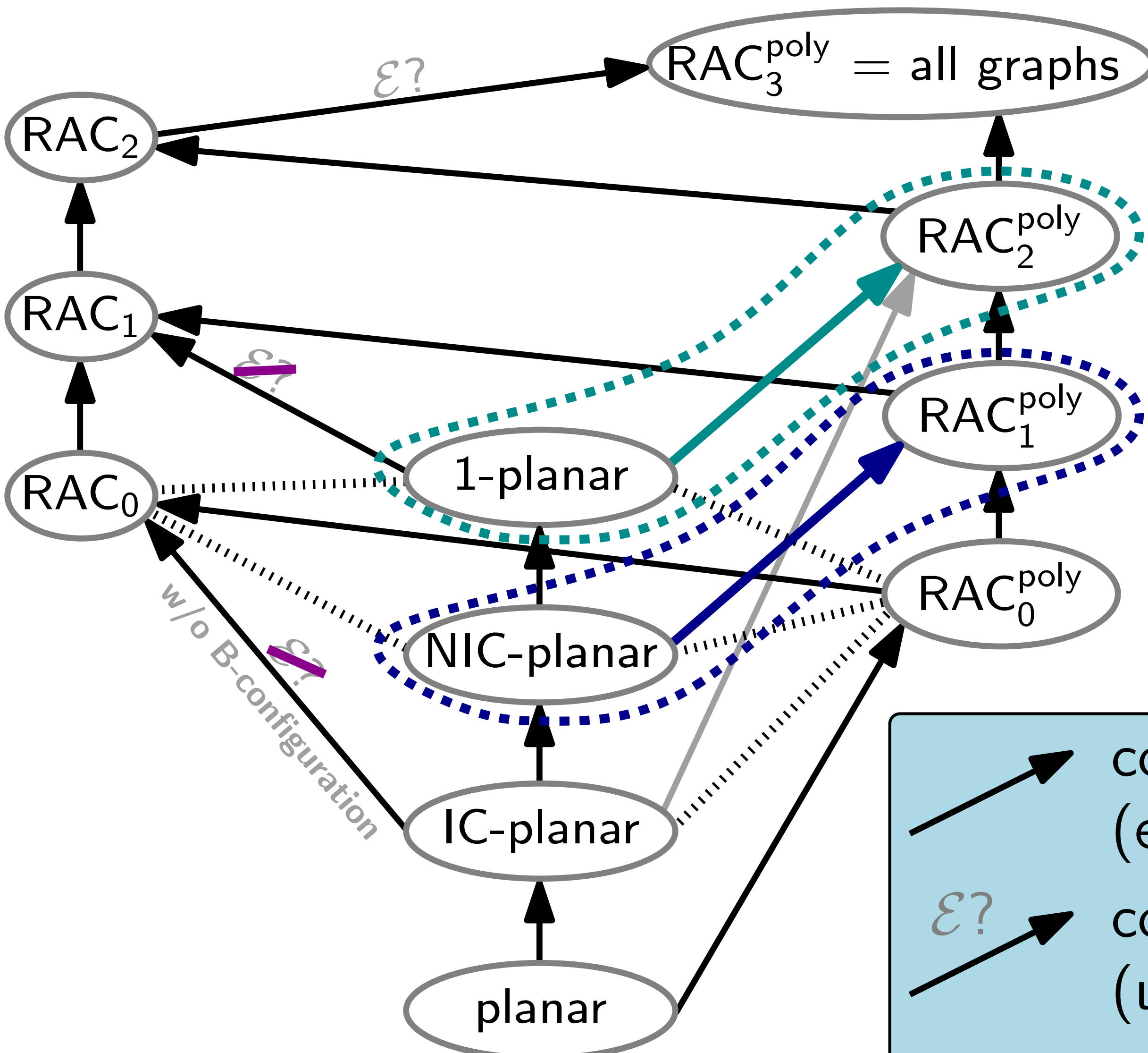
Introduction: Related Work



Our first main result:

NIC-plane graphs $\subseteq RAC_1^{poly}$

Introduction: Related Work

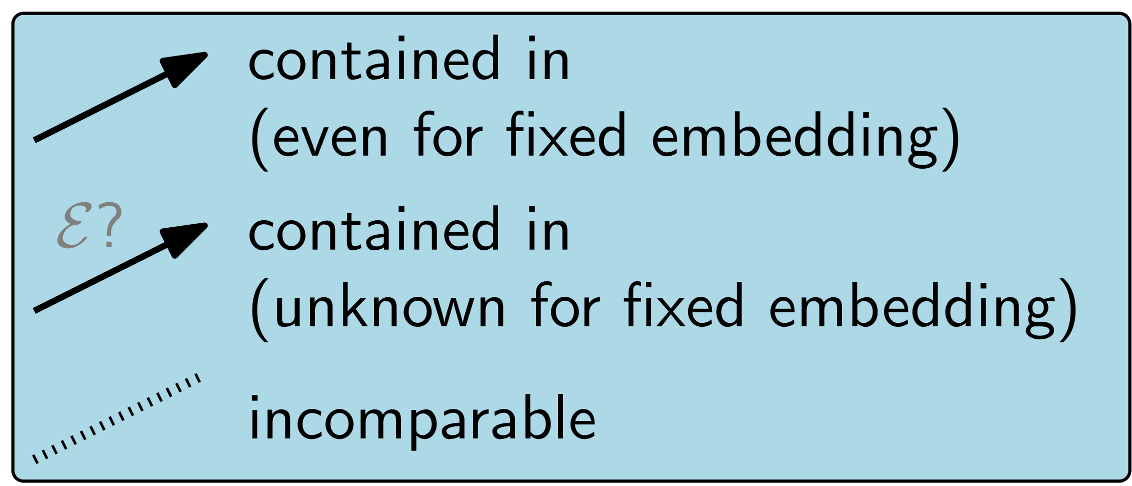


Our second main result:

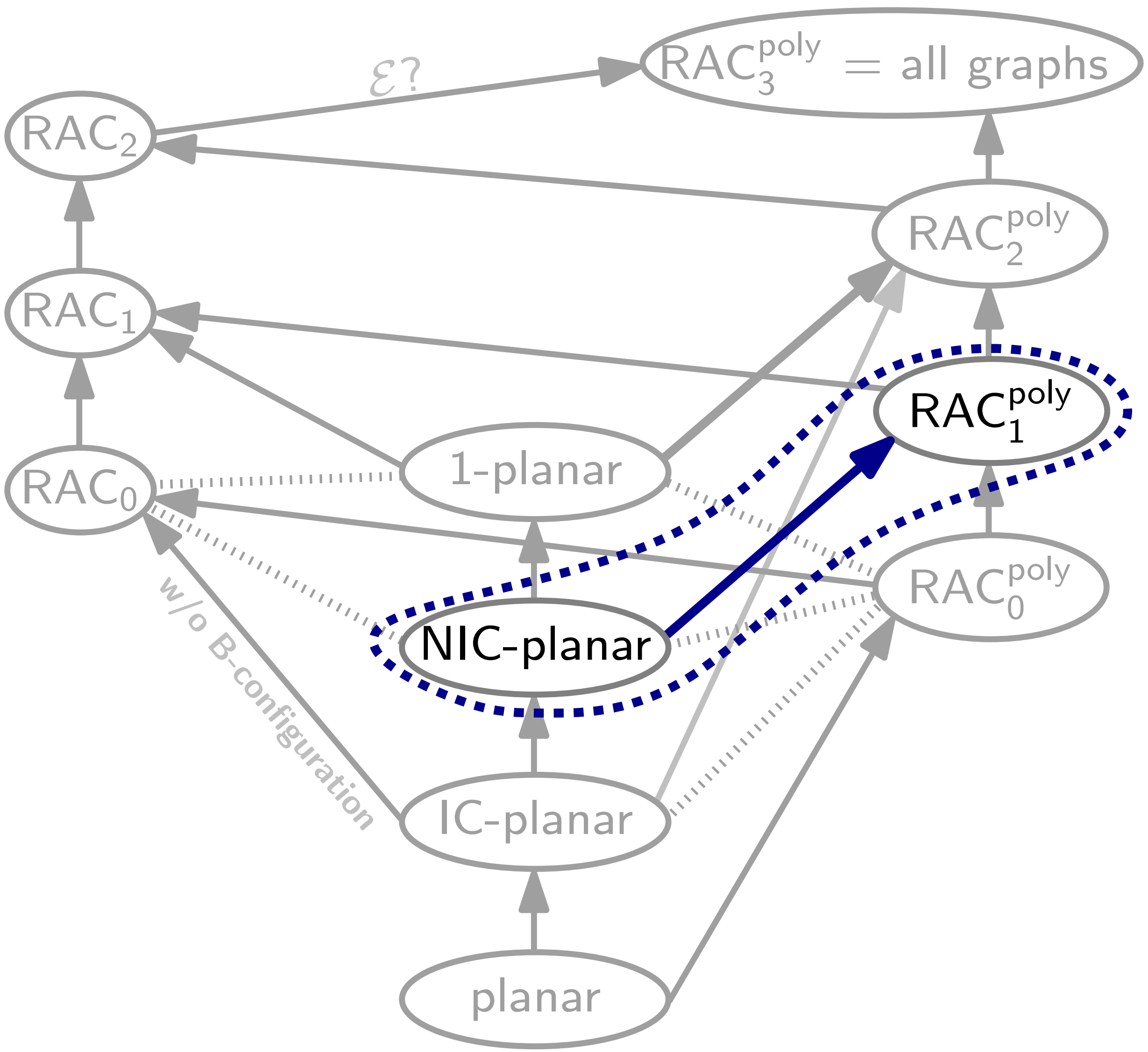
1-plane graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Our first main result:

NIC-plane graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



Result 1: NIC-Plane Graphs $\subseteq$ RAC_1^{poly}



Result 1: NIC-Plane Graphs $\subseteq$ $\mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\mathsf{poly}}$

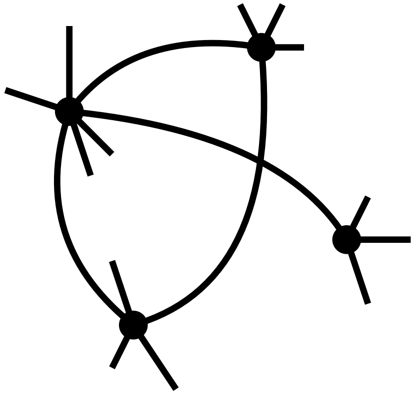
- Input: a NIC-plane graph

Approach that nearly works:

Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

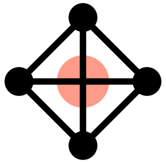
Approach that nearly works:

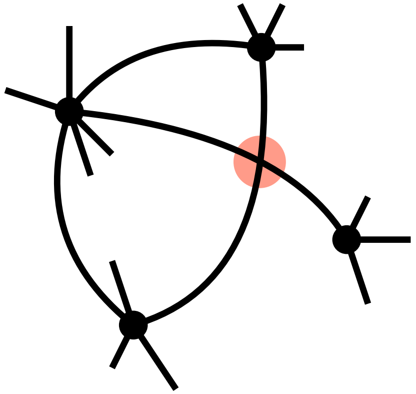


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

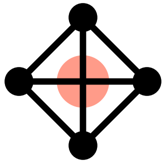
- Enclose each crossing by a so called *empty kite*: 

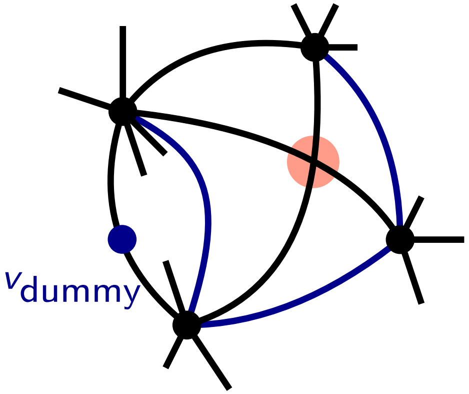


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

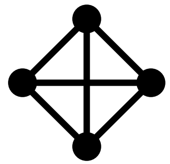
- Enclose each crossing by a so called *empty kite*: 

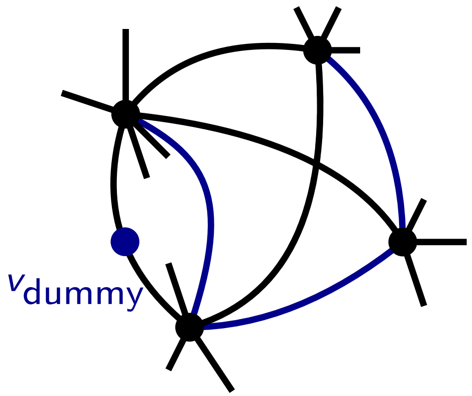


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

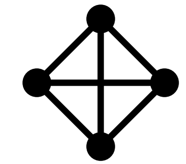
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge

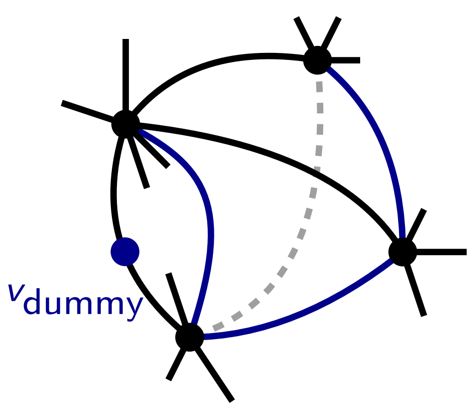


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

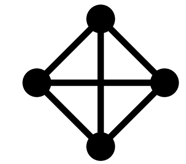
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge

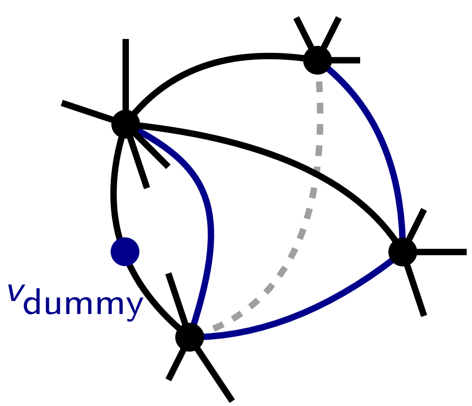


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

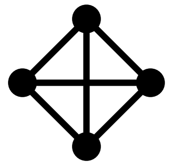
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm

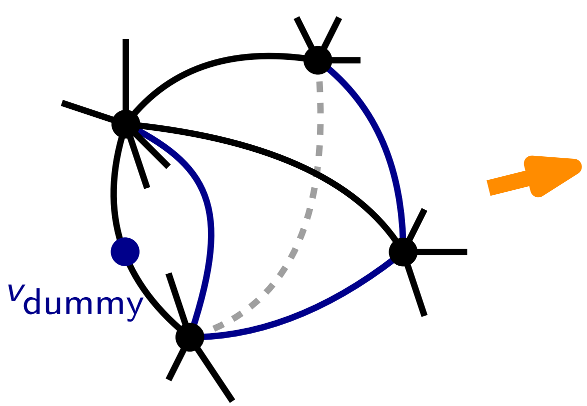


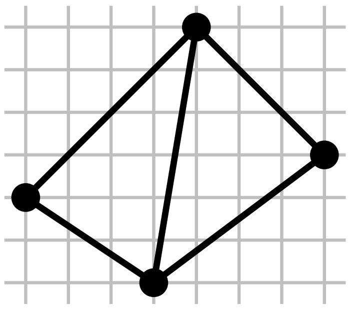
Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm

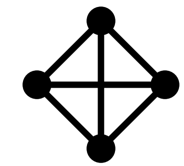


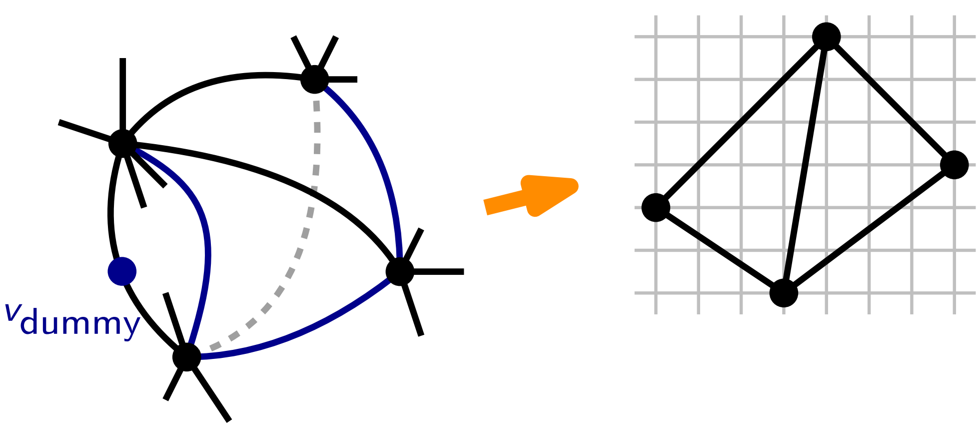


Result 1: NIC-Plane Graphs $\subseteq \text{RAC}_1^{\text{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

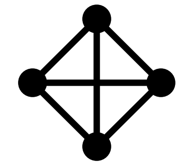
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

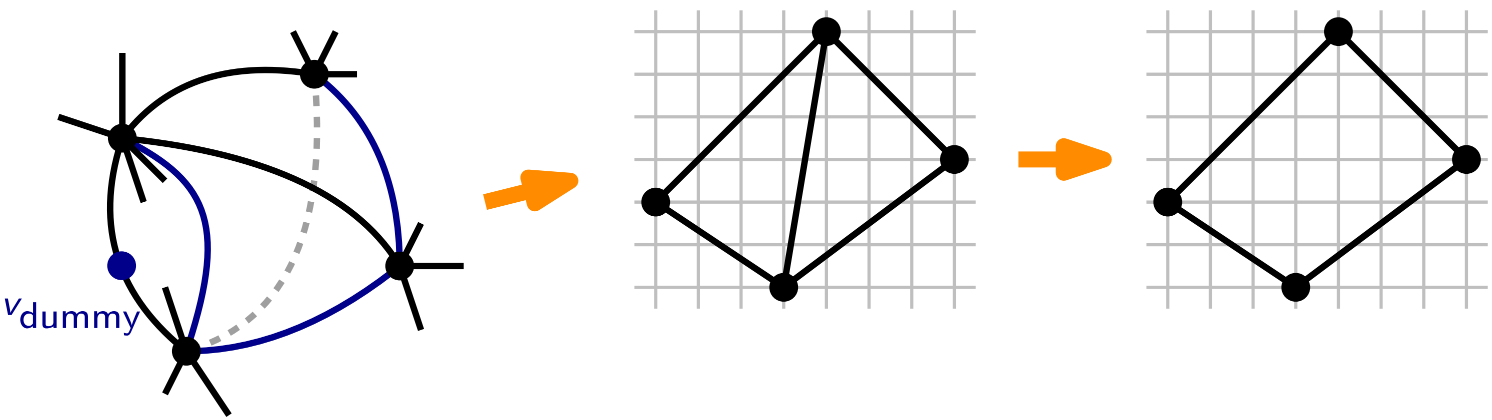


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

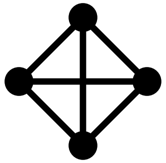
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

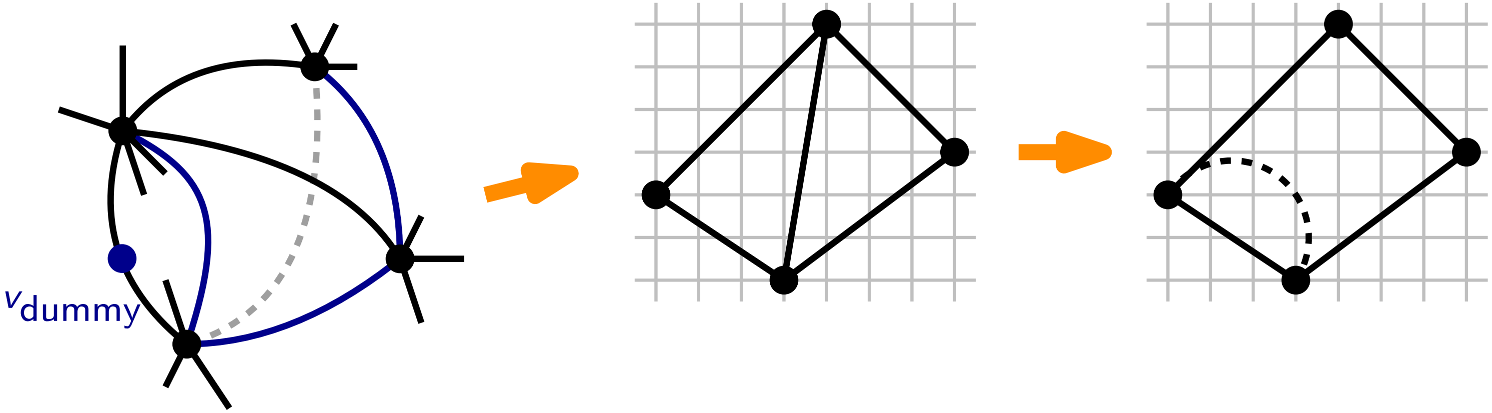


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

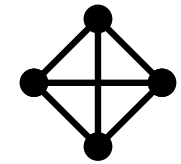
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

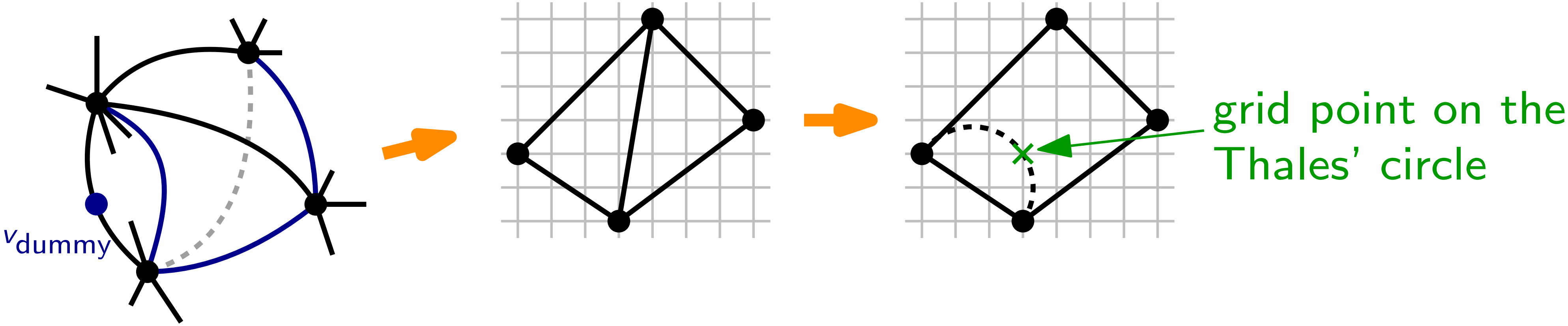


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

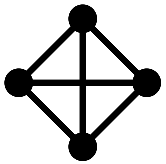
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

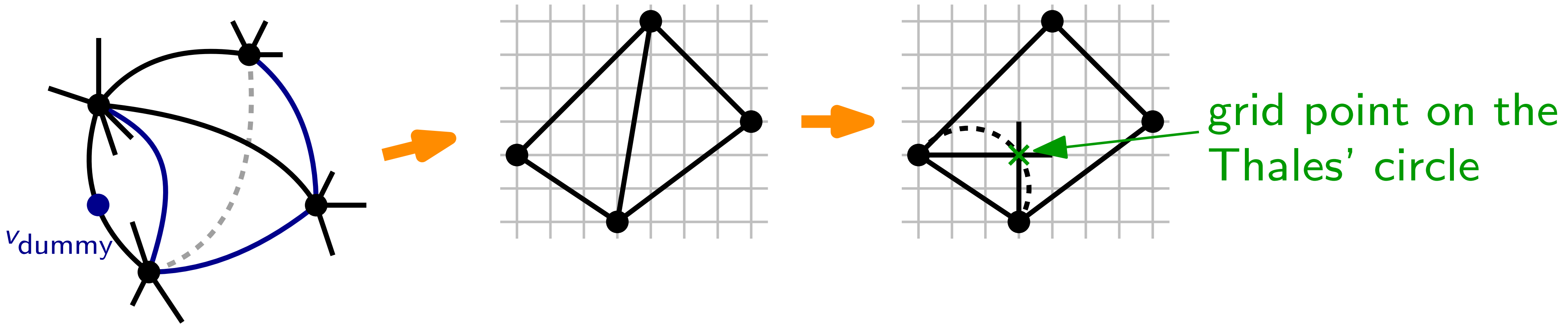


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

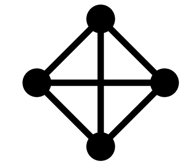
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

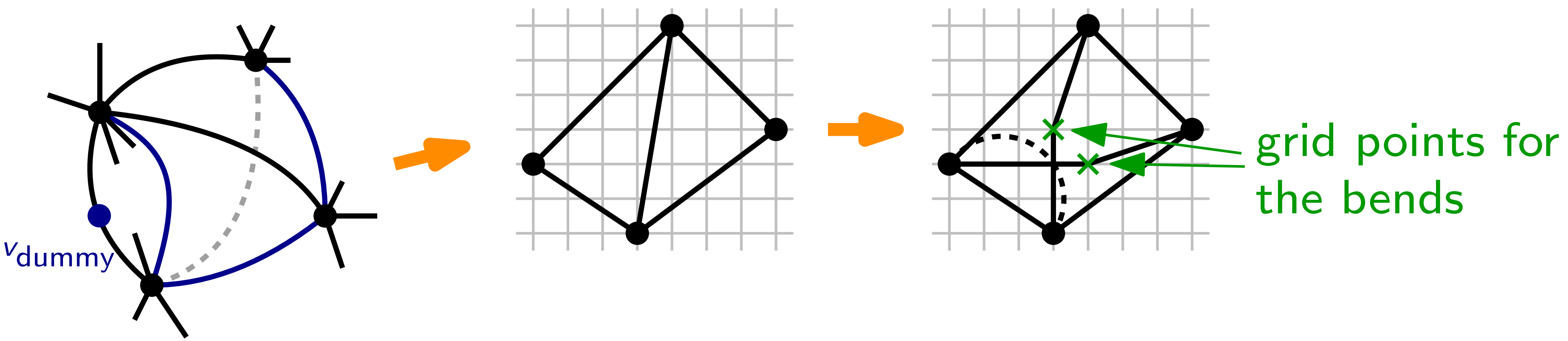


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

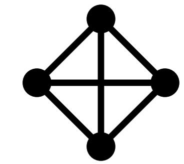
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

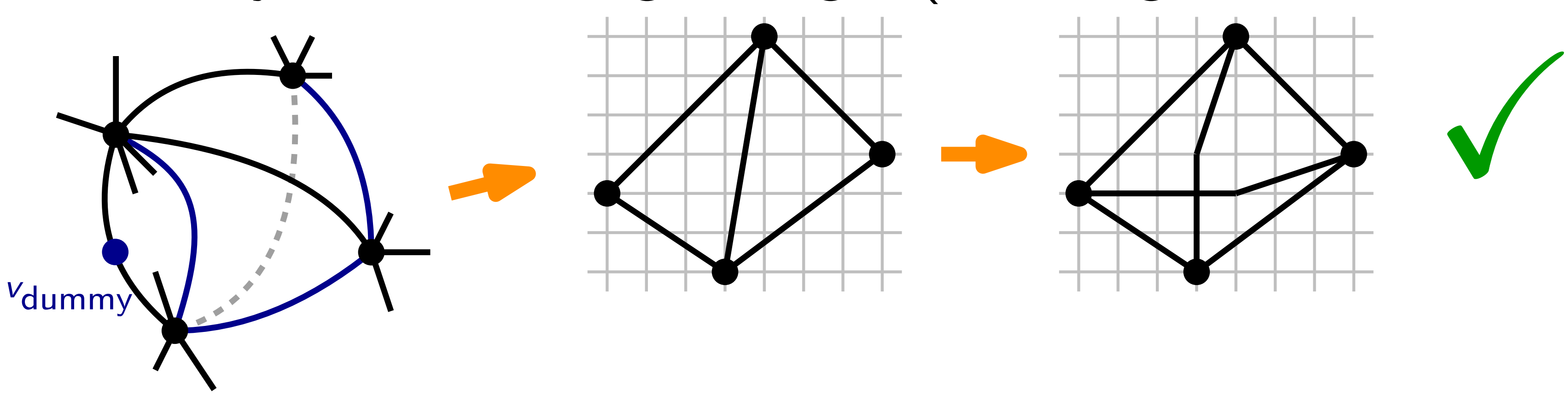


Result 1: NIC-Plane Graphs $\subseteq$ $\mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

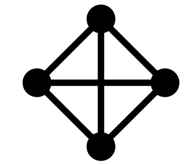
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

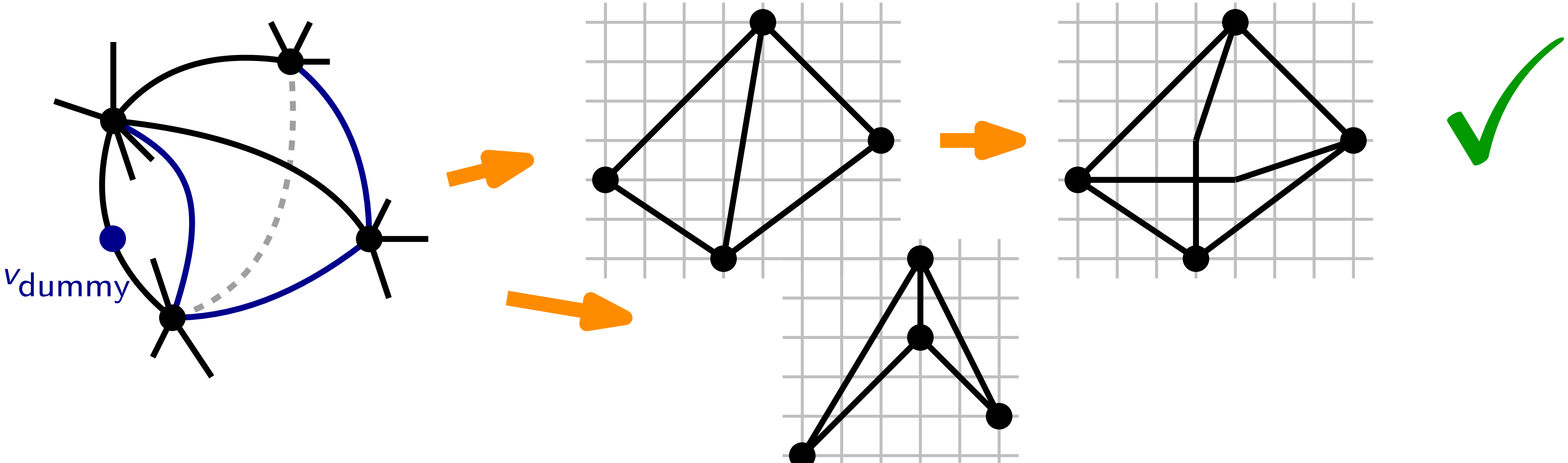


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

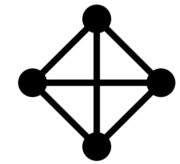
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

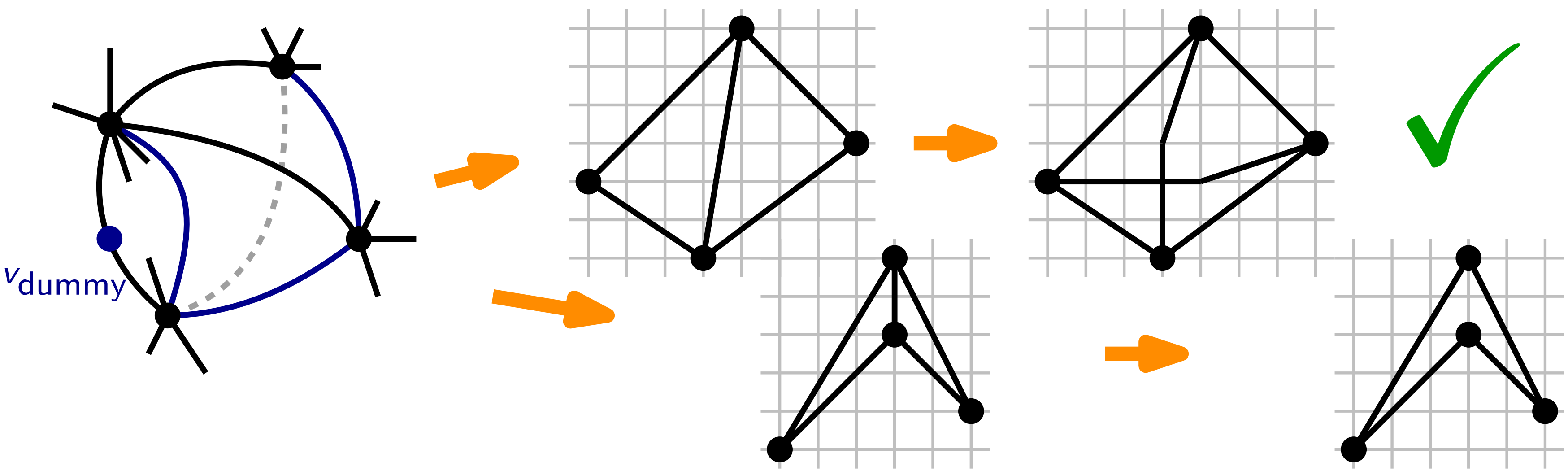


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

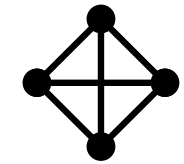
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

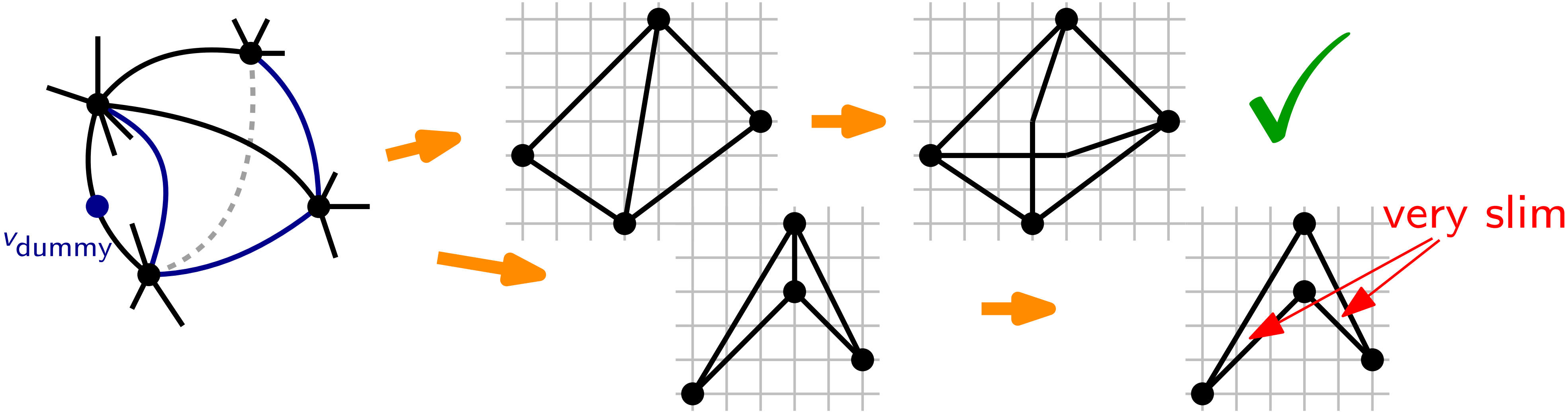


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

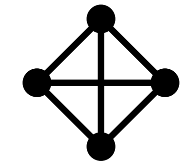
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

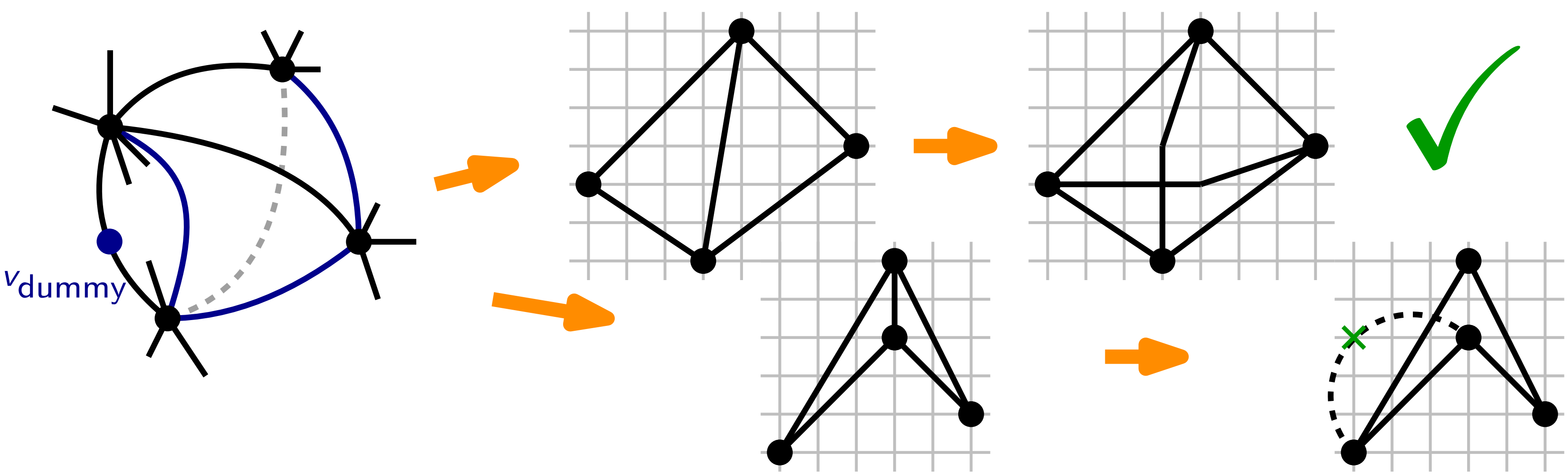


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

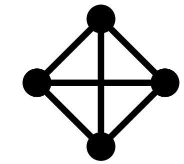
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

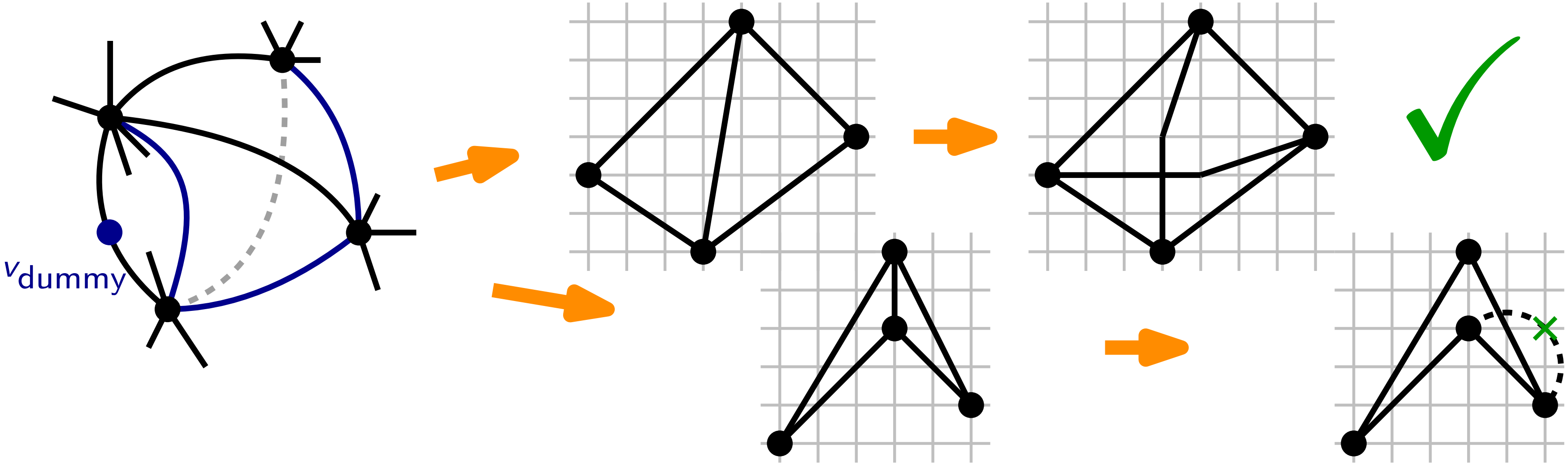


Result 1: NIC-Plane Graphs $\subseteq$ $\mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

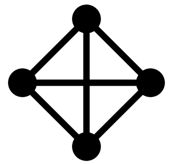
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

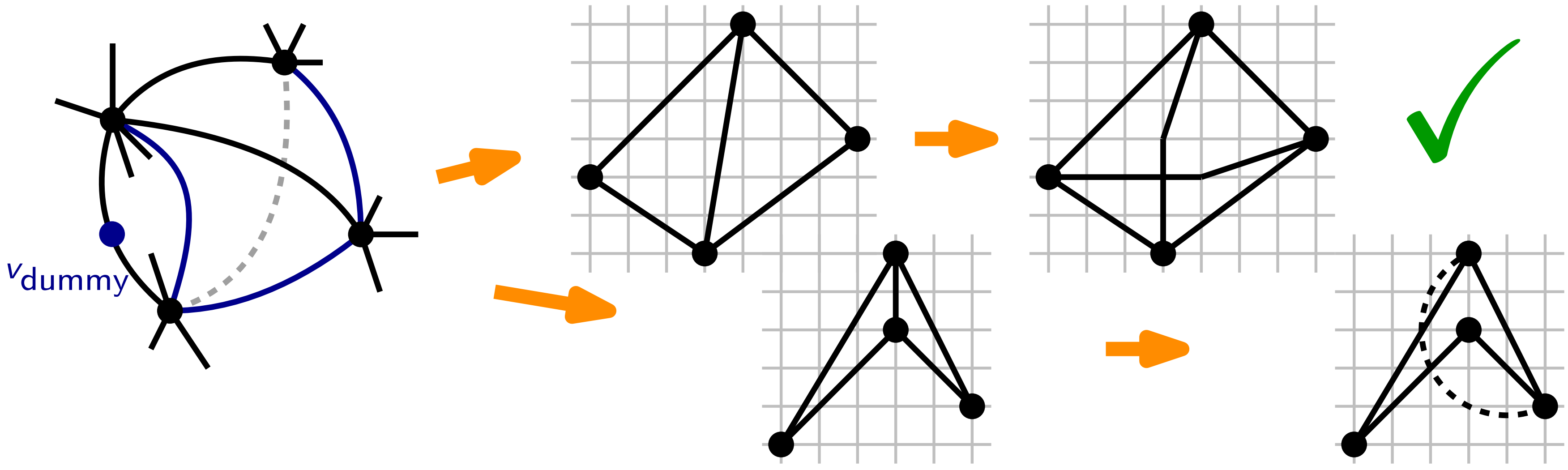


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

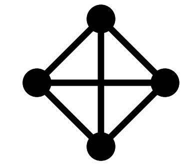
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

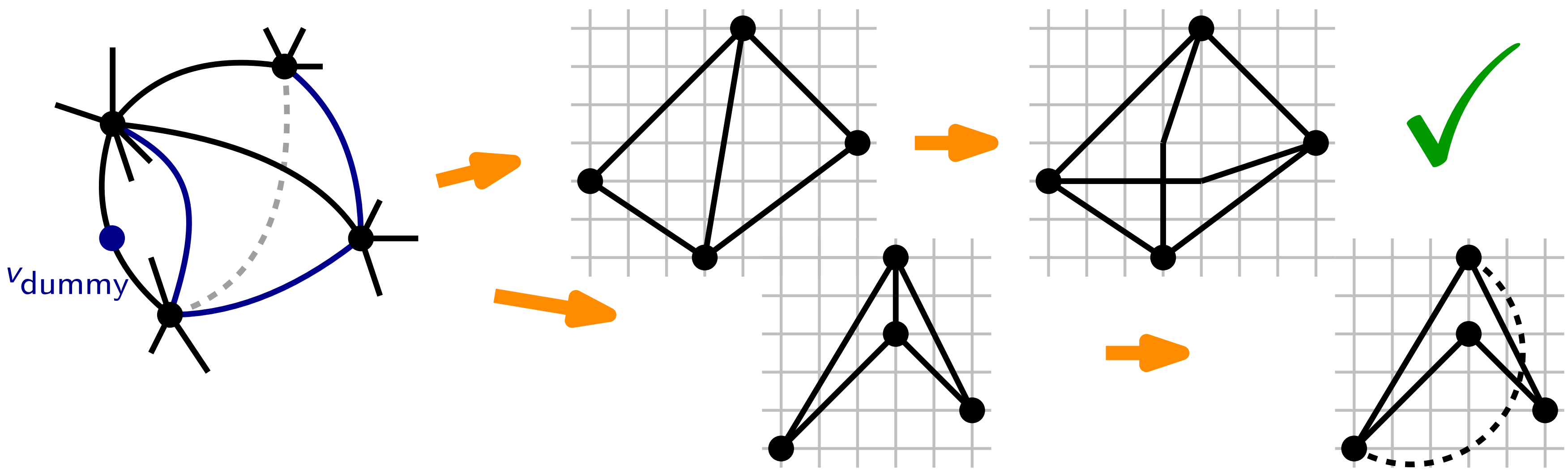


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

- Input: a NIC-plane graph

Approach that nearly works:

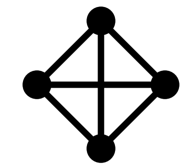
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)

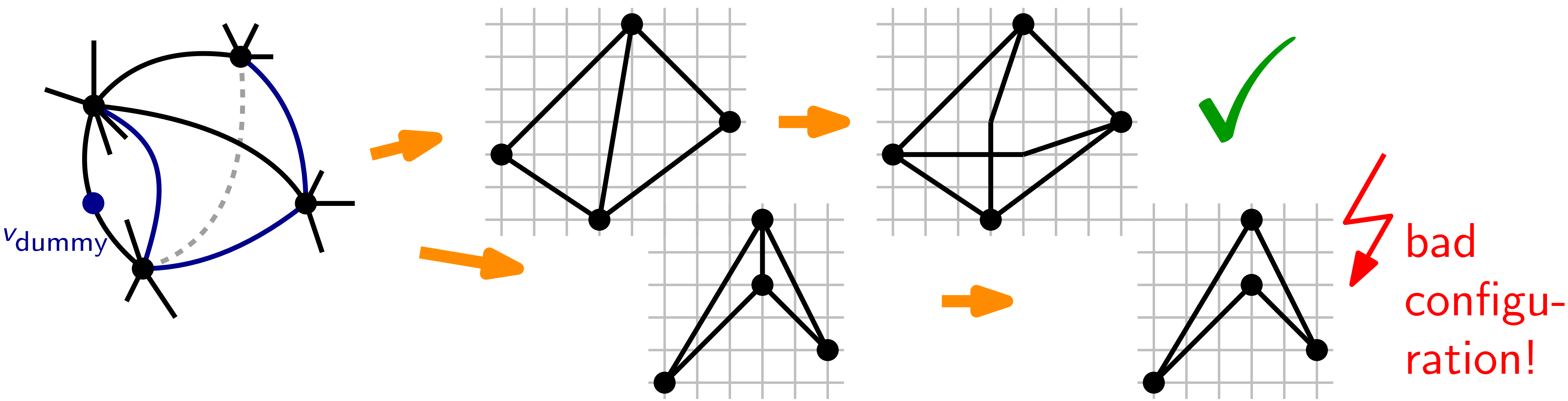


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

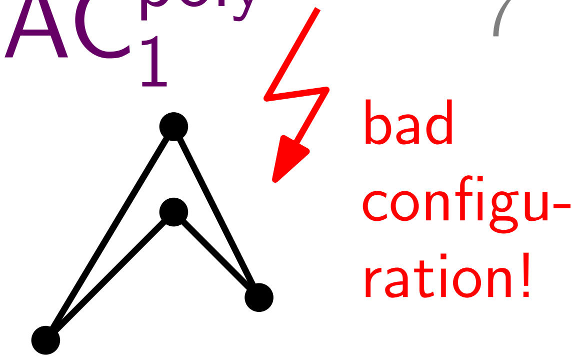
- Input: a NIC-plane graph

Approach that nearly works:

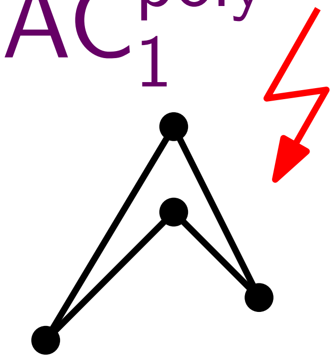
- Enclose each crossing by a so called *empty kite*: 
- Replace each pair of crossing edges by a single edge
- Draw the obtained plane graph with the Shift Algorithm
- Manually reinsert the removed edges with 1 bend so that they cross in a right angle (crossings and bends on the grid)



Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\mathrm{poly}}$



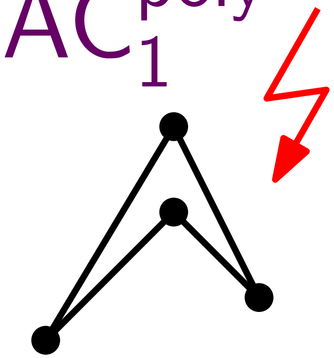
Result 1: NIC-Plane Graphs $\subseteq$ RAC_1^{poly}



Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

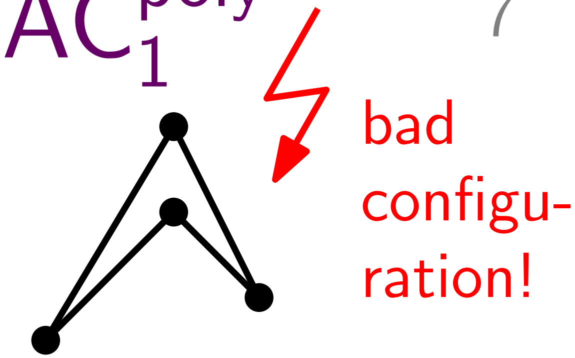
Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs).

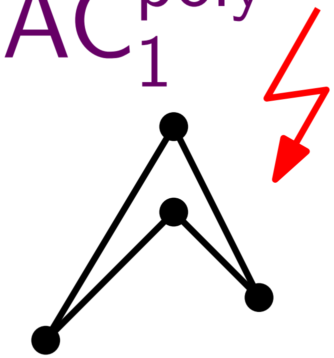
Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



Solution:

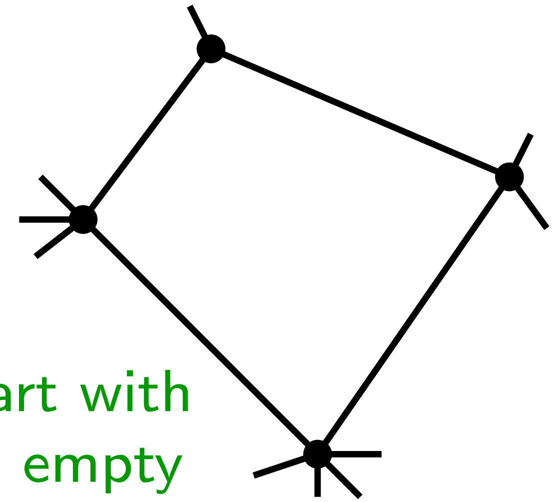
- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.

Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

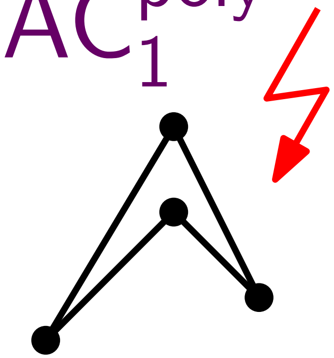


Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.



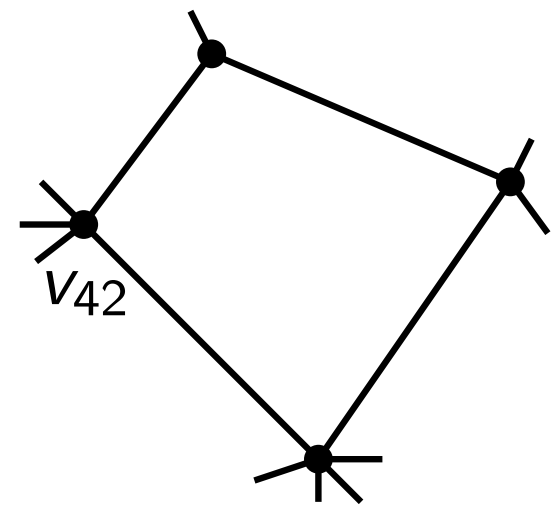
Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.

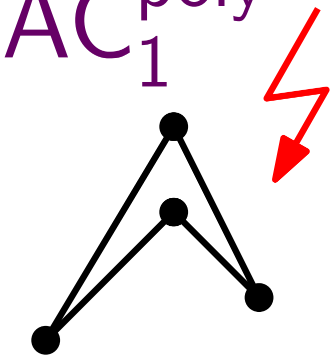


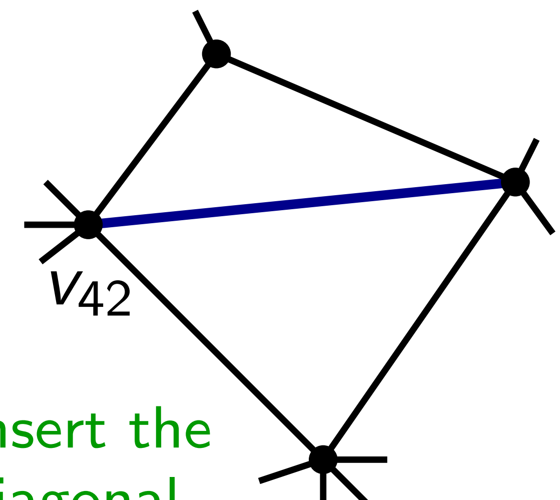
Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

Solution:

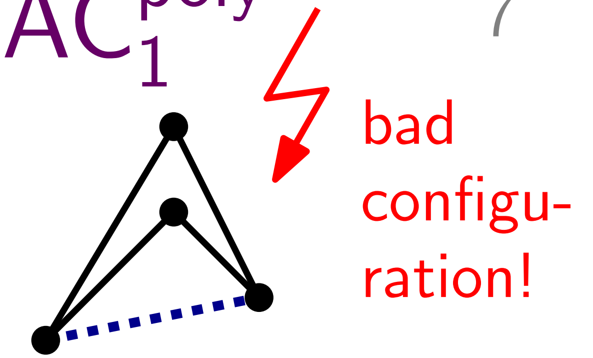
- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.



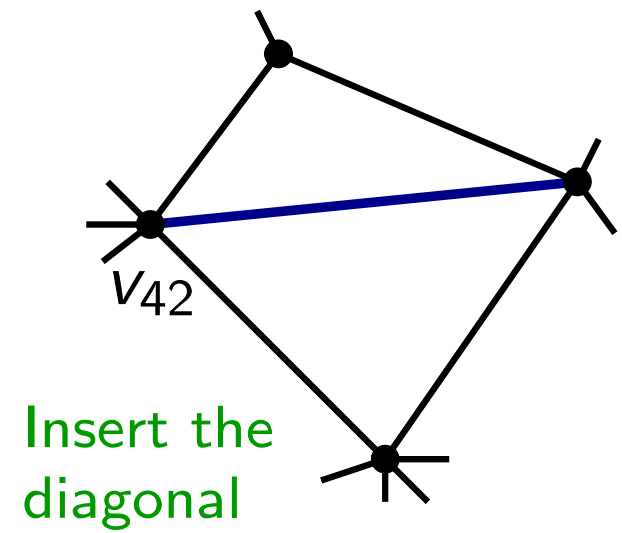


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

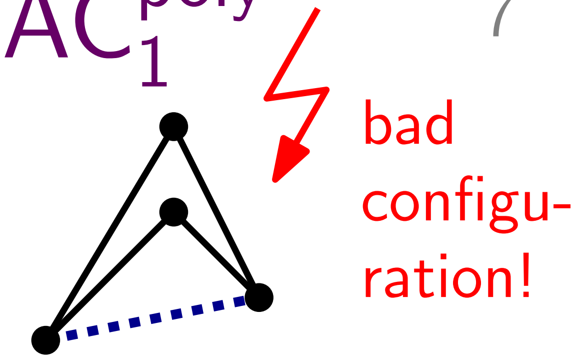


Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.

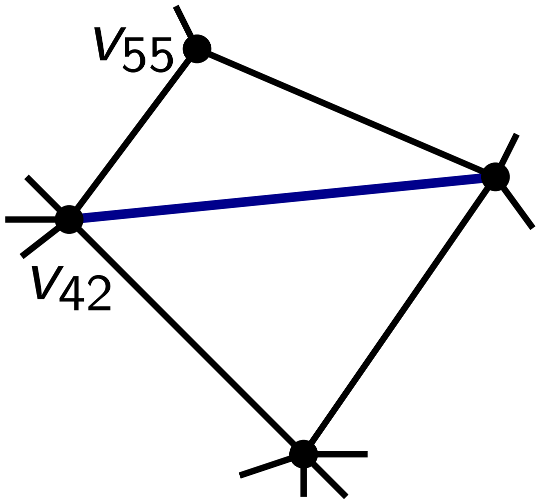


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

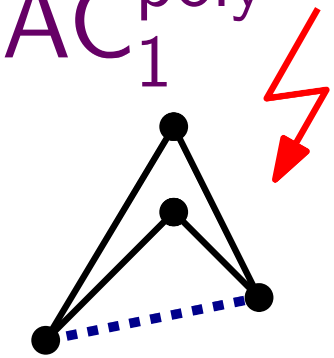


Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.



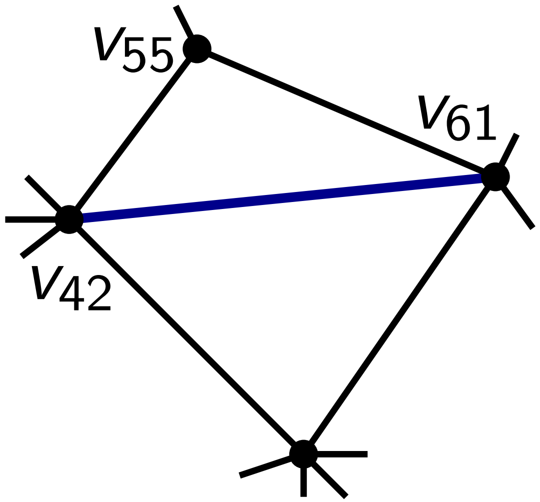
Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



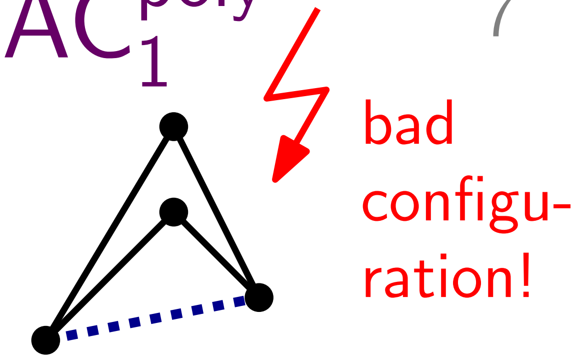
Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.

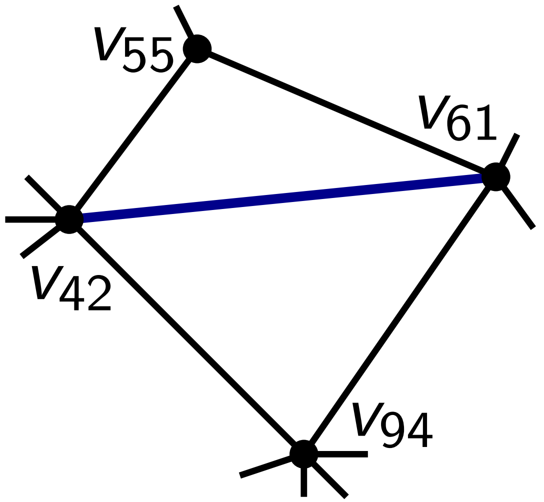


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

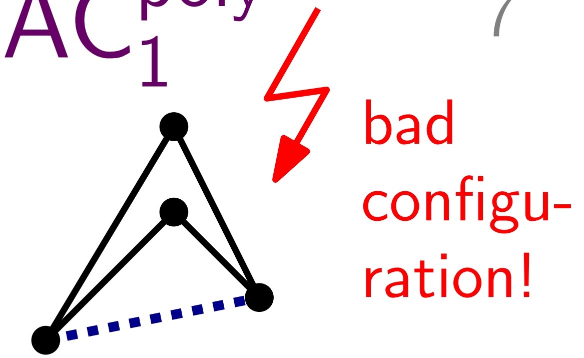


Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.

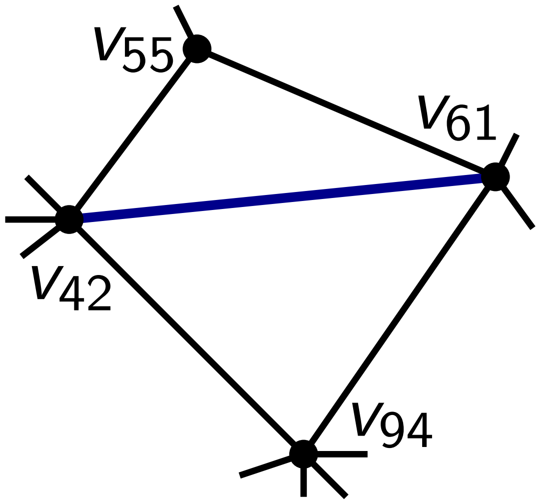


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

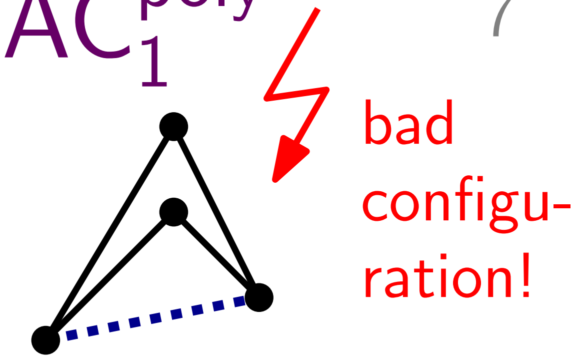


Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three "good" cases can appear:

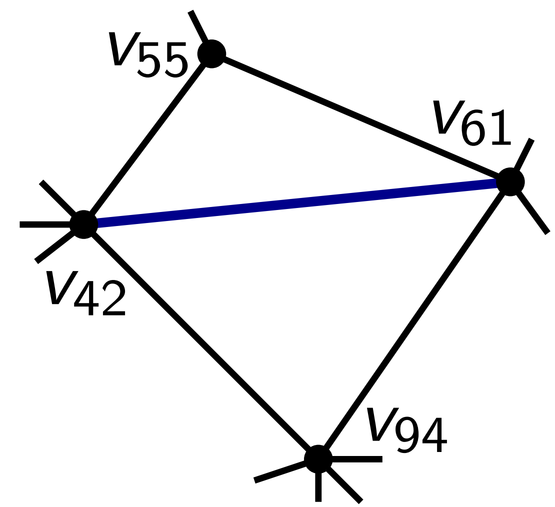


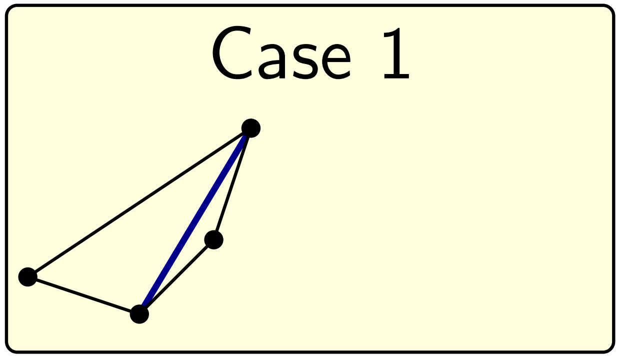
Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$



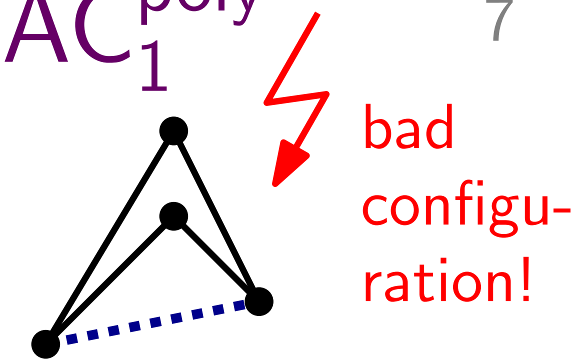
Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three "good" cases can appear:



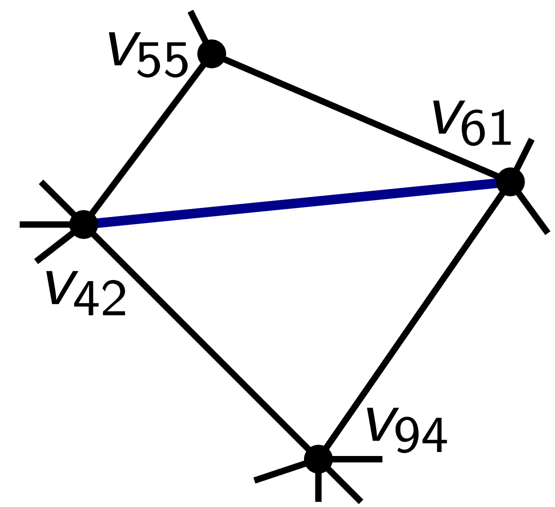


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{poly}$

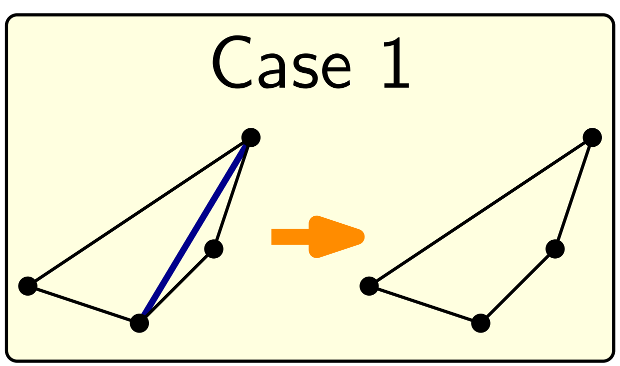


Solution:

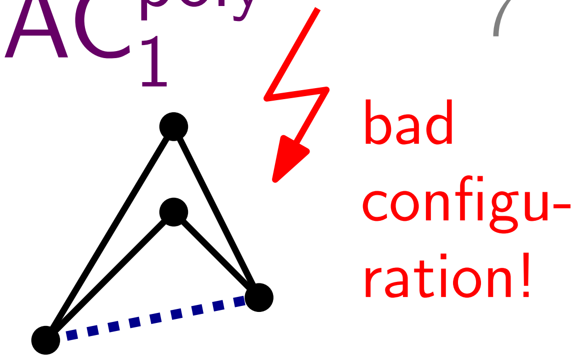
- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.



- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three “good” cases can appear:

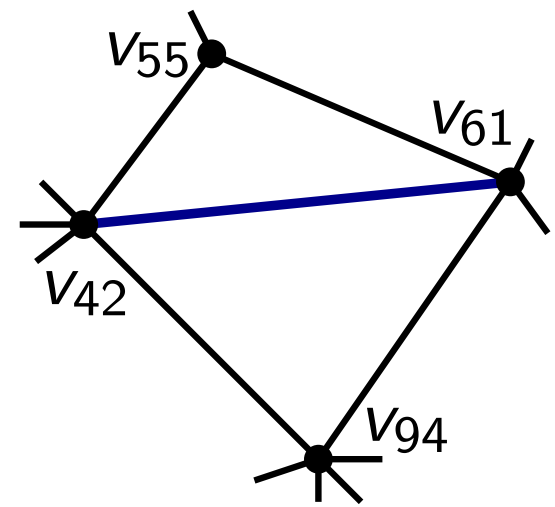


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



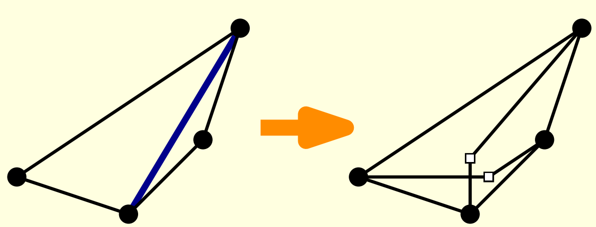
Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

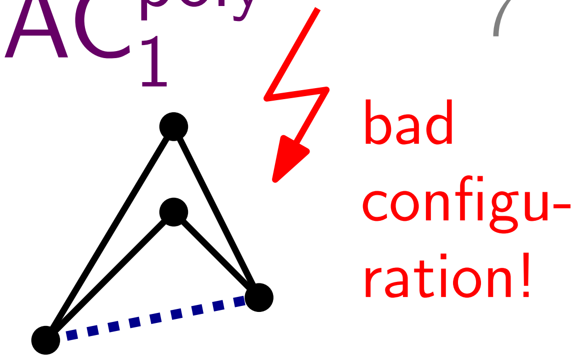


- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three "good" cases can appear:

Case 1

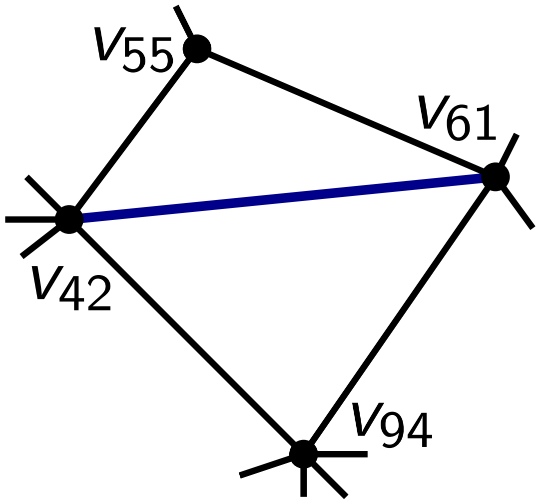


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

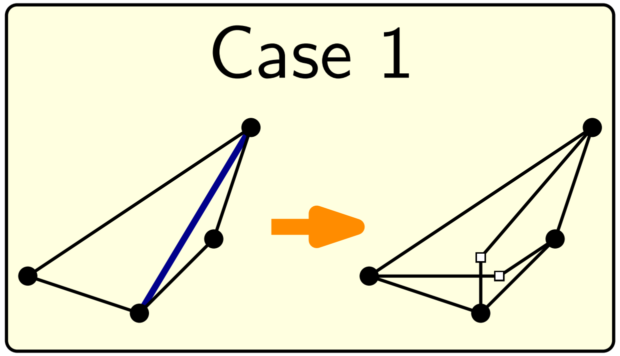


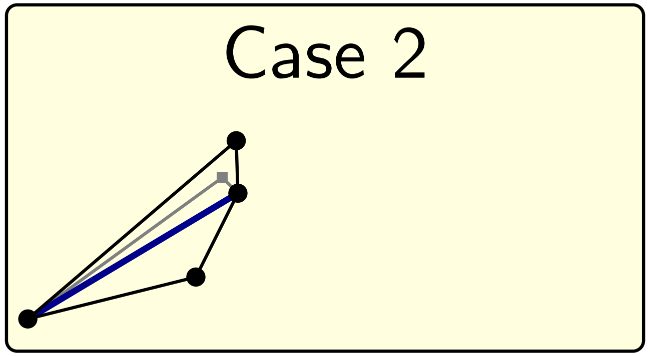
Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

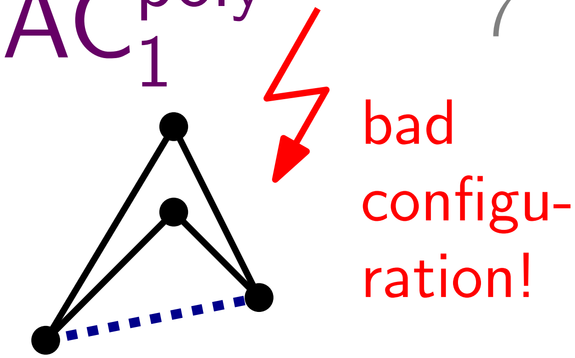


- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three “good” cases can appear:



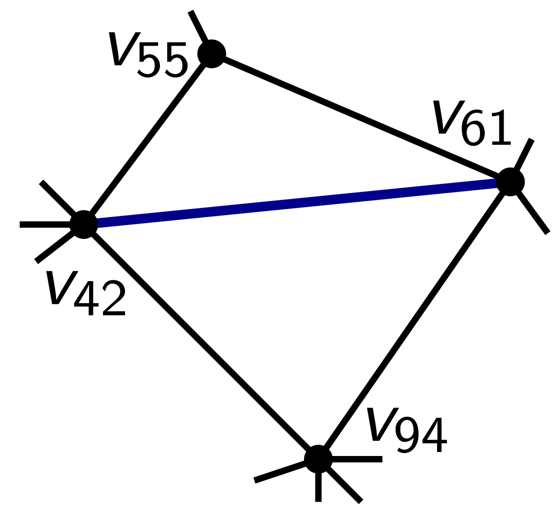


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

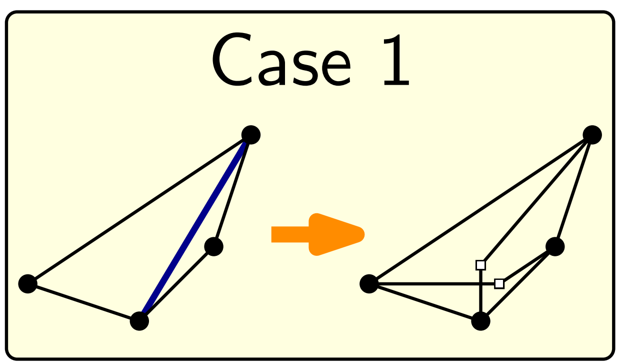


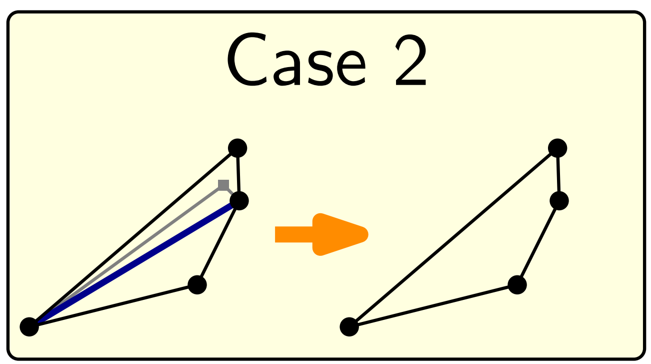
Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

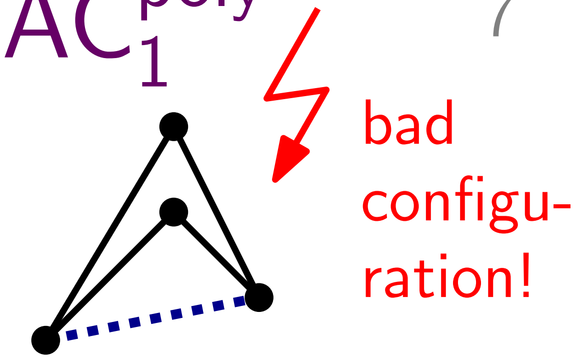


- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three "good" cases can appear:



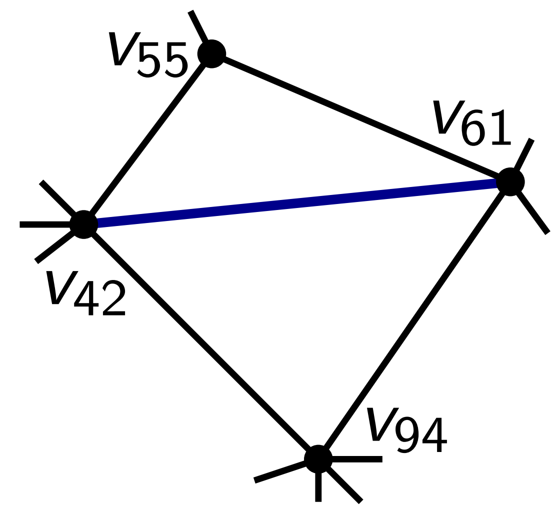


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



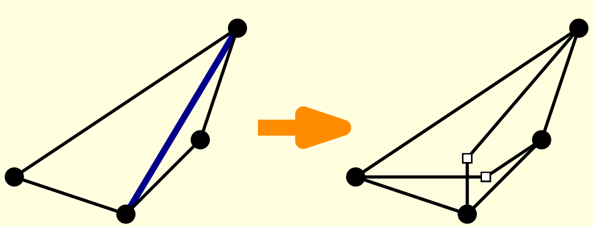
Solution:

- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.

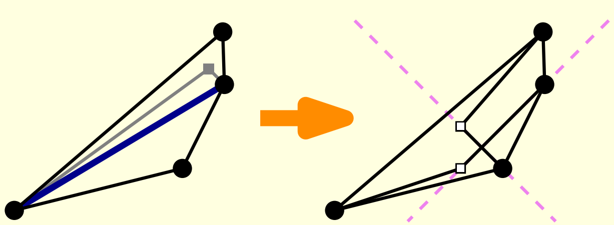


- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three "good" cases can appear:

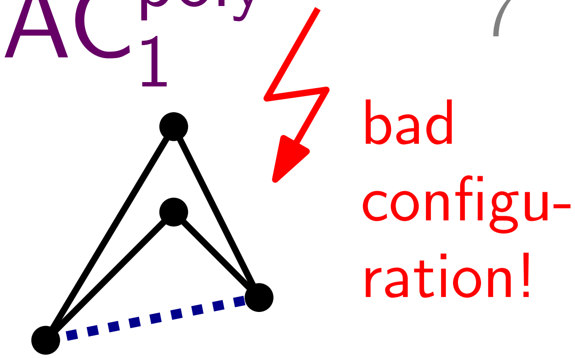
Case 1



Case 2

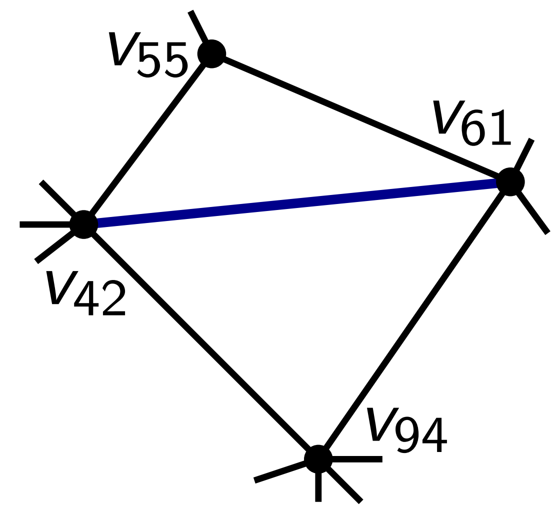


Result 1: NIC-Plane Graphs $\subseteq RAC_1^{poly}$

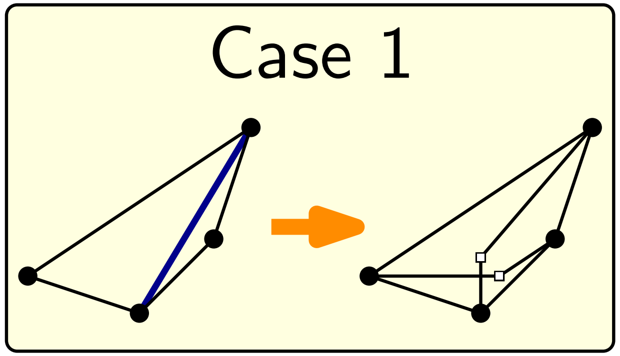


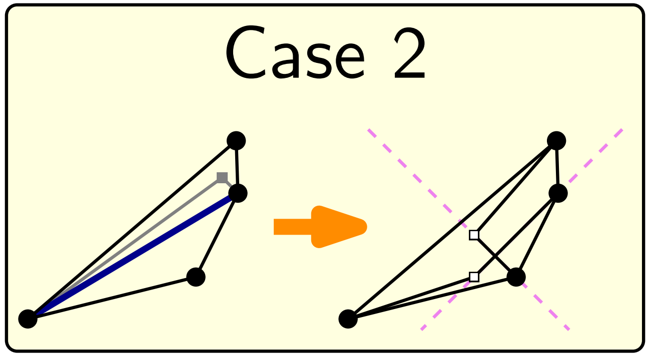
Solution:

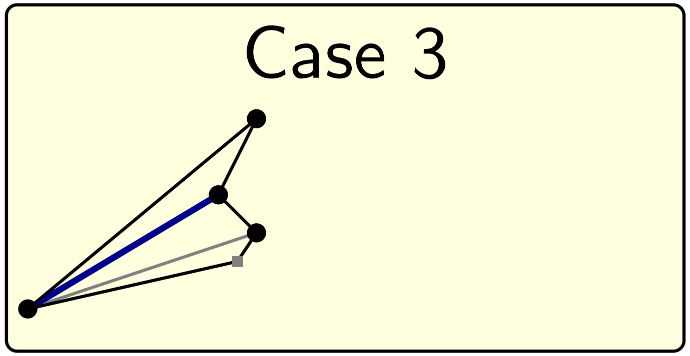
- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.



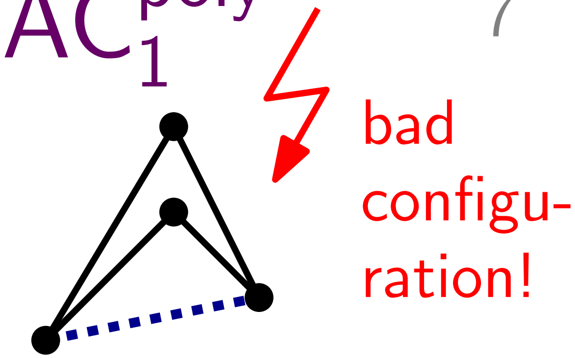
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three "good" cases can appear:





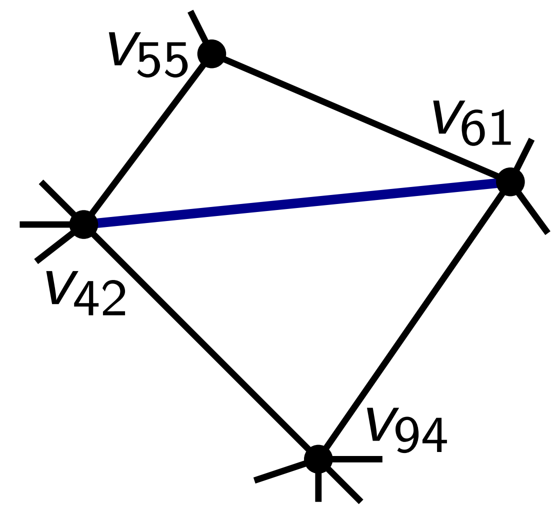


Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

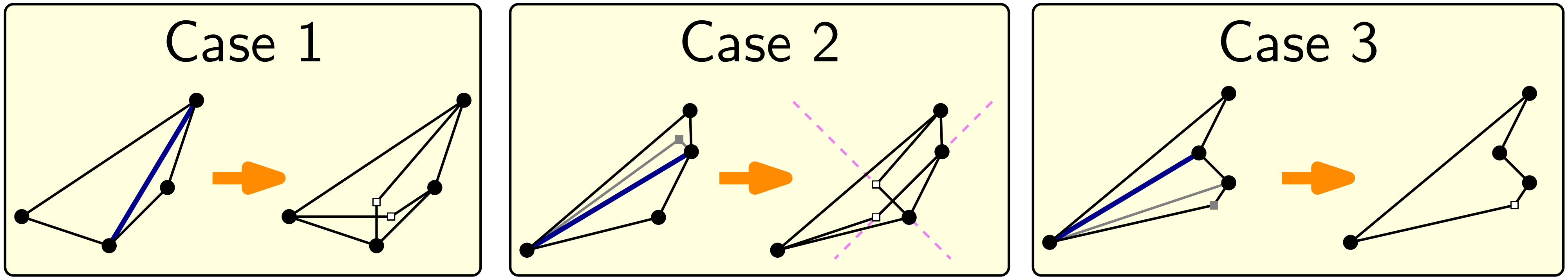


Solution:

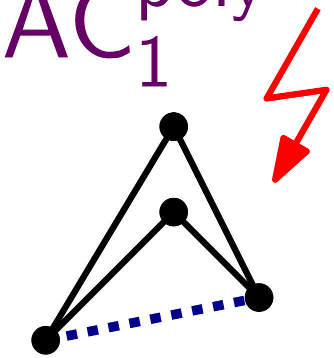
- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.



- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.
- Now only three "good" cases can appear:



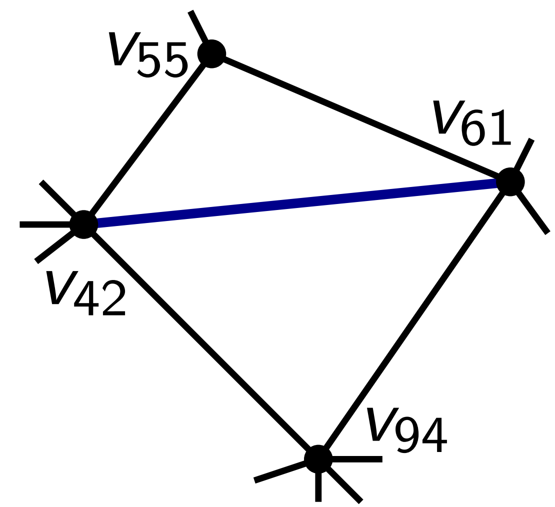
Result 1: NIC-Plane Graphs $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



bad configu-ration!

Solution:

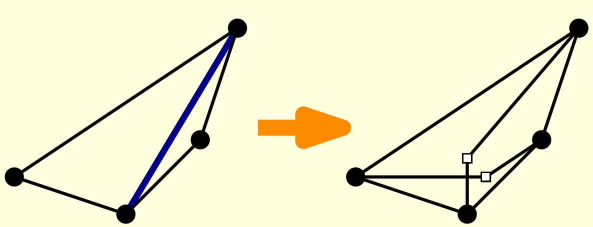
- Make the first vertex in the qudrangle (regarding the canonical ordering) adjacent to the other three vertices.



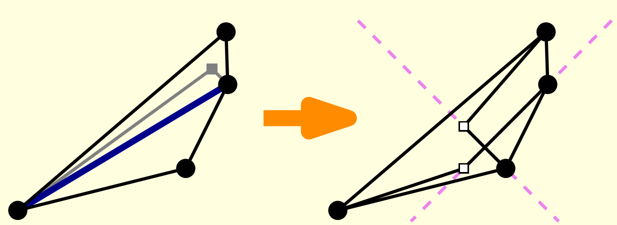
- Use the algorithm by Harel and Sardas (Shift Algorithm for biconnected graphs). It builds a canonical ordering bottom-up instead of top-down.

- Now only three “good” cases can appear:

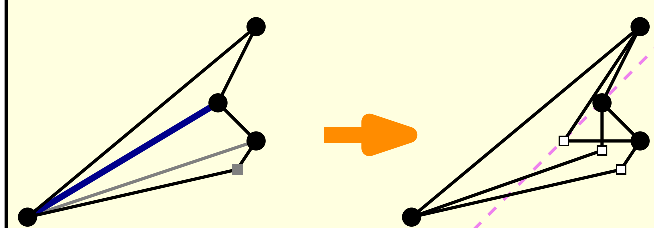
Case 1



Case 2

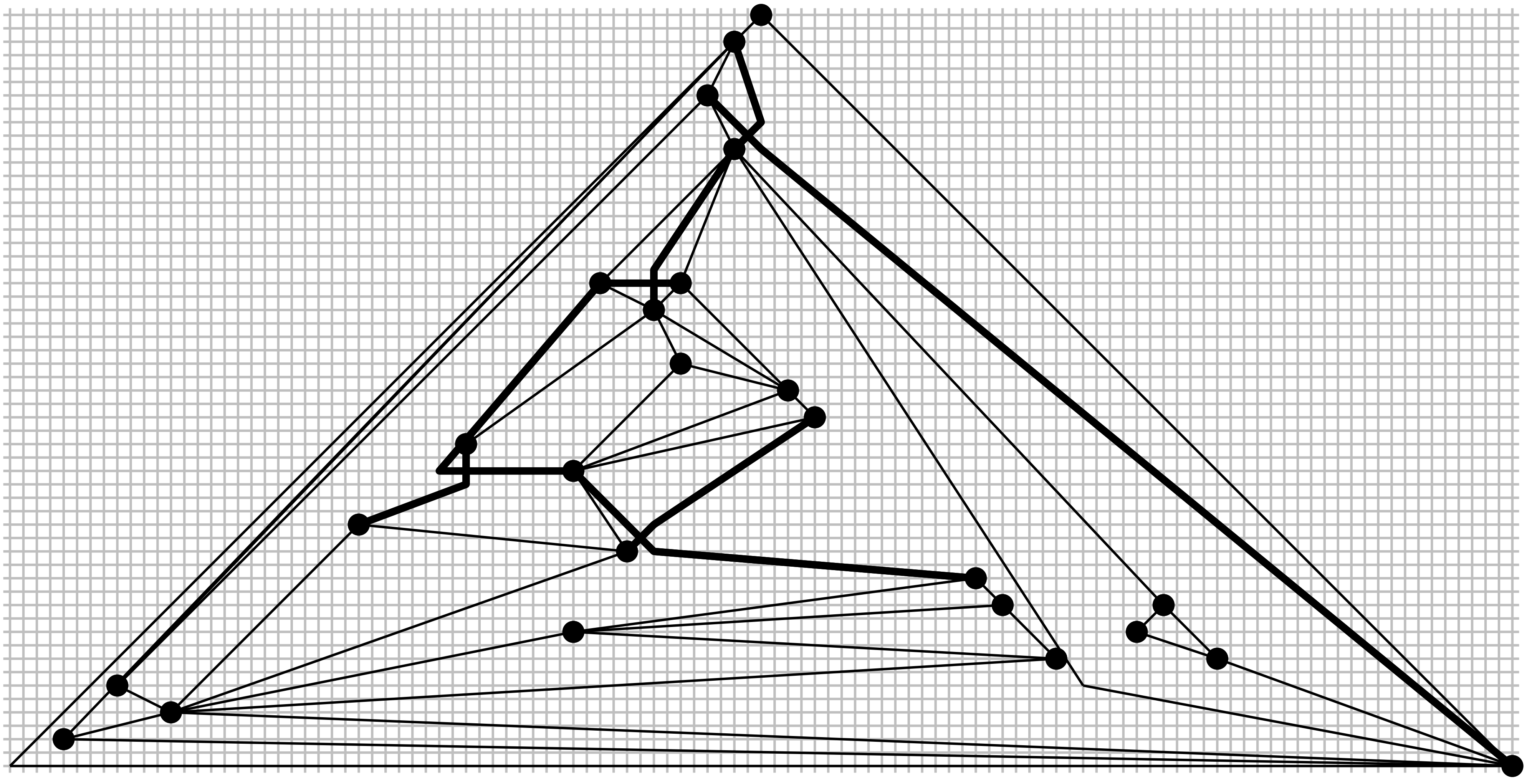


Case 3



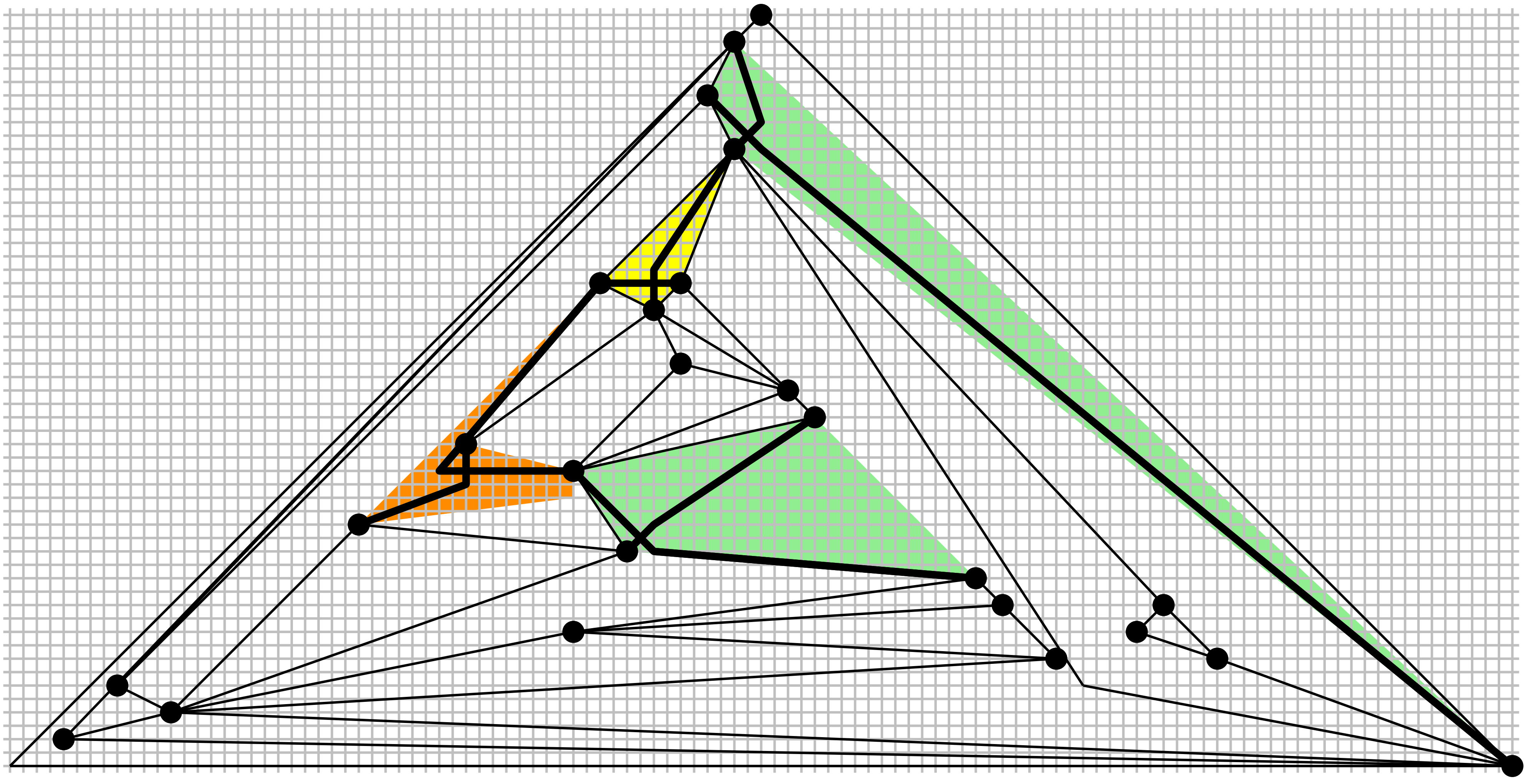
Result 1: NIC-Plane Graphs $\subseteq \text{RAC}_1^{\text{poly}}$

Full example:

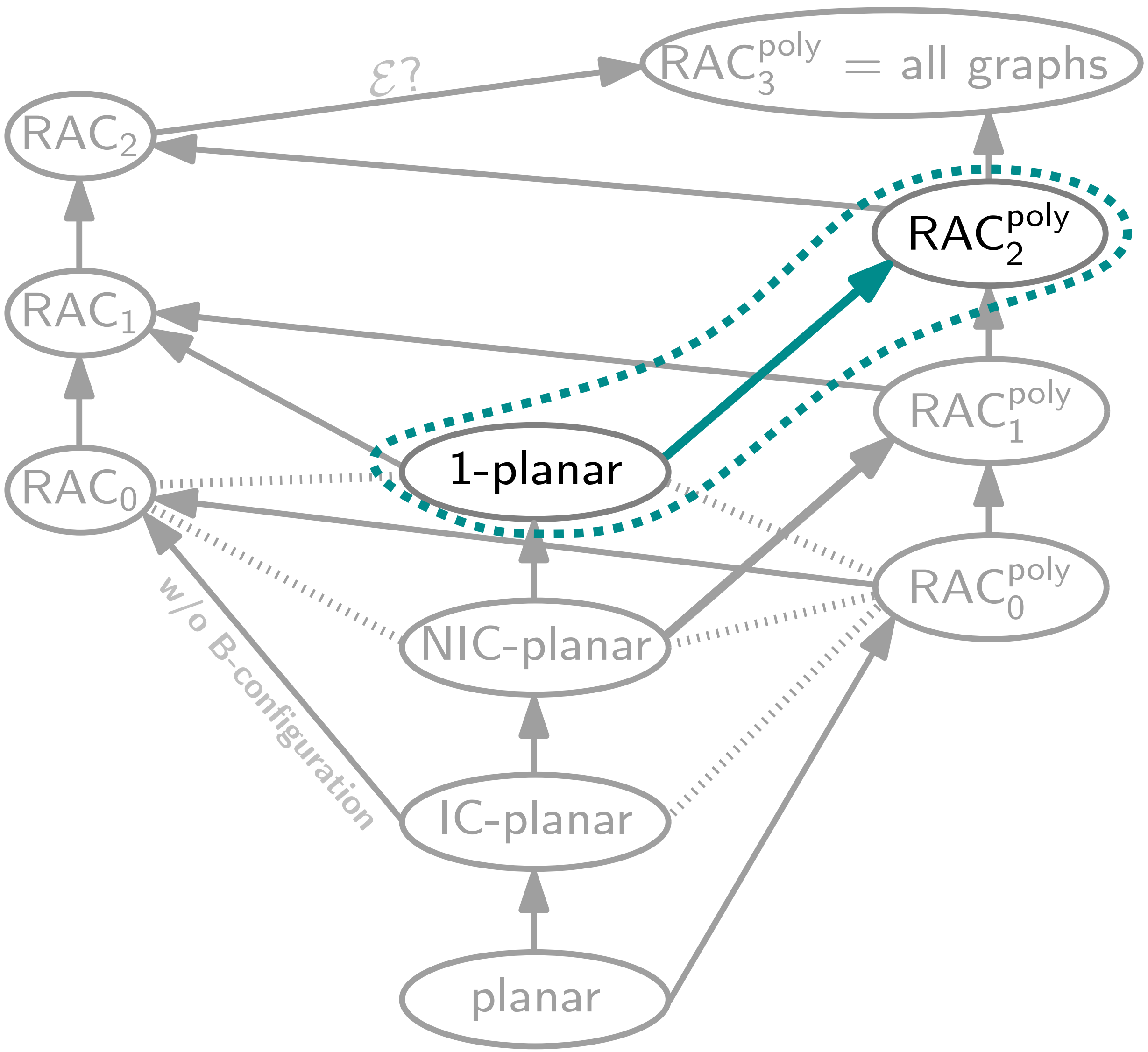


Result 1: NIC-Plane Graphs $\subseteq$ RAC$_1^{\text{poly}}$

Full example:



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$



Result 2: 1-Plane Graphs $\subseteq \mathsf{RAC}_2^{\mathsf{poly}}$

- Input: a 1-plane graph

Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

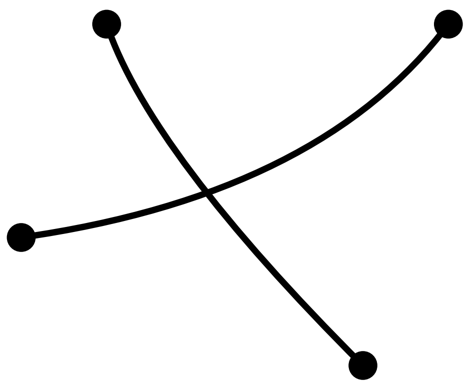
- Input: a 1-plane graph

Preprocessing:

Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

- Input: a 1-plane graph

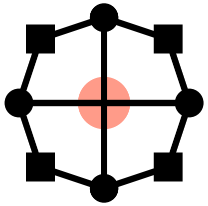
Preprocessing:

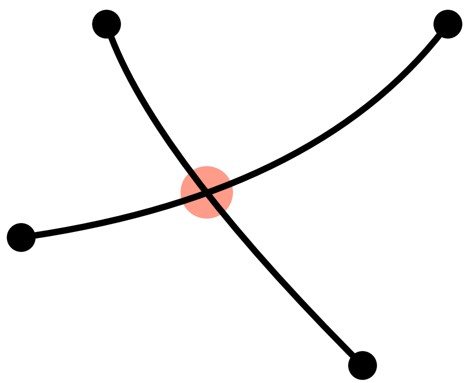


Result 2: 1-Plane Graphs $\subseteq$ RAC_2^{poly}

- Input: a 1-plane graph

Preprocessing:

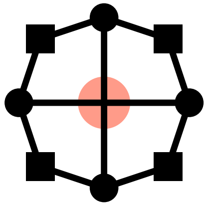
- Enclose each crossing by a so called *subdivided kite*: 

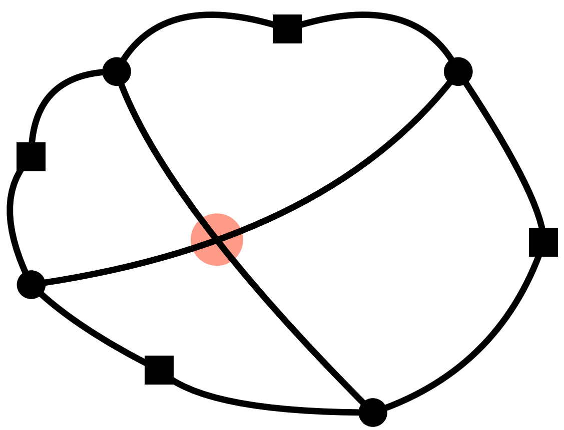


Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

- Input: a 1-plane graph

Preprocessing:

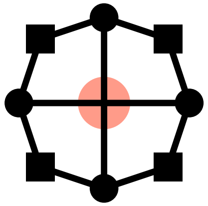
- Enclose each crossing by a so called *subdivided kite*: 

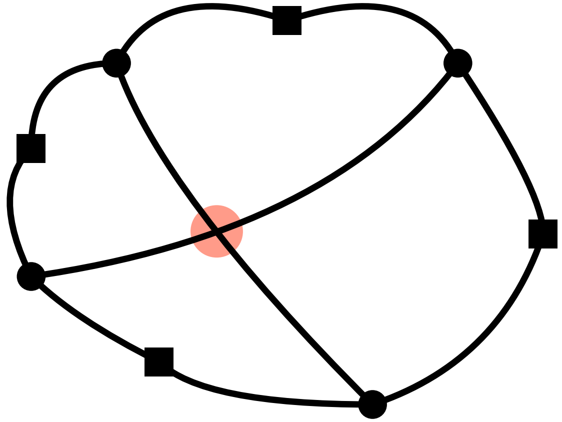


Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

- Input: a 1-plane graph

Preprocessing:

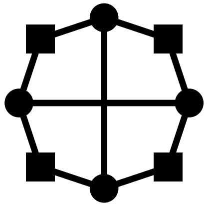
- Enclose each crossing by a so called *subdivided kite*: 
- Planarize the graph by replacing each crossing by a vertex

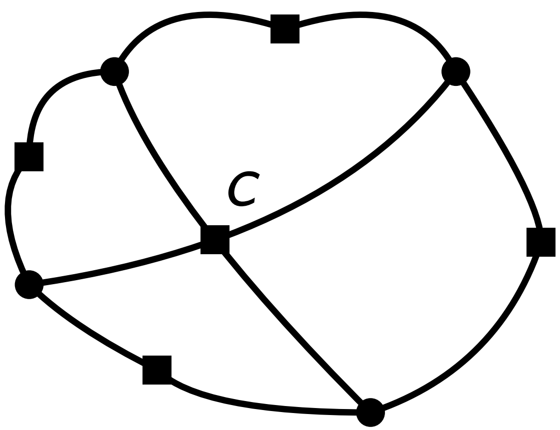


Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

- Input: a 1-plane graph

Preprocessing:

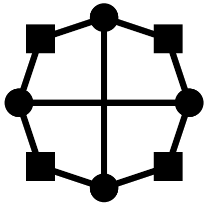
- Enclose each crossing by a so called *subdivided kite*: 
- Planarize the graph by replacing each crossing by a vertex



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

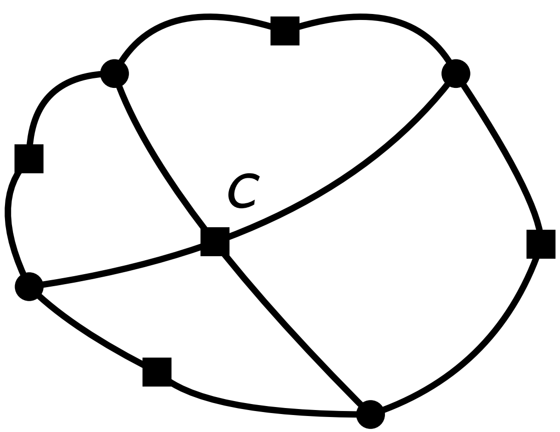
- Input: a 1-plane graph

Preprocessing:

- Enclose each crossing by a so called *subdivided kite*: 
- Planarize the graph by replacing each crossing by a vertex

Drawing phase:

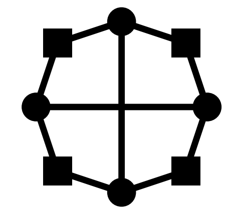
- Draw the obtained plane graph using the Shift Algorithm



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

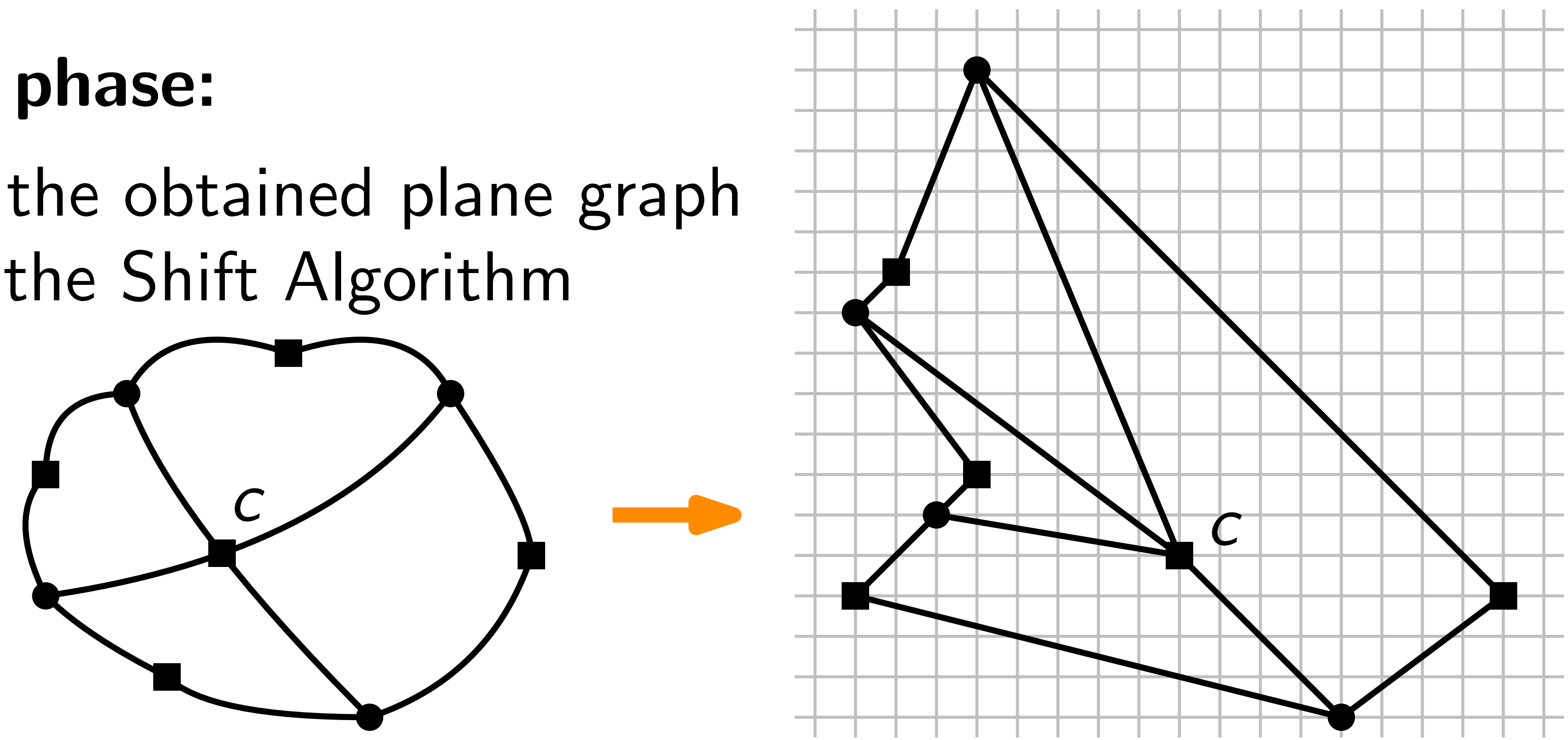
- Input: a 1-plane graph

Preprocessing:

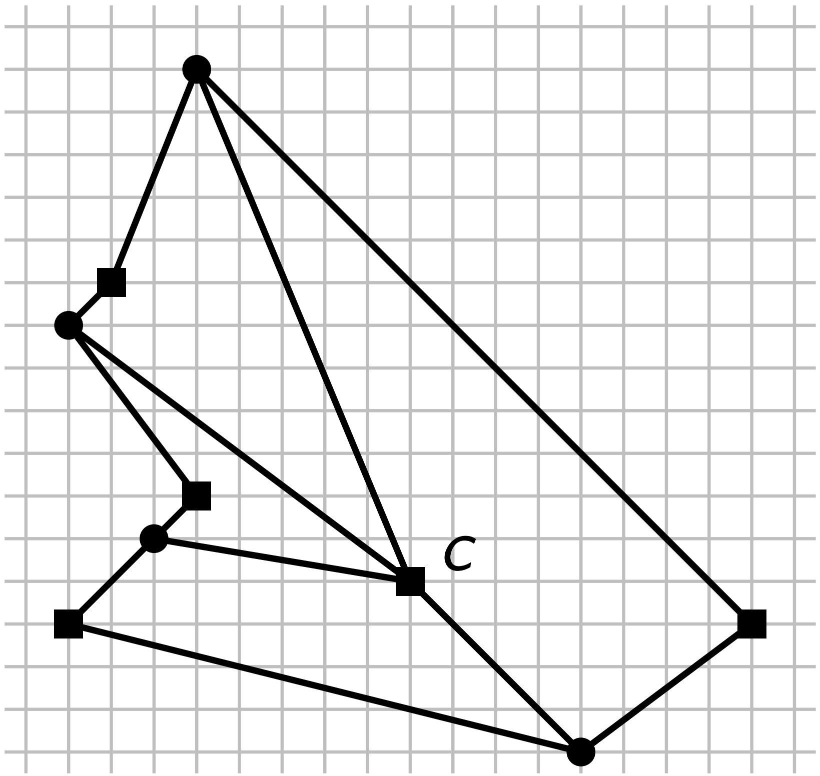
- Enclose each crossing by a so called *subdivided kite*: 
- Planarize the graph by replacing each crossing by a vertex

Drawing phase:

- Draw the obtained plane graph using the Shift Algorithm

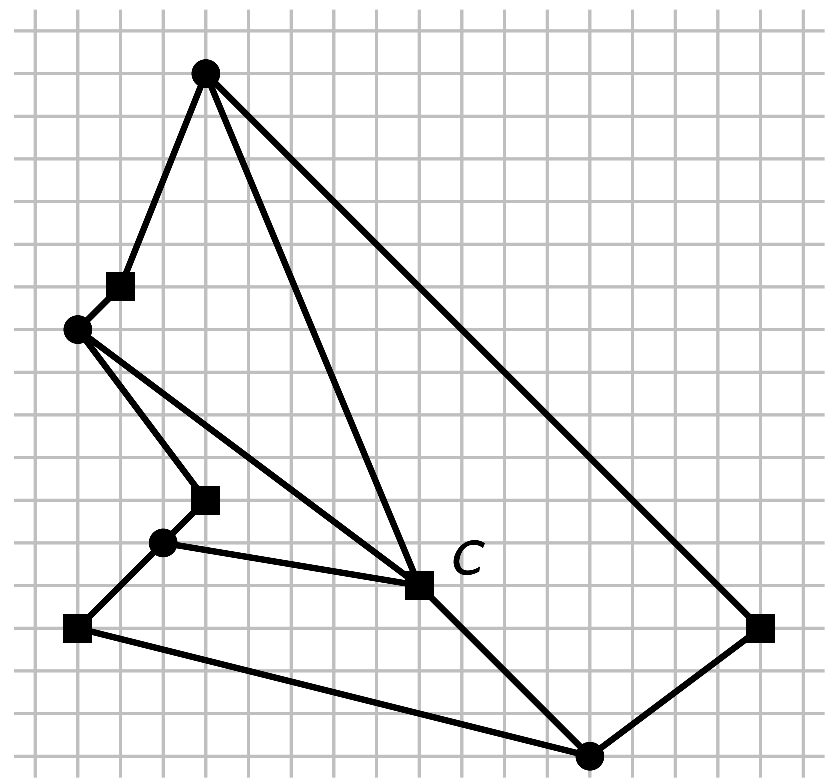


Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$



Result 2: 1-Plane Graphs $\subseteq \text{RAC}_2^{\text{poly}}$

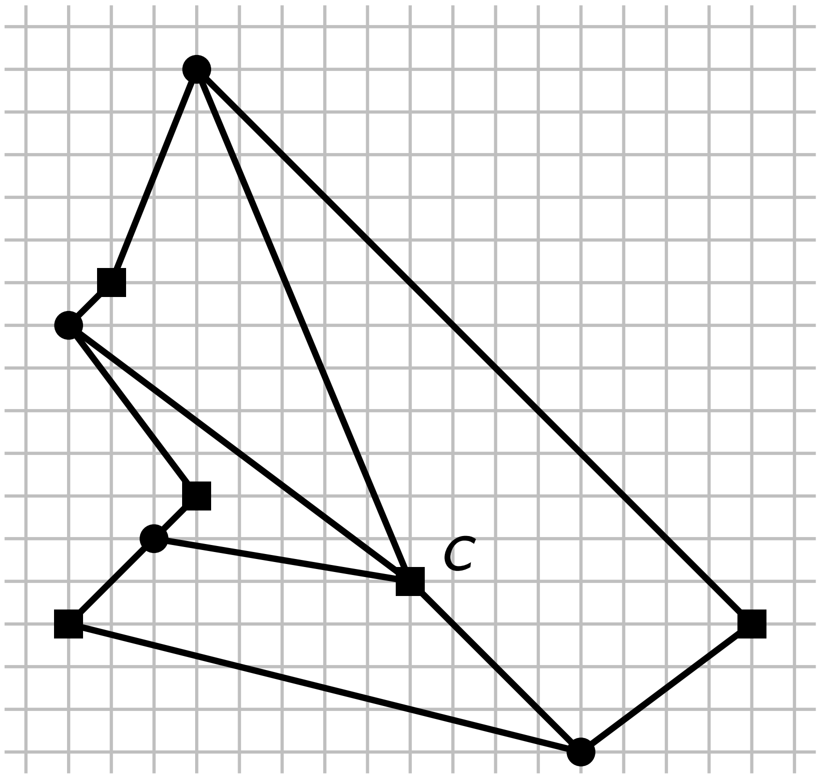
Postprocessing (obtaining crossings at right angles):



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

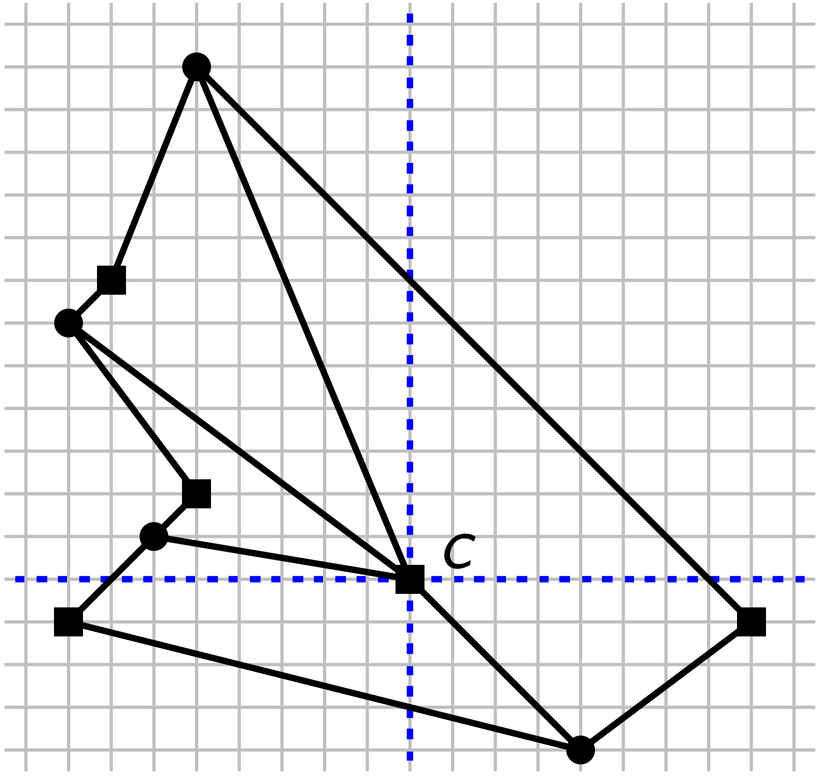
- Consider the four axis-parallel half-lines originating at c



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

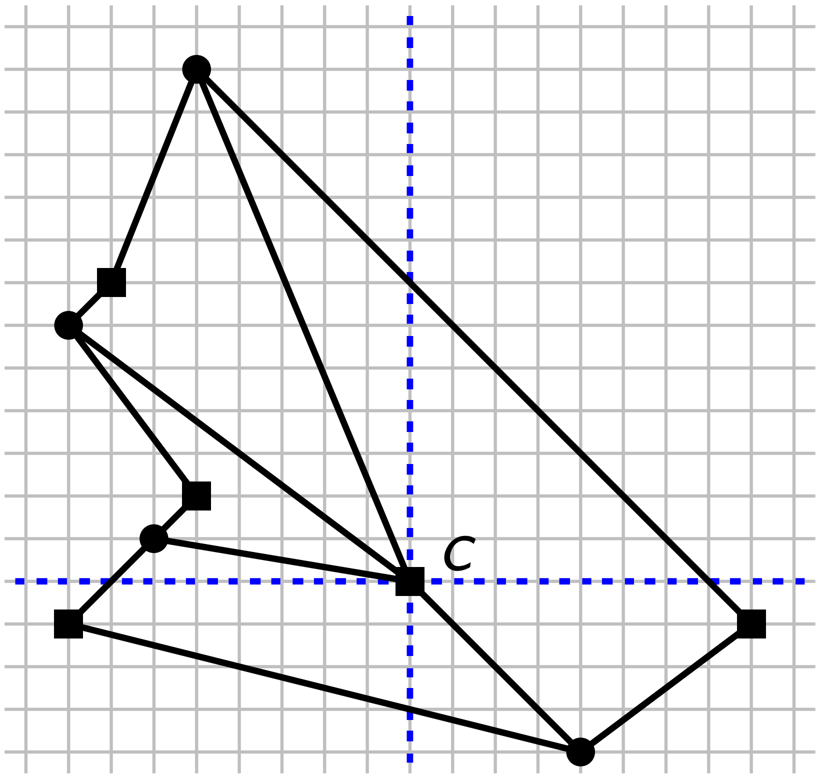
- Consider the four axis-parallel half-lines originating at c



Result 2: 1-Plane Graphs $\subseteq RAC_2^{poly}$

Postprocessing (obtaining crossings at right angles):

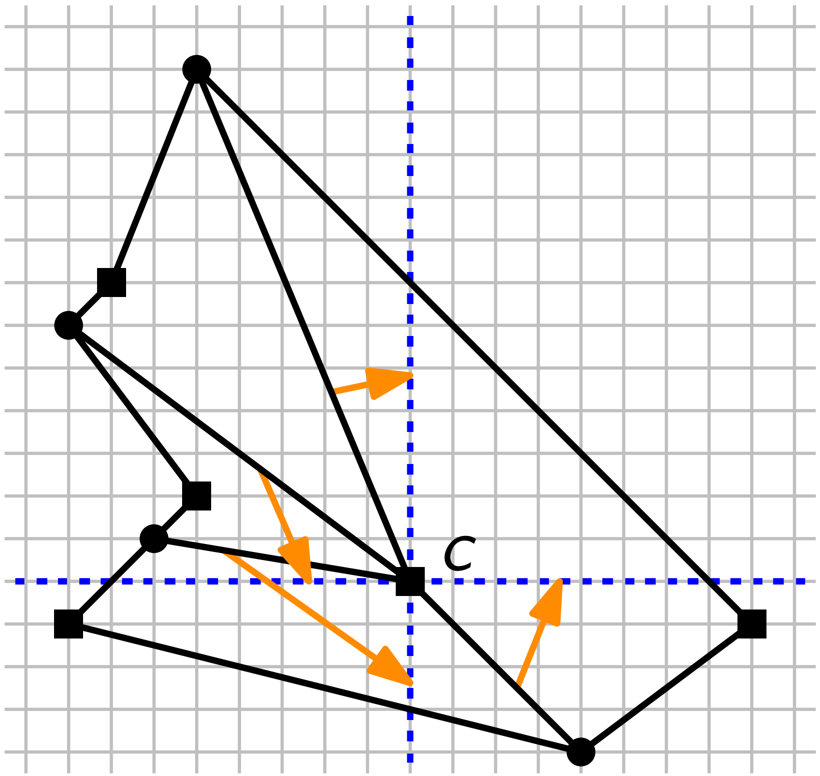
- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines



Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

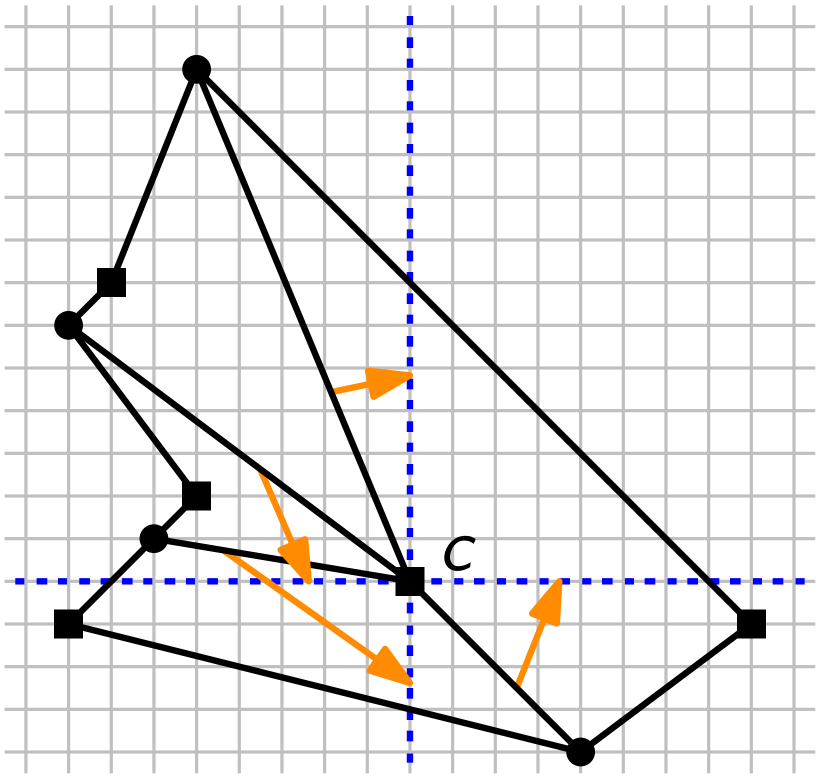
- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines



Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

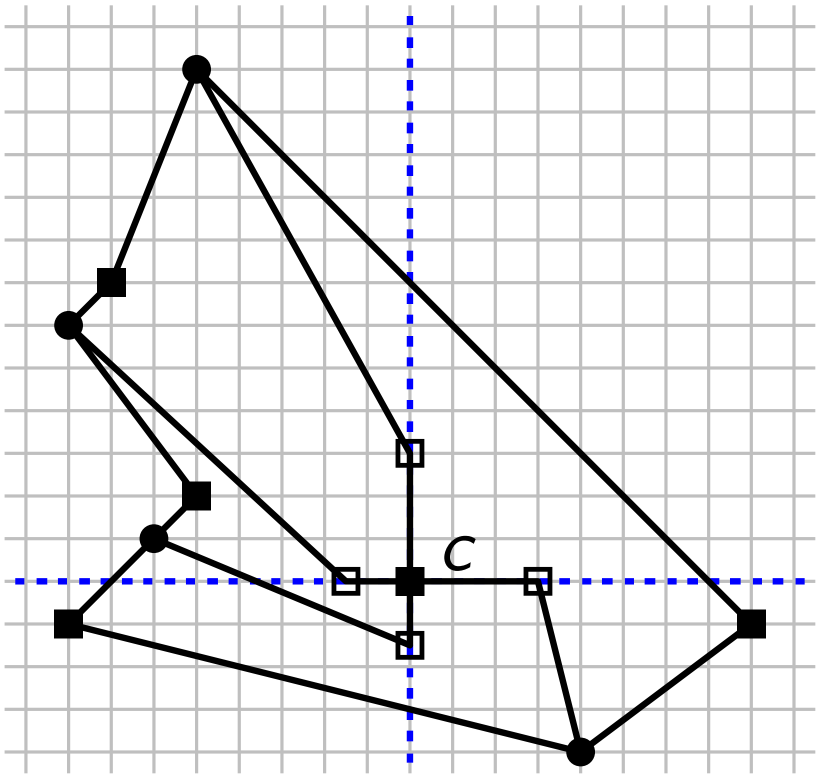
- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:



Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

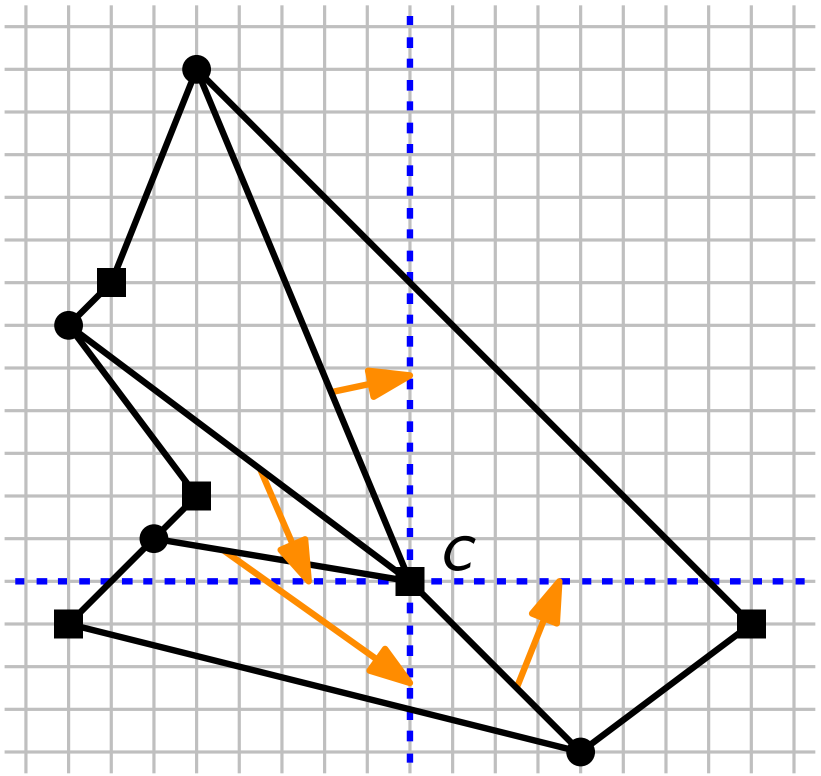
- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:



Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:

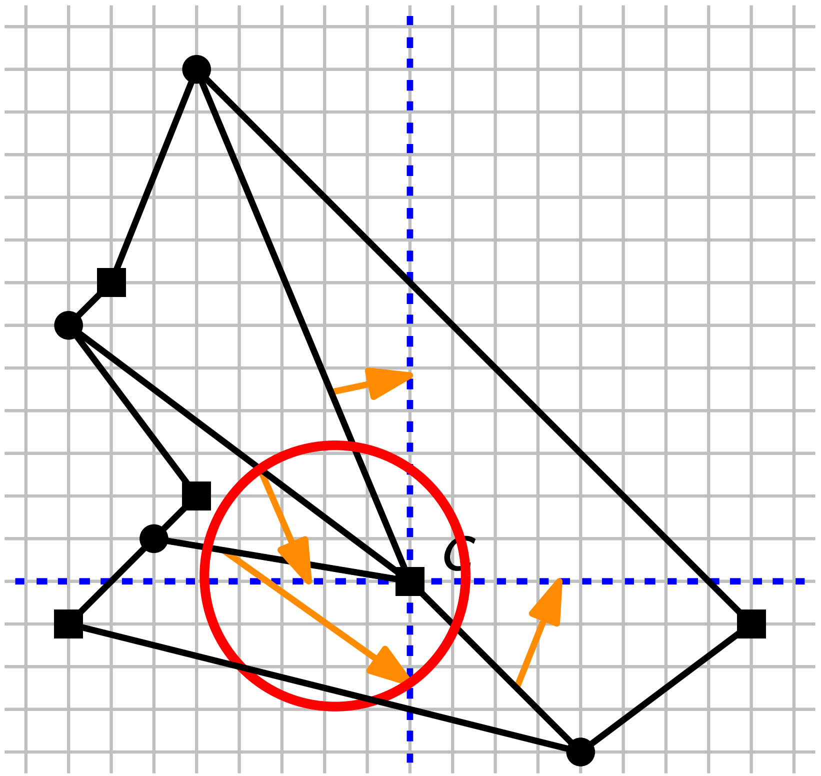


Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:

Be careful:
One assignment
might depend on
another one



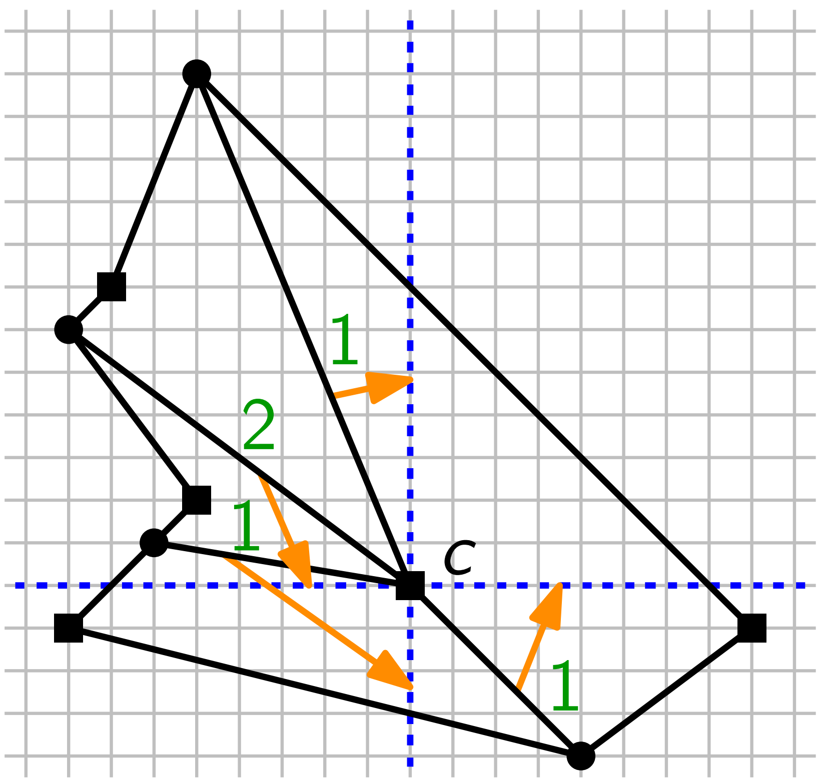
Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:

Be careful:
One assignment
might depend on
another one

Solution:
re-draw the
independent
ones first



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

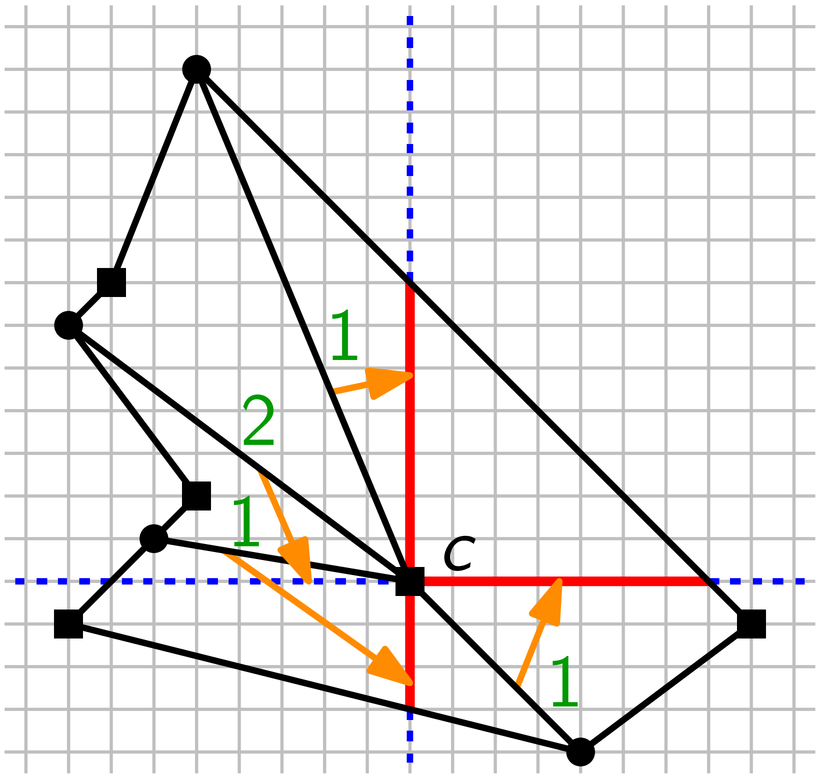
Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:

Be careful:
One assignment might depend on another one

Solution:
re-draw the independent ones first

Be careful:
There might be no grid points to bend the edges



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

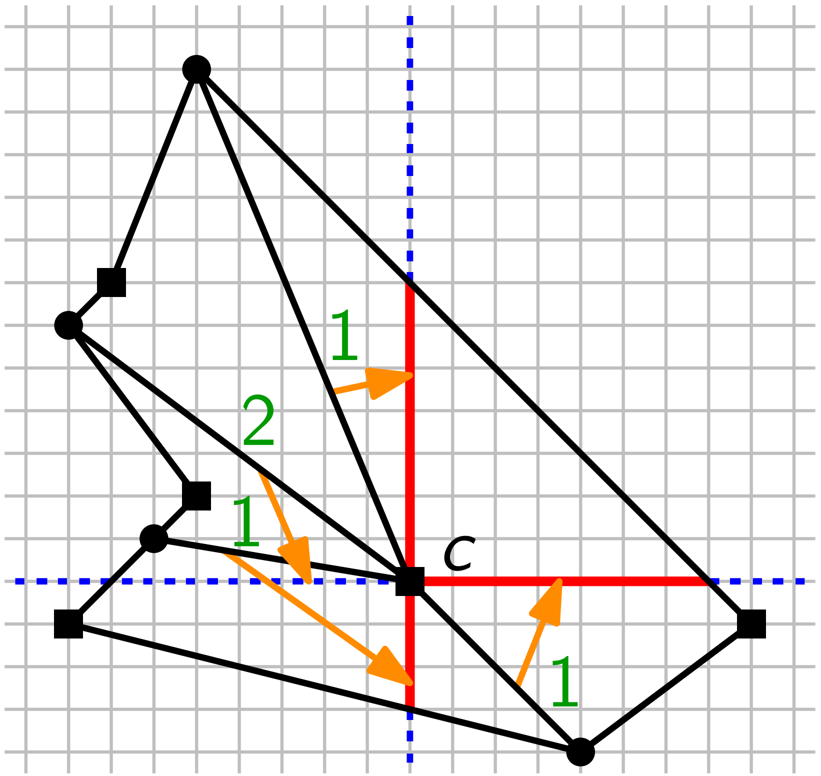
- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:

Be careful:
One assignment might depend on another one

Solution:
re-draw the independent ones first

Be careful:
There might be no grid points to bend the edges

Solution:
make the grid sufficiently fine



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:

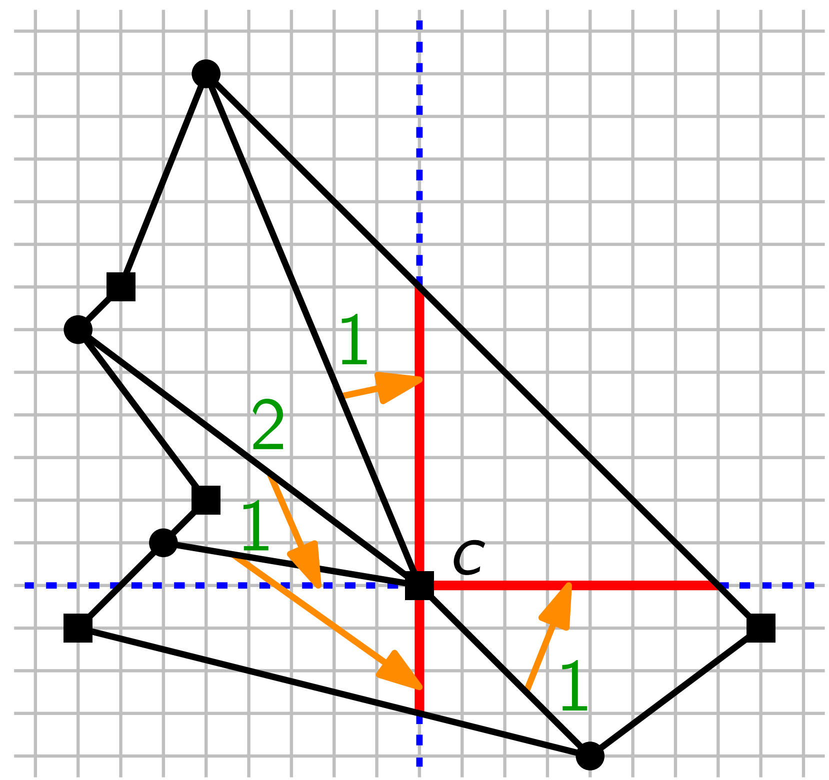
grid size: $O(n) \times O(n)$

Be careful:
One assignment might depend on another one

Solution:
re-draw the independent ones first

Be careful:
There might be no grid points to bend the edges

Solution:
make the grid sufficiently fine

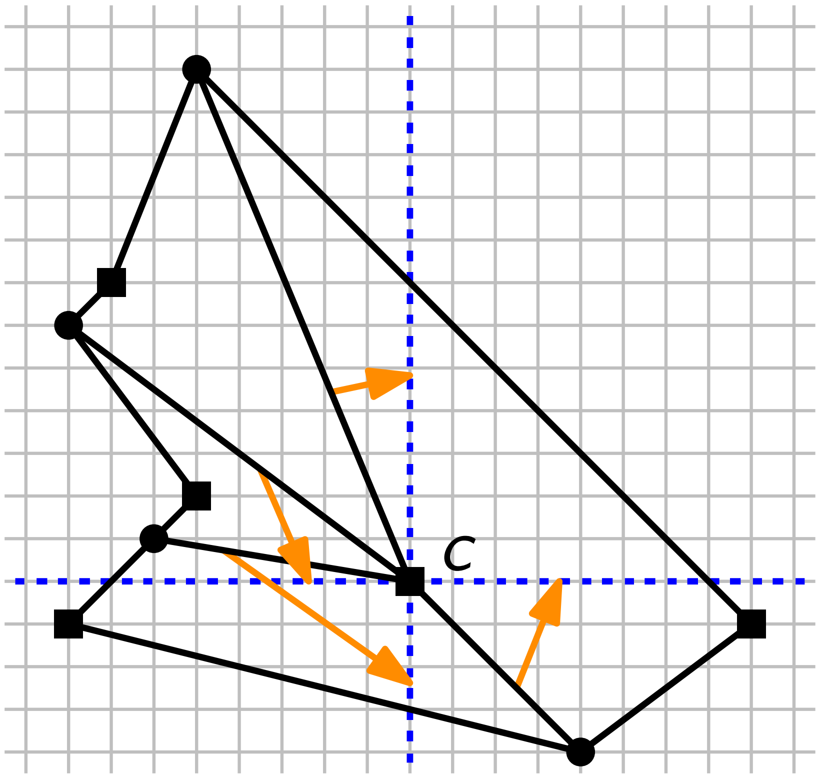


Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$

grid size: $O(n) \times O(n)$

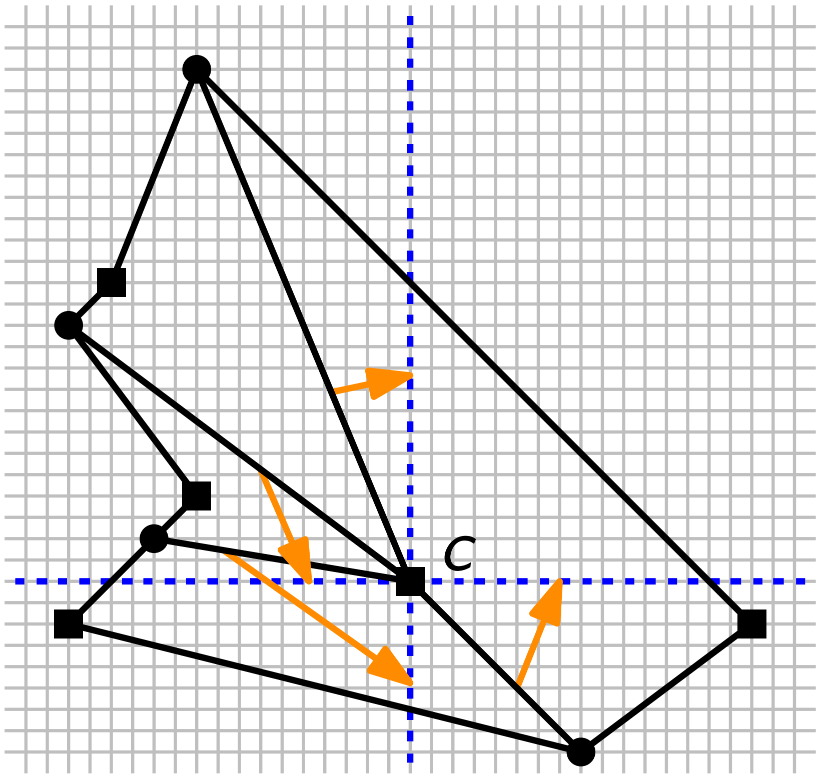


Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$

grid size:
$O(n^2) \times O(n^2)$

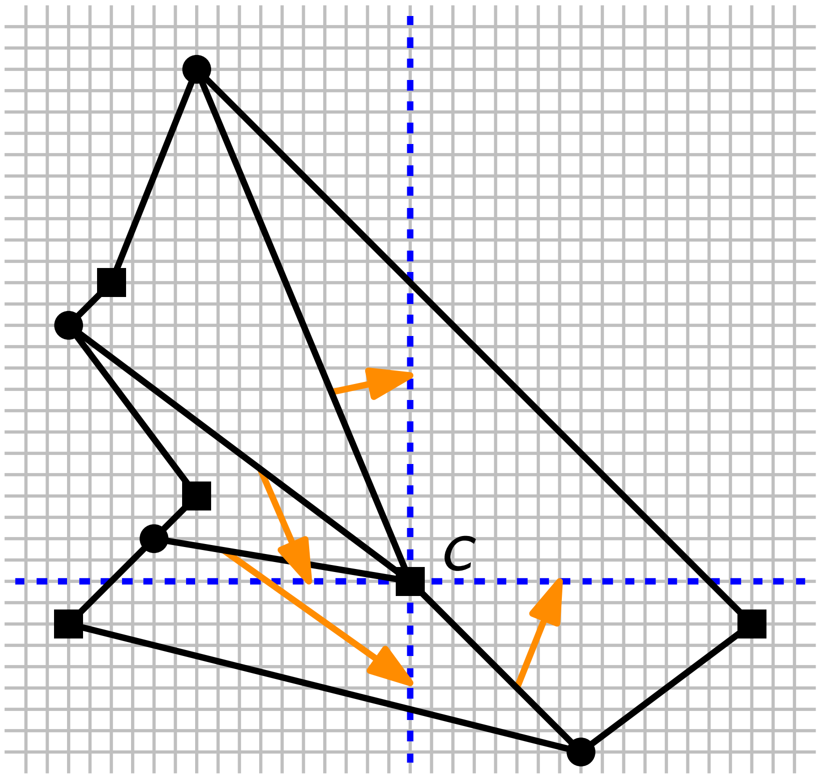


Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges

grid size: $O(n^2) \times O(n^2)$

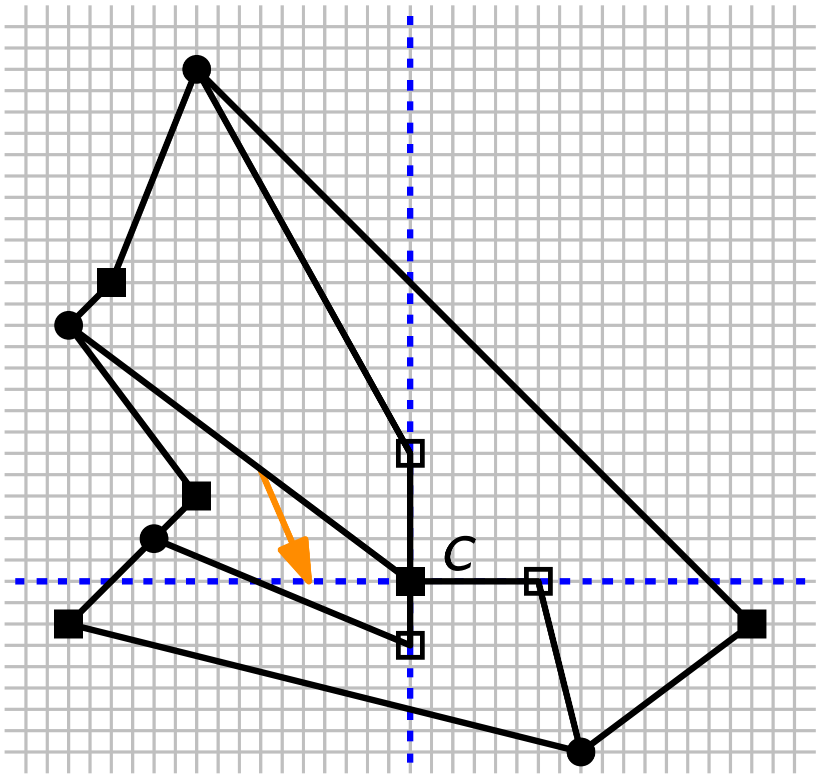


Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges

grid size:
$O(n^2) \times O(n^2)$

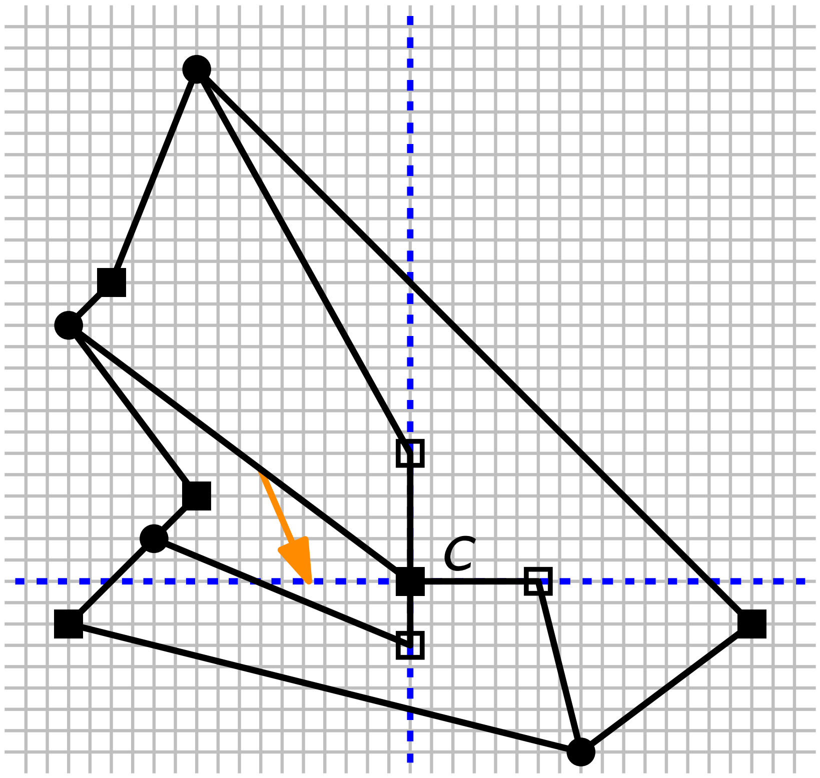


Result 2: 1-Plane Graphs $\subseteq \text{RAC}_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges
  3. Refine the grid by $\tilde{n}$ again

grid size:
$O(n^2) \times O(n^2)$

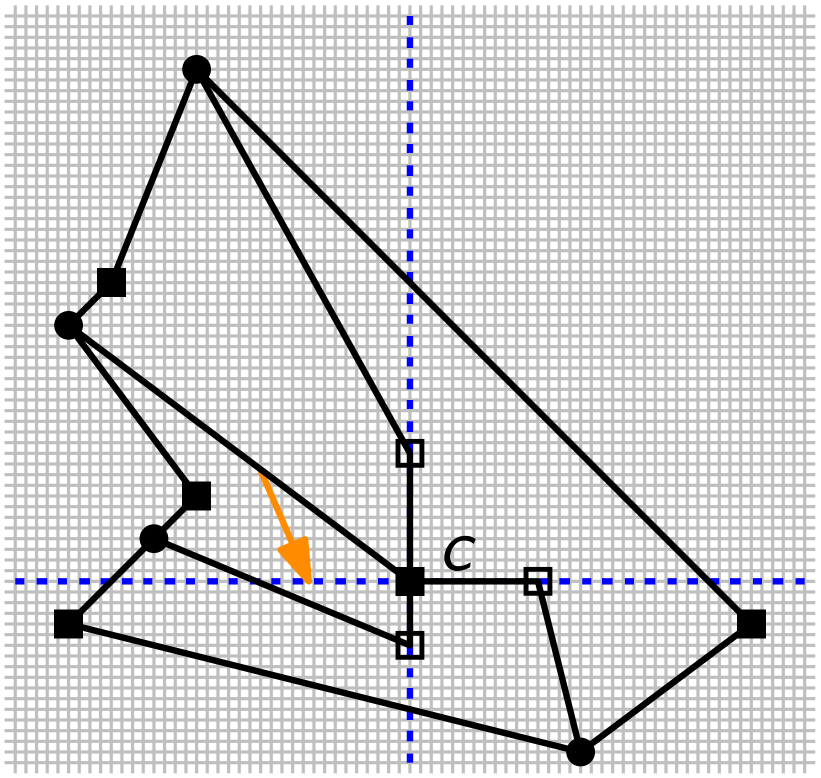


Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges
  3. Refine the grid by $\tilde{n}$ again

grid size:
$O(n^3) \times O(n^3)$

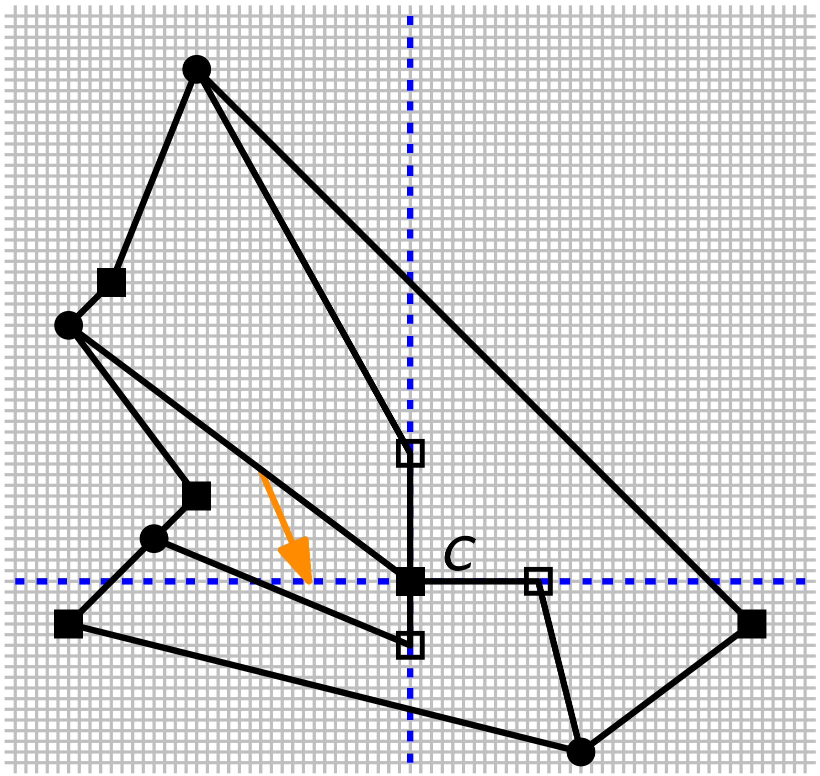


Result 2: 1-Plane Graphs $\subseteq$ RAC$_2^{\text{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges
  3. Refine the grid by $\tilde{n}$ again
  4. Re-draw dependent edges

grid size:
$O(n^3) \times O(n^3)$

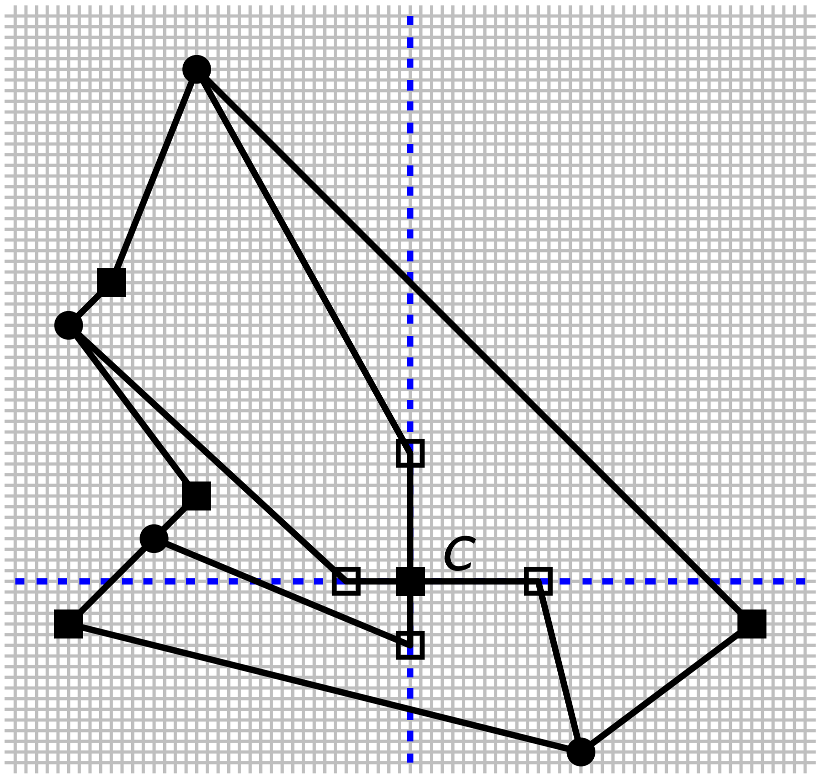


Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges
  3. Refine the grid by $\tilde{n}$ again
  4. Re-draw dependent edges

grid size: $O(n^3) \times O(n^3)$

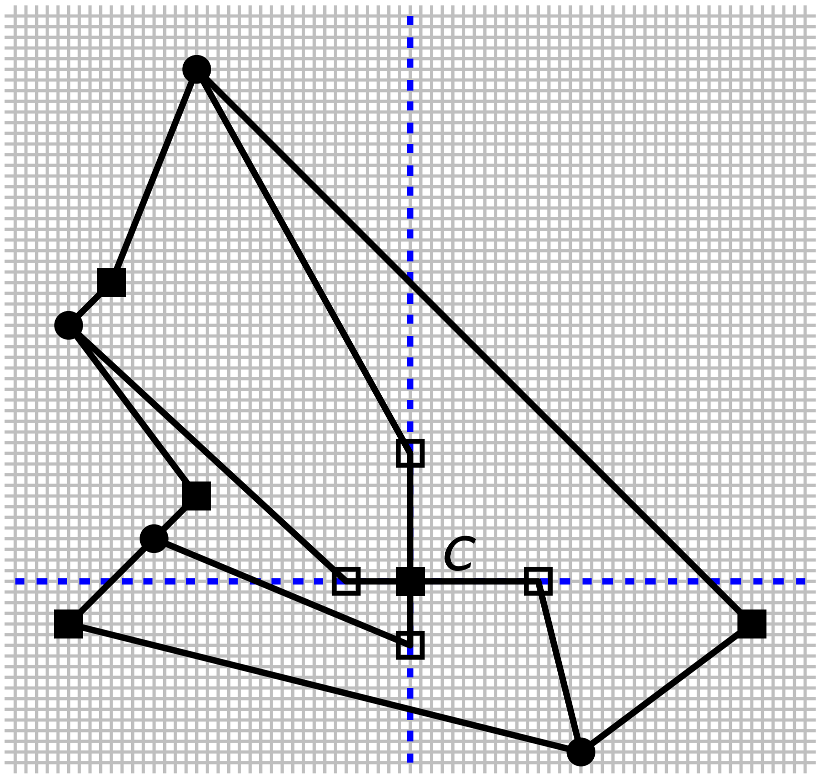


Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:
  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges
  3. Refine the grid by $\tilde{n}$ again
  4. Re-draw dependent edges
- Remove the dummy objects

grid size: $O(n^3) \times O(n^3)$



Result 2: 1-Plane Graphs $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$

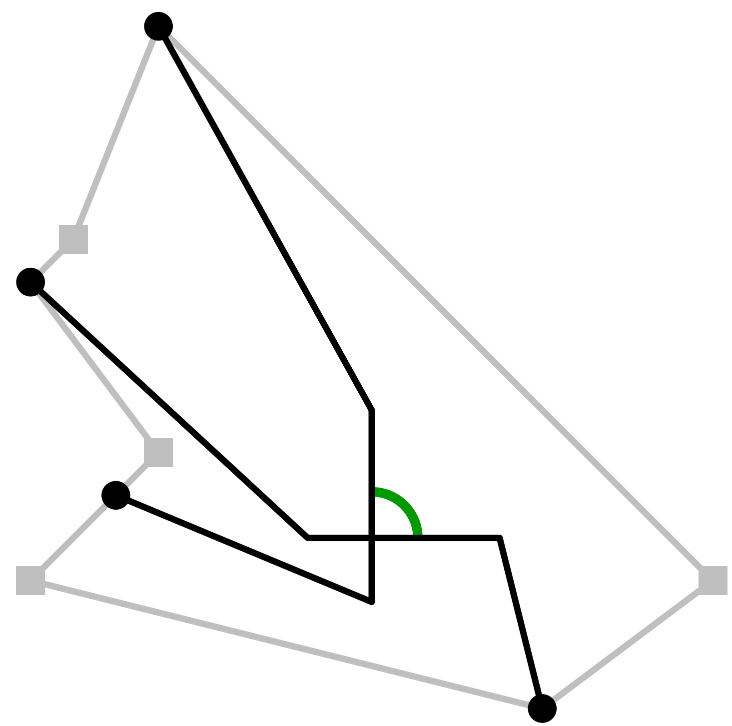
Postprocessing (obtaining crossings at right angles):

- Consider the four axis-parallel half-lines originating at c
- Assign the four edges being incident to c to these half-lines
- Bend these edges at their assigned half-lines:

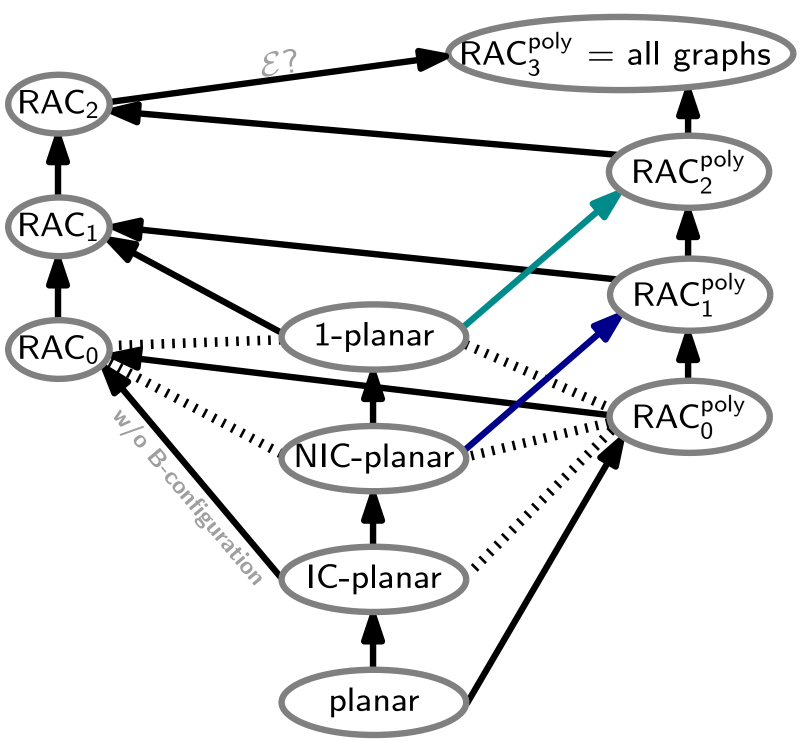
grid size: $O(n^3) \times O(n^3)$

  1. Refine the grid by $\tilde{n} \in O(n)$
  2. Re-draw independent edges
  3. Refine the grid by $\tilde{n}$ again
  4. Re-draw dependent edges

- Remove the dummy objects

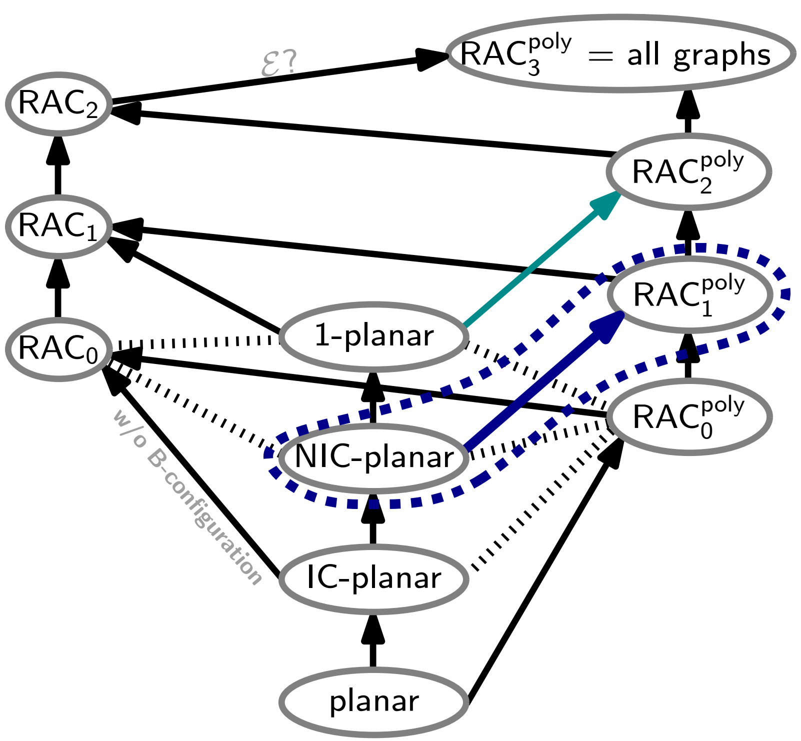


Summary and Open Questions



Summary and Open Questions

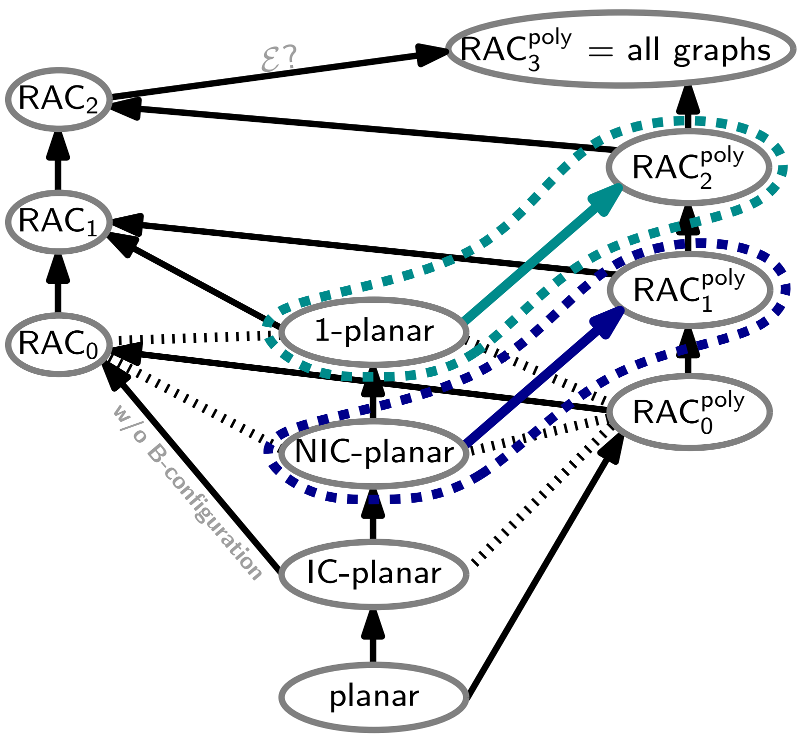
NIC-plane
$\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$



Summary and Open Questions

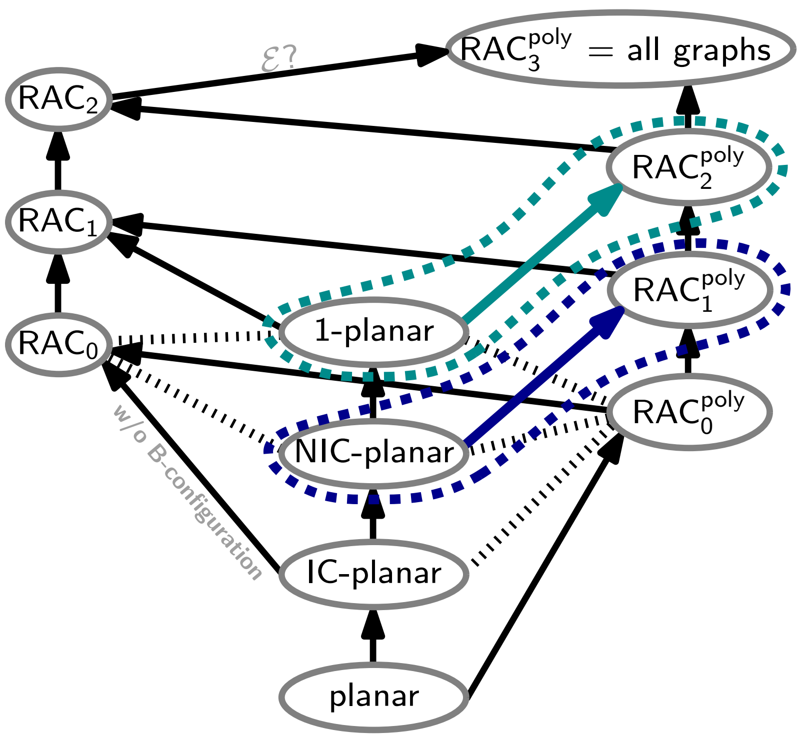
NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$

1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$



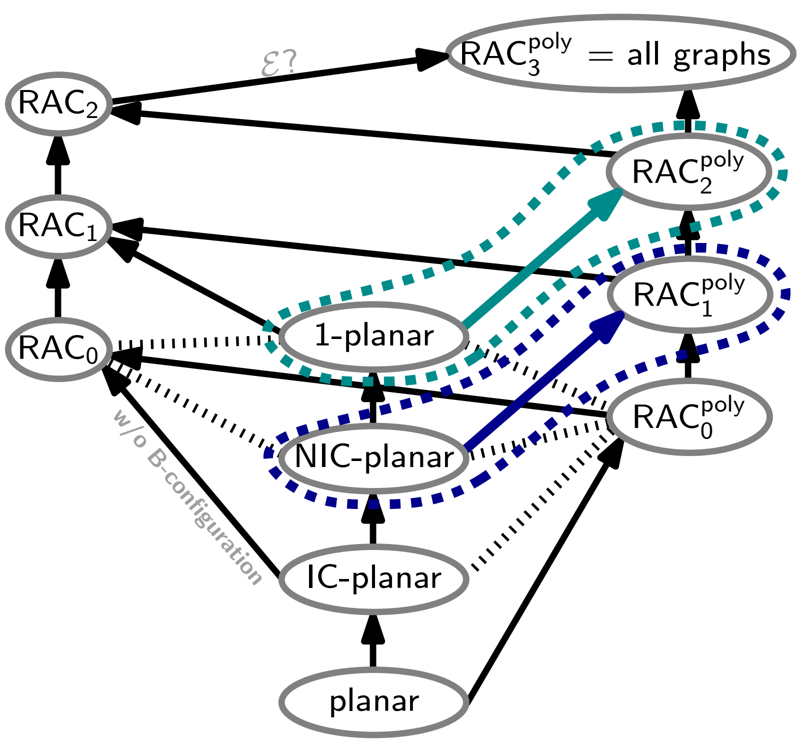
Summary and Open Questions

	NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$	1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$
Preserves embedding	Yes	Yes



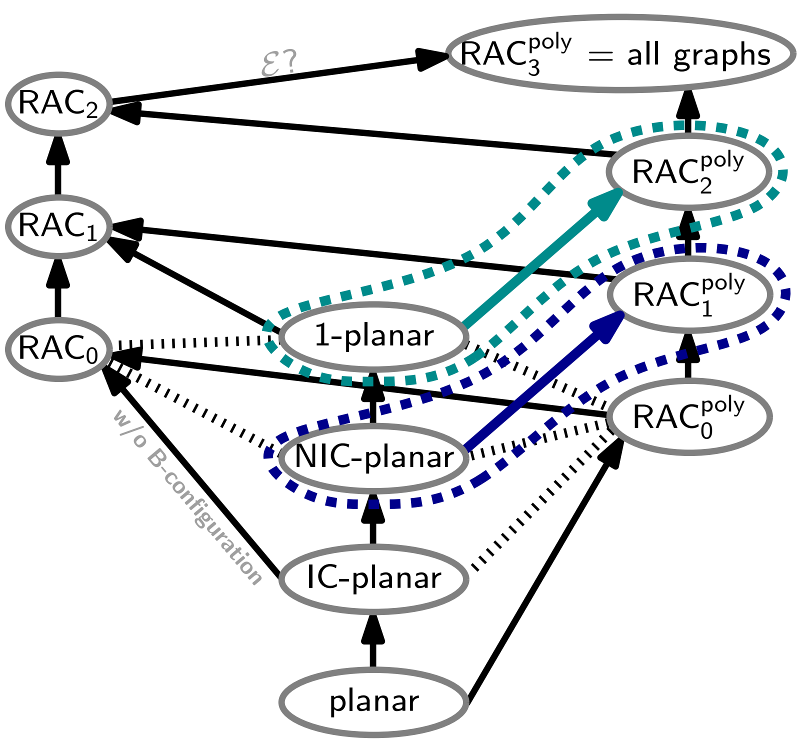
Summary and Open Questions

	NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$	1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$
Preserves embedding	Yes	Yes
Runtime	$O(n)$	$O(n)$



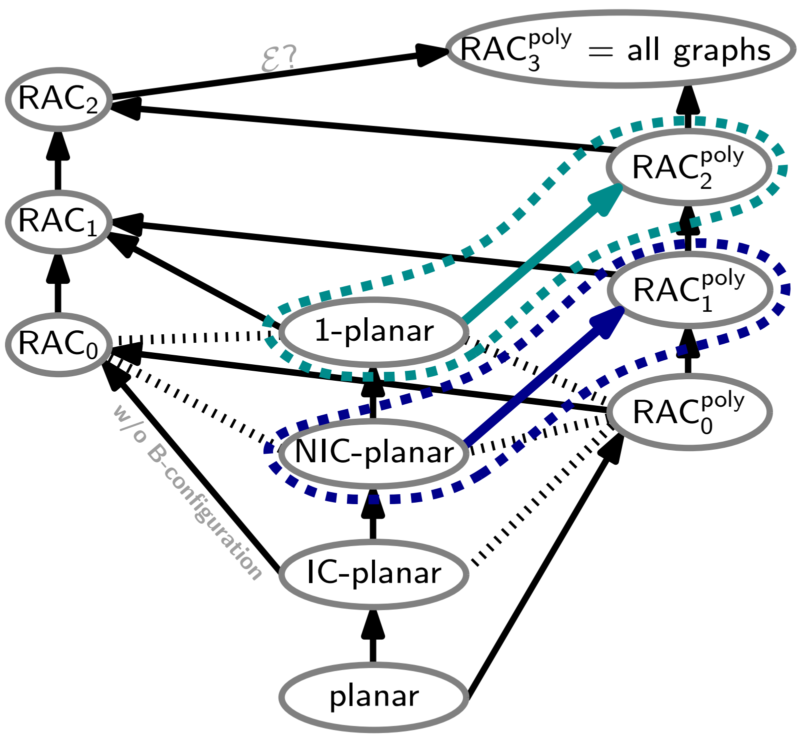
Summary and Open Questions

	NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$	1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$
Preserves embedding	Yes	Yes
Runtime	$O(n)$	$O(n)$
Bends per edge	≤ 1	≤ 2



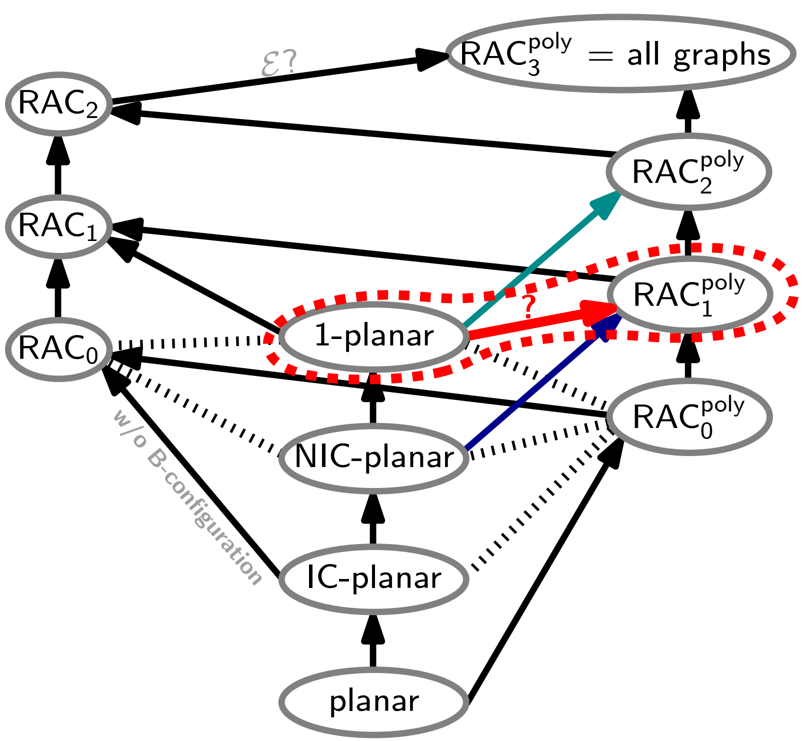
Summary and Open Questions

	NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$	1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$
Preserves embedding	Yes	Yes
Runtime	$O(n)$	$O(n)$
Bends per edge	≤ 1	≤ 2
Grid size	$O(n) \times O(n)$	$O(n^3) \times O(n^3)$



Summary and Open Questions

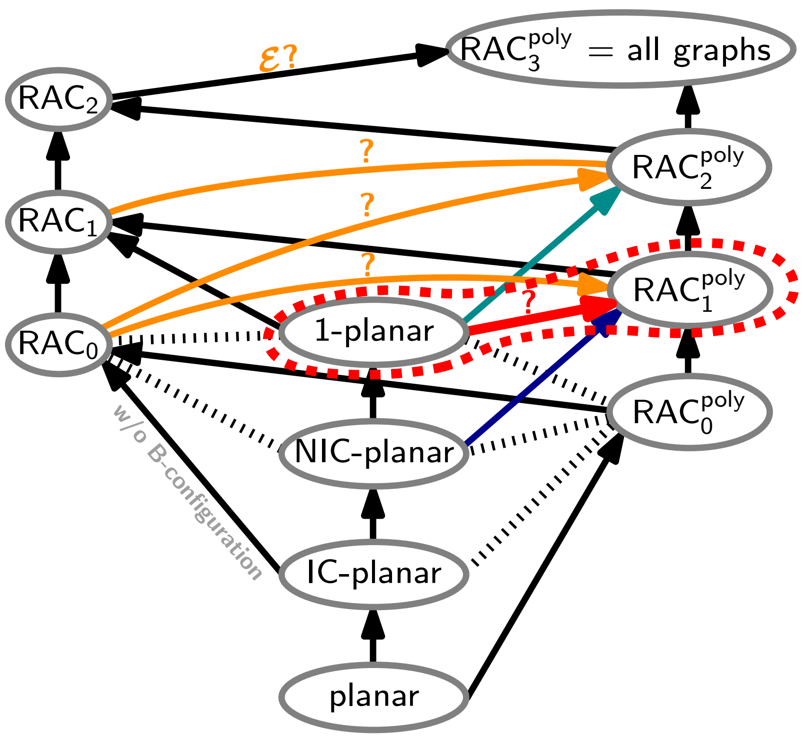
	NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$	1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$
Preserves embedding	Yes	Yes
Runtime	$O(n)$	$O(n)$
Bends per edge	≤ 1	≤ 2
Grid size	$O(n) \times O(n)$	$O(n^3) \times O(n^3)$



Open question:
1-planar $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$?

Summary and Open Questions

	NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$	1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$
Preserves embedding	Yes	Yes
Runtime	$O(n)$	$O(n)$
Bends per edge	≤ 1	≤ 2
Grid size	$O(n) \times O(n)$	$O(n^3) \times O(n^3)$

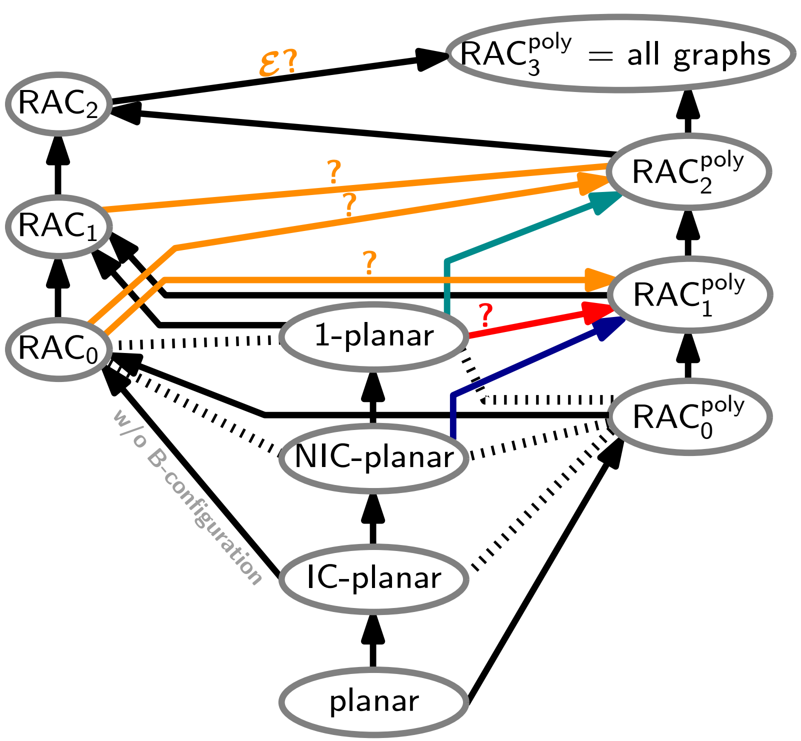


More open questions

Open question:
1-planar $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$?

Summary and Open Questions

	NIC-plane $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$	1-plane $\subseteq \mathrm{RAC}_2^{\mathrm{poly}}$
Preserves embedding	Yes	Yes
Runtime	$O(n)$	$O(n)$
Bends per edge	≤ 1	≤ 2
Grid size	$O(n) \times O(n)$	$O(n^3) \times O(n^3)$



More open questions

Open question:
1-planar $\subseteq \mathrm{RAC}_1^{\mathrm{poly}}$?