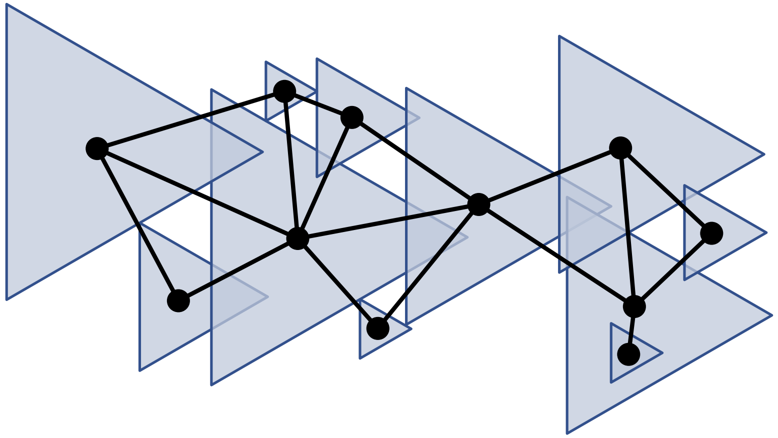
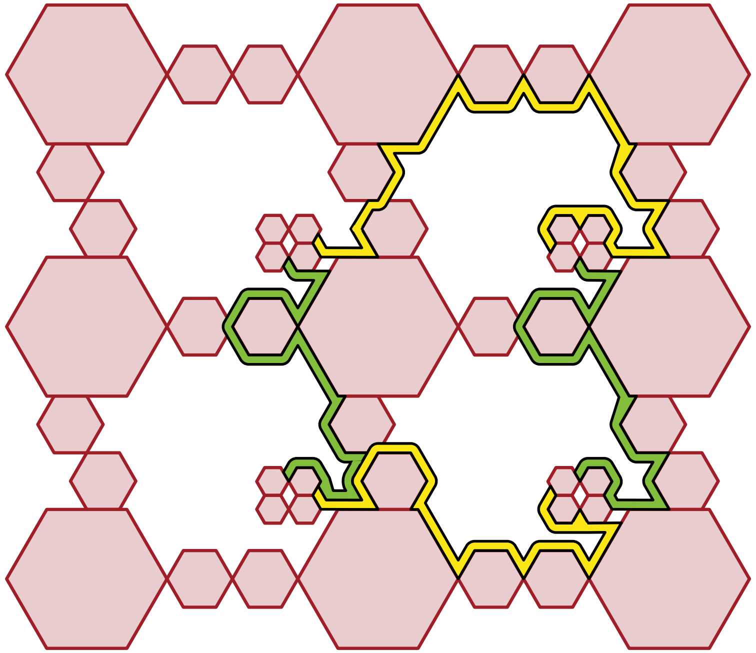
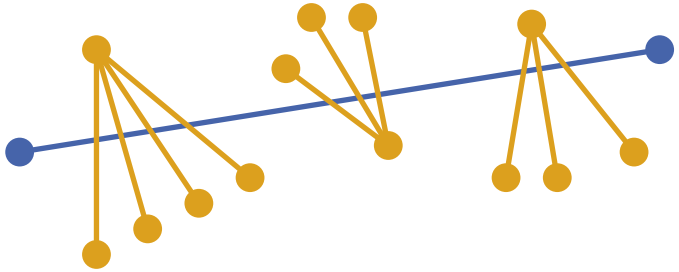
Intersection Graphs with and without Product Structure

GD 2024 · 19.09.2024

Laura Merker, Lena Scherzer, **Samuel Schneider**, Torsten Ueckerdt

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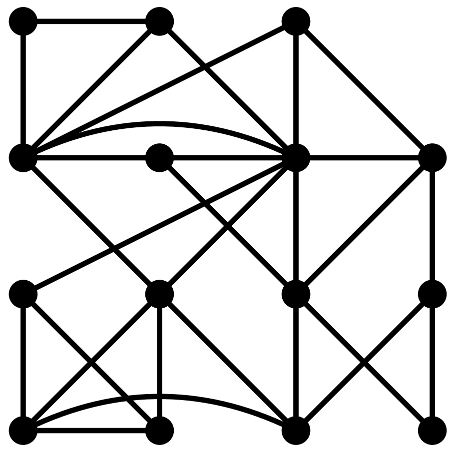

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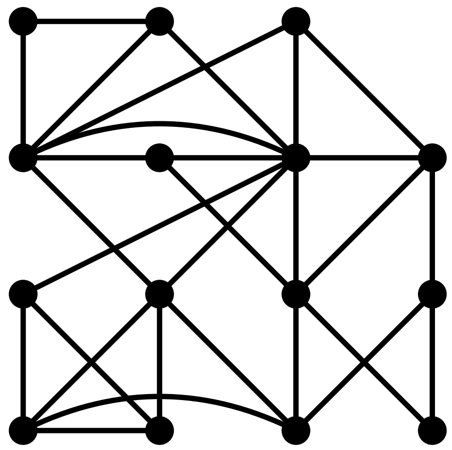

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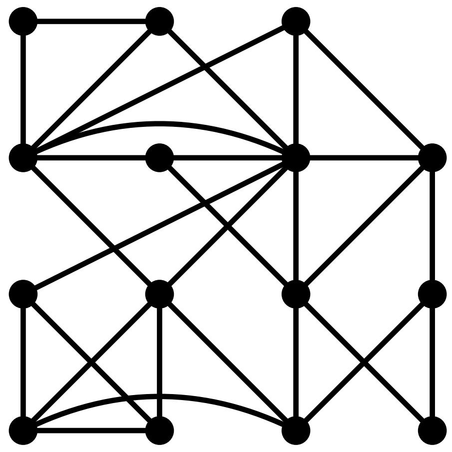

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treewidth c

path

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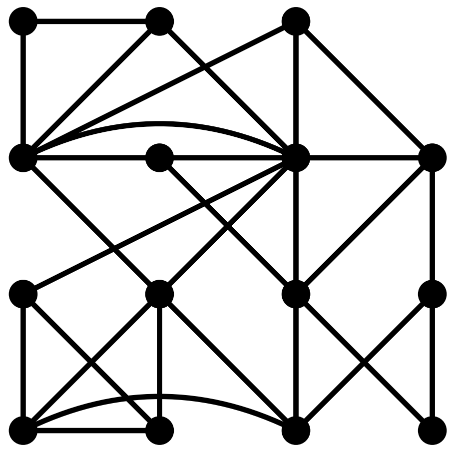

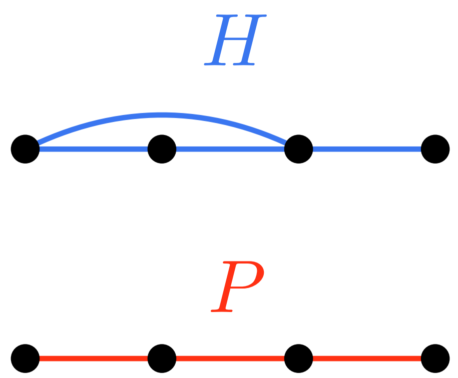

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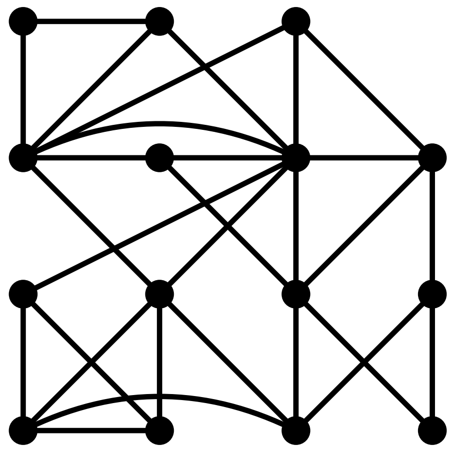

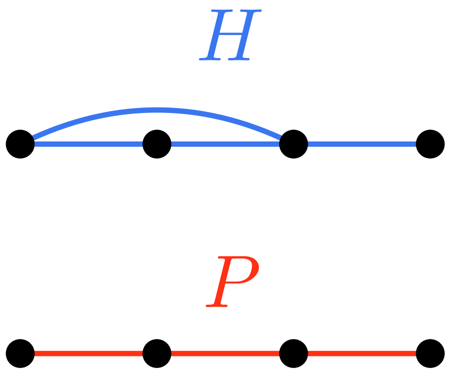

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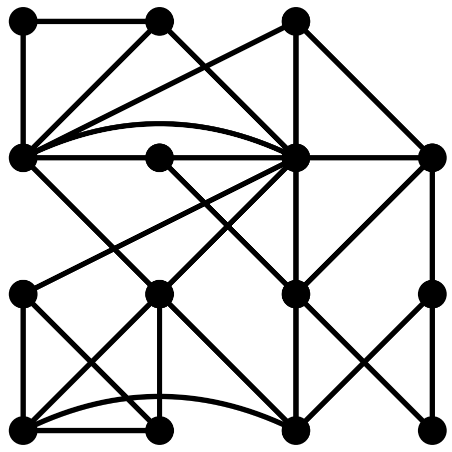

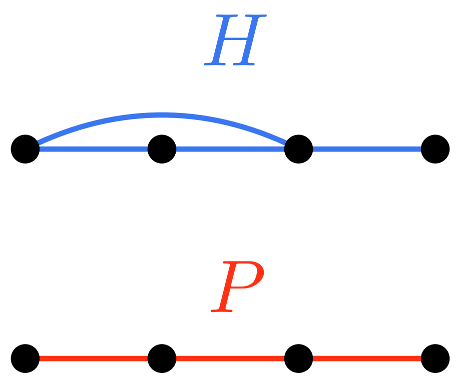

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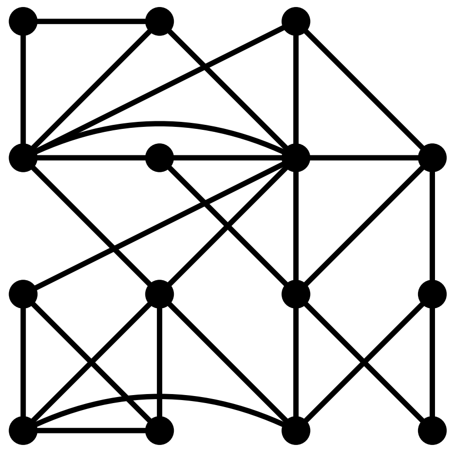

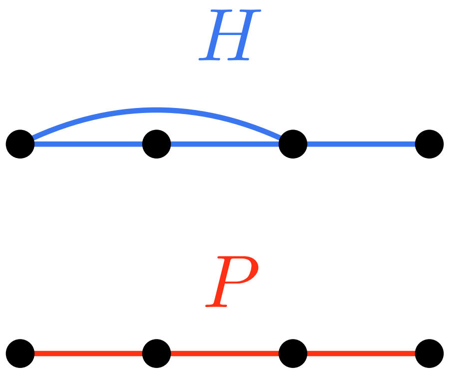

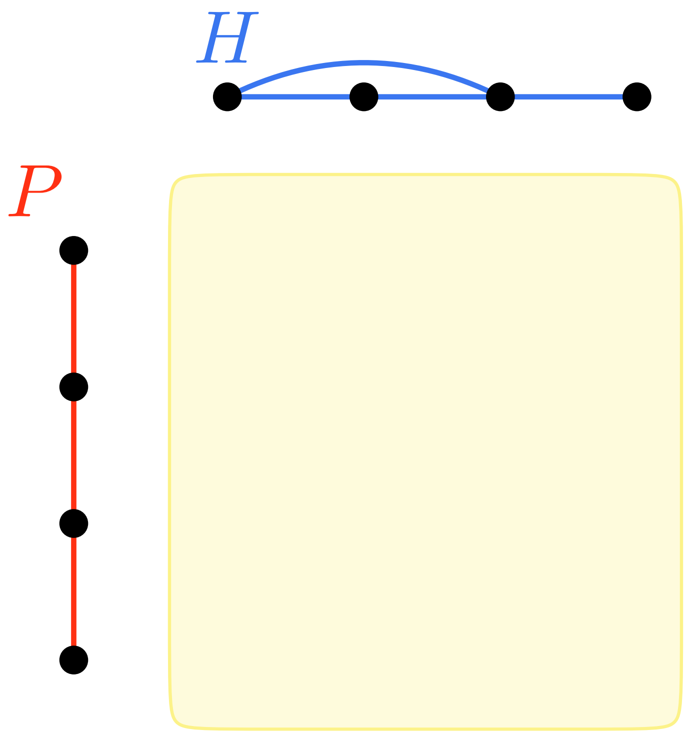

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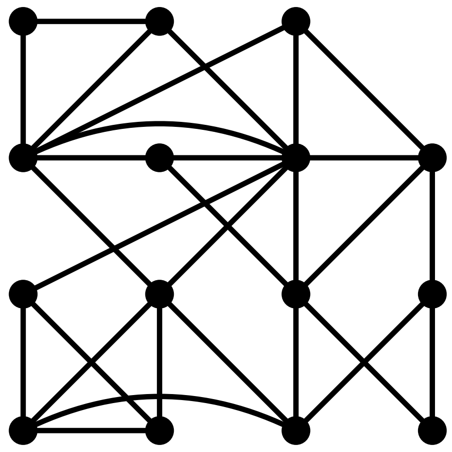

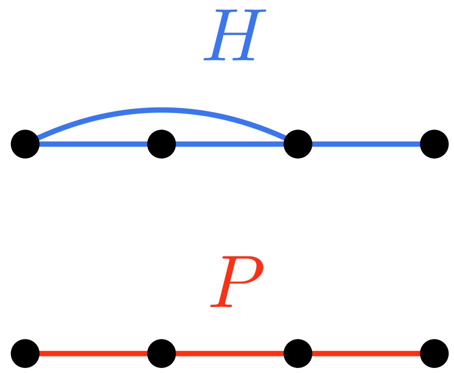

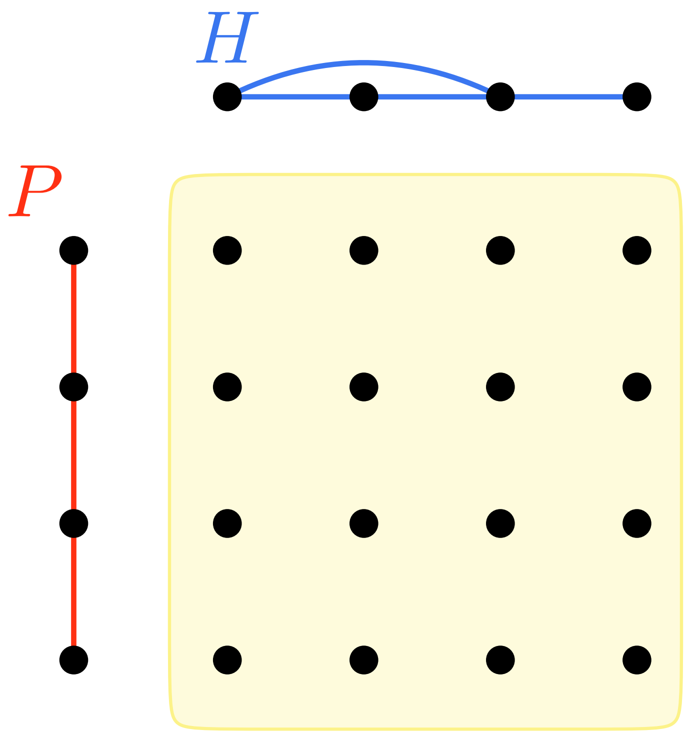

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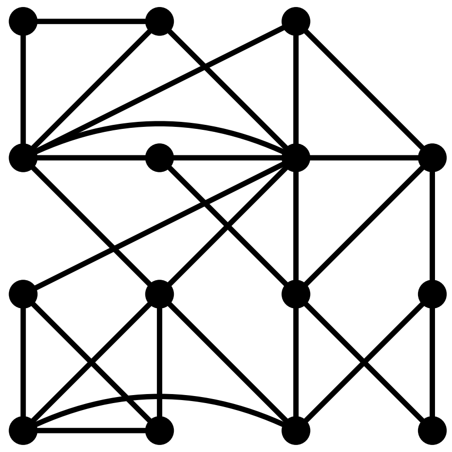

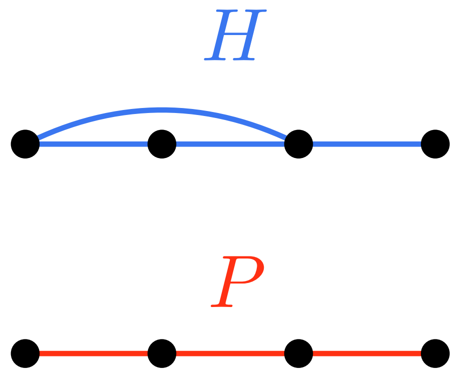

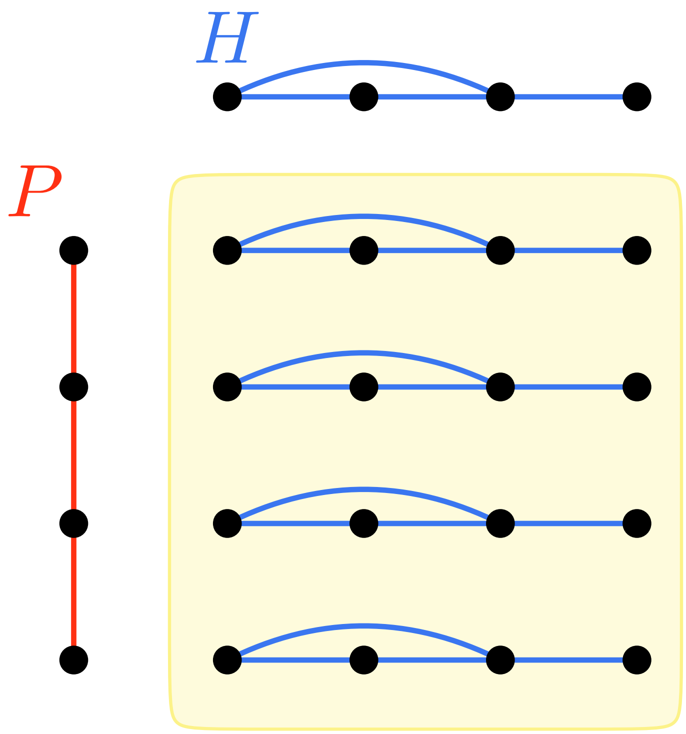

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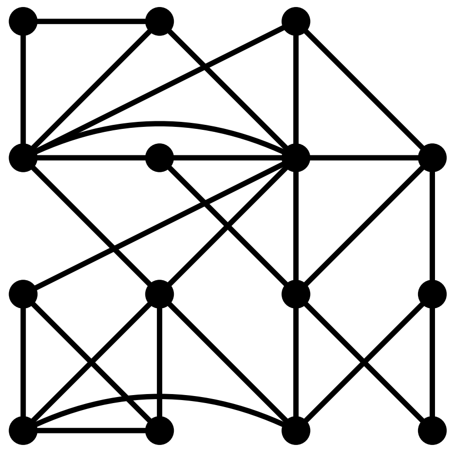

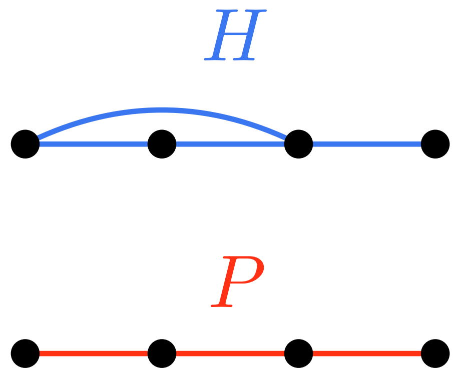

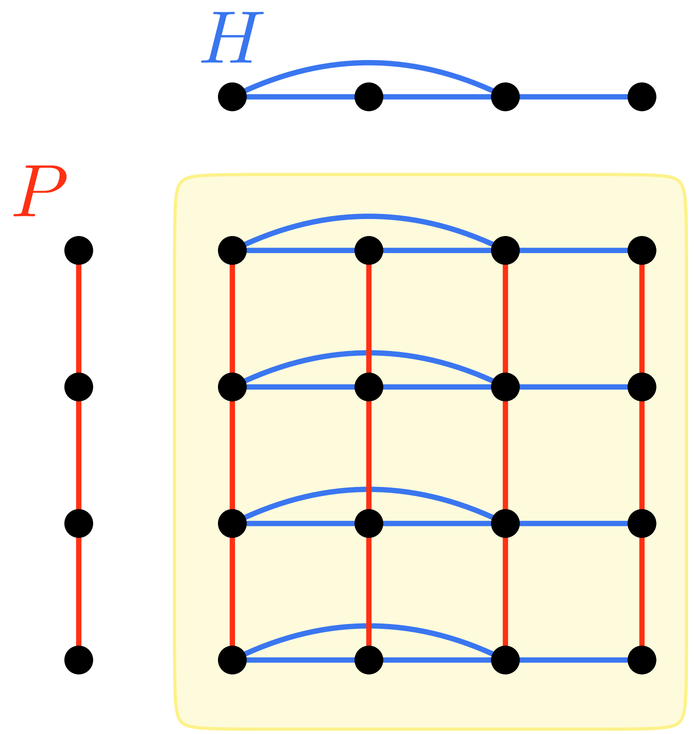

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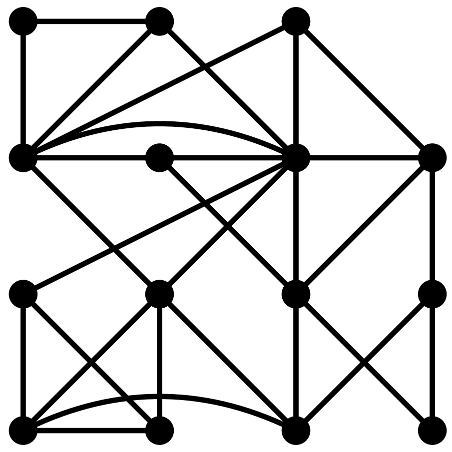

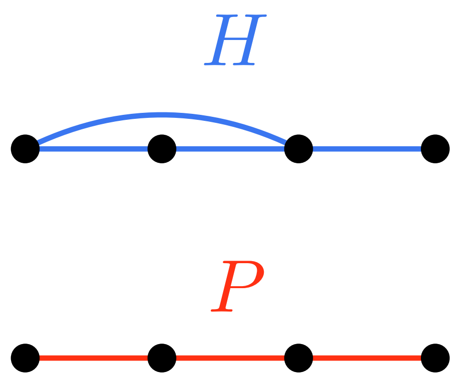

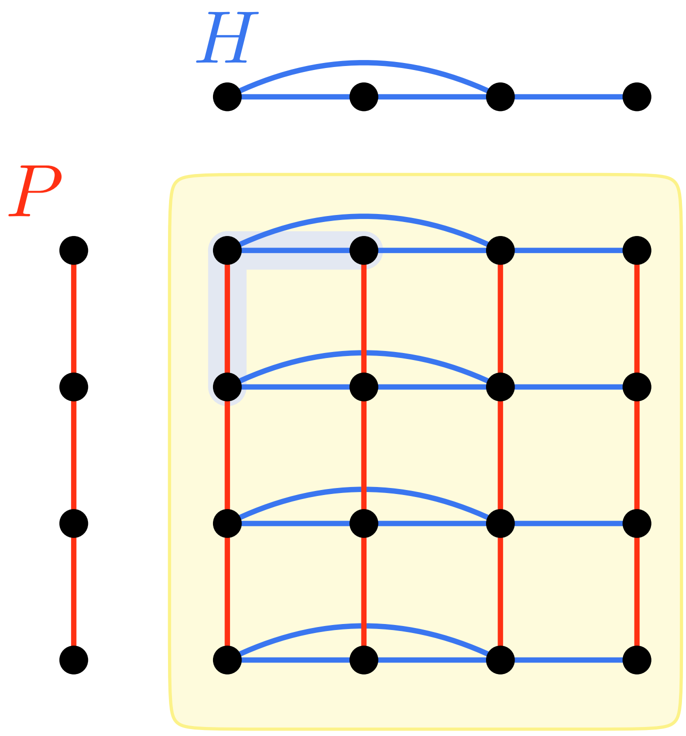

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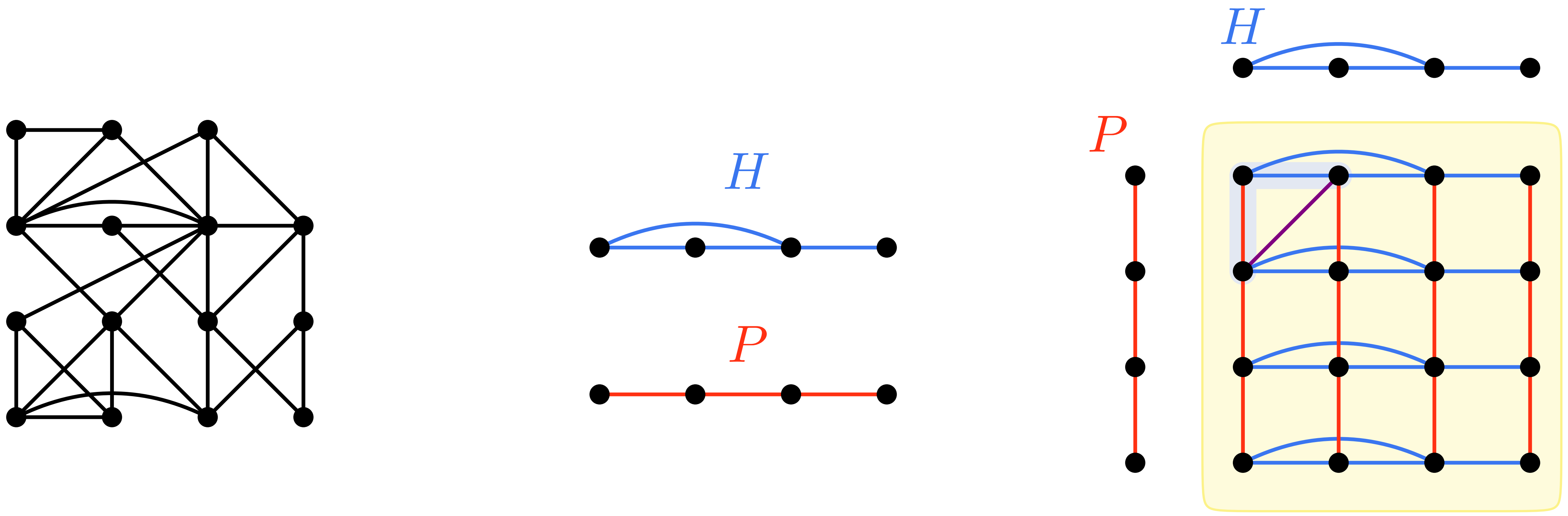

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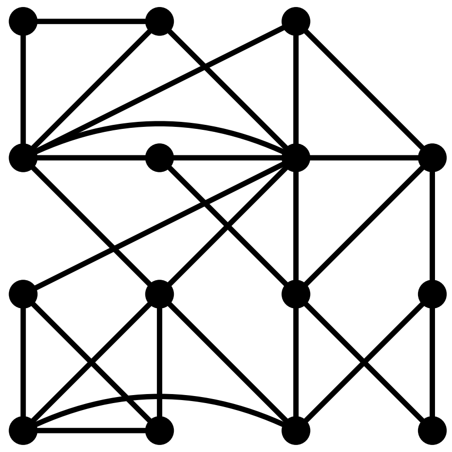

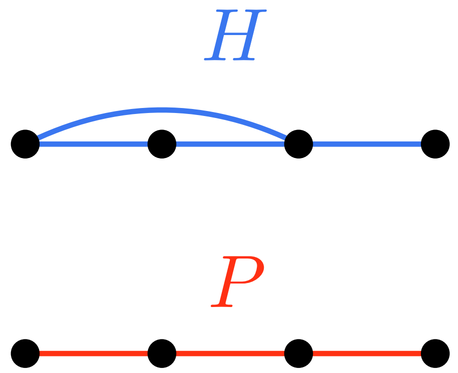

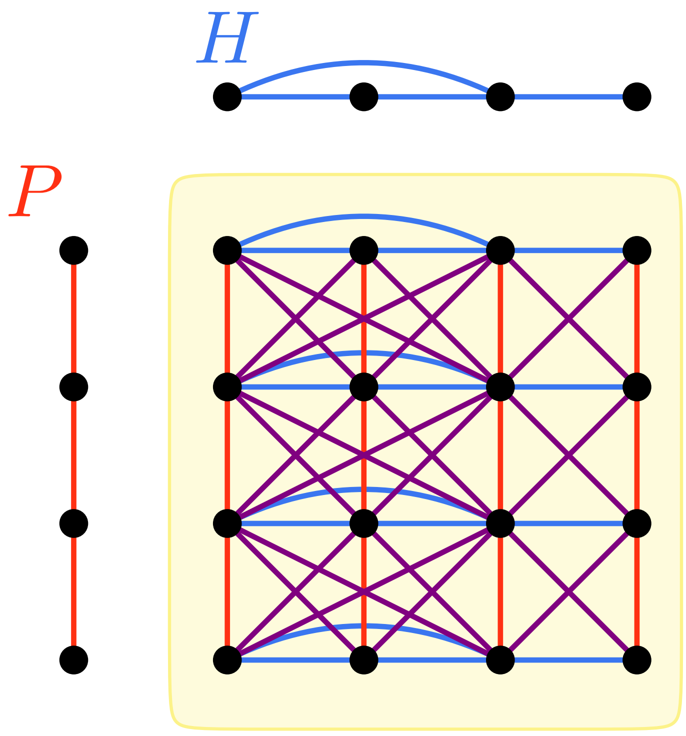

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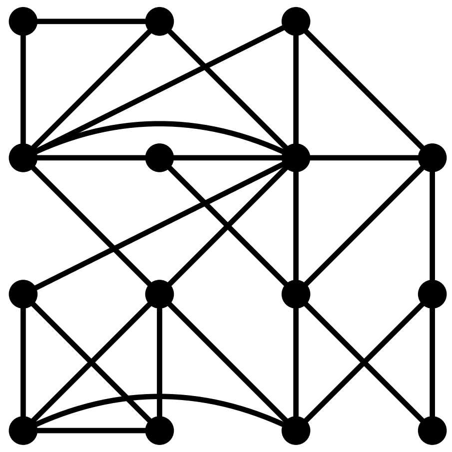

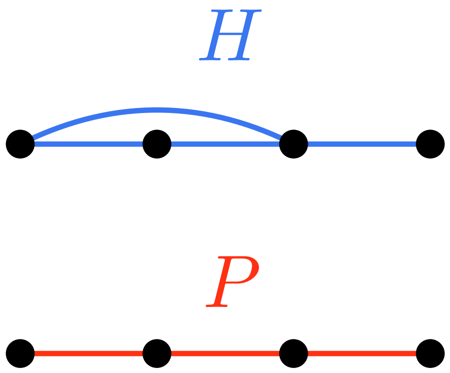

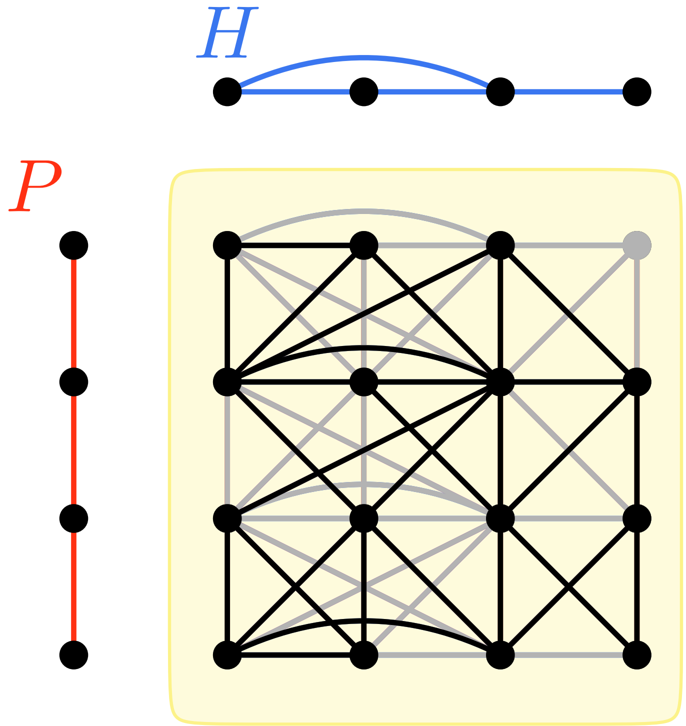

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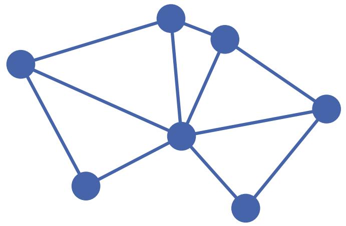

planar

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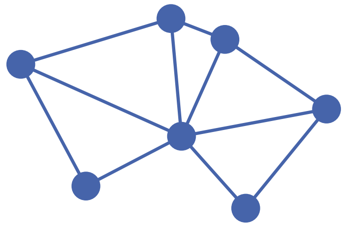

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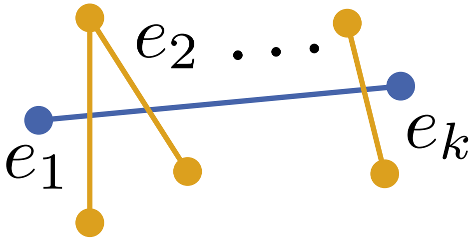

k-planar

[Dujmović et al.]

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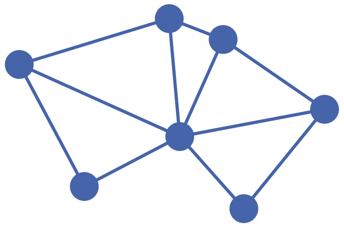

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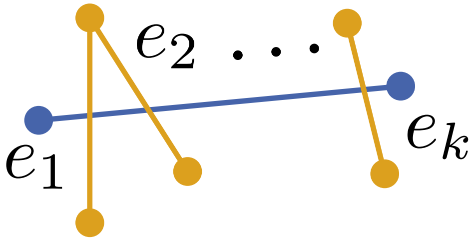

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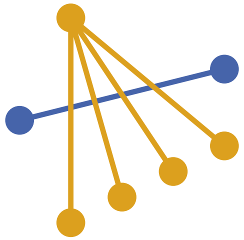

fan-planar

[Hickingbotham and Wood]

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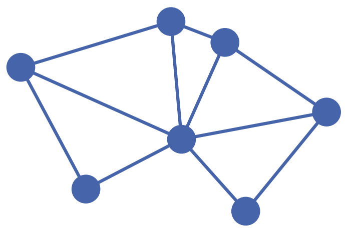

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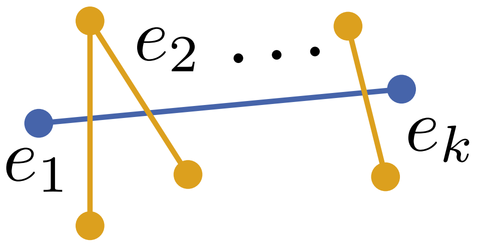

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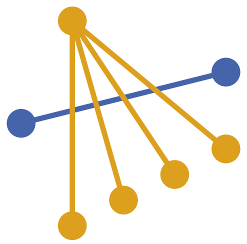

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[Hickingbotham and Wood]

- Large cliques $\implies$ **no** product structure.

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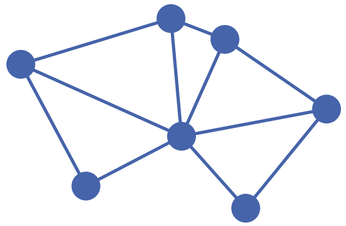

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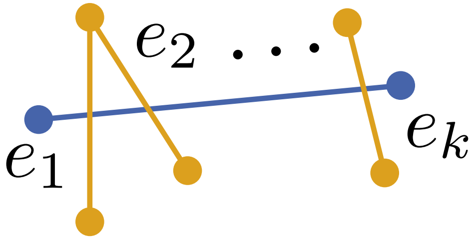

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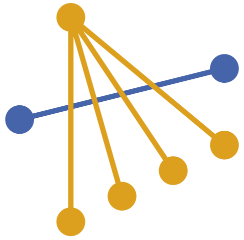

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[Hickingbotham and Wood]

- Large cliques $\Longrightarrow$ **no** product structure.
- Large treewidth in neighborhood $\Longrightarrow$ **no** product structure.

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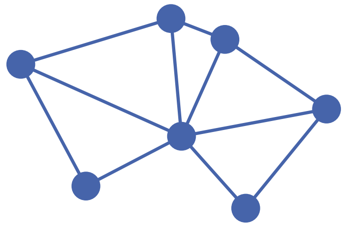

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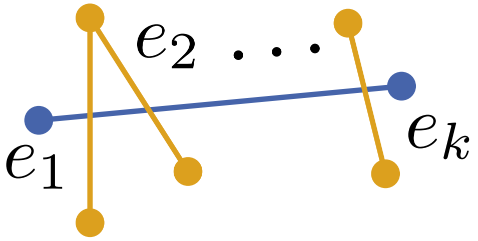

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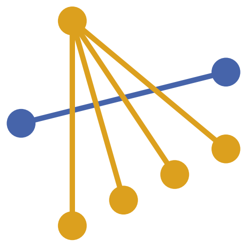

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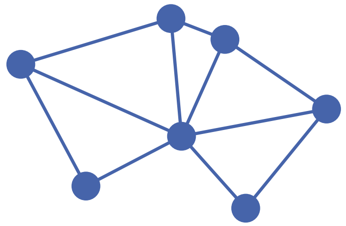

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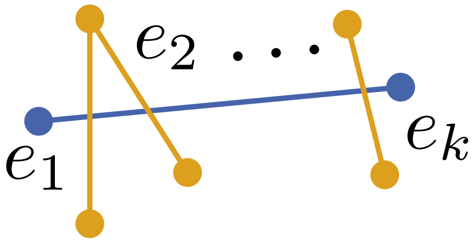

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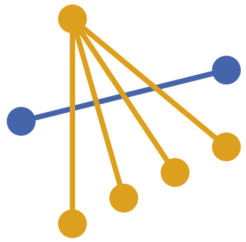

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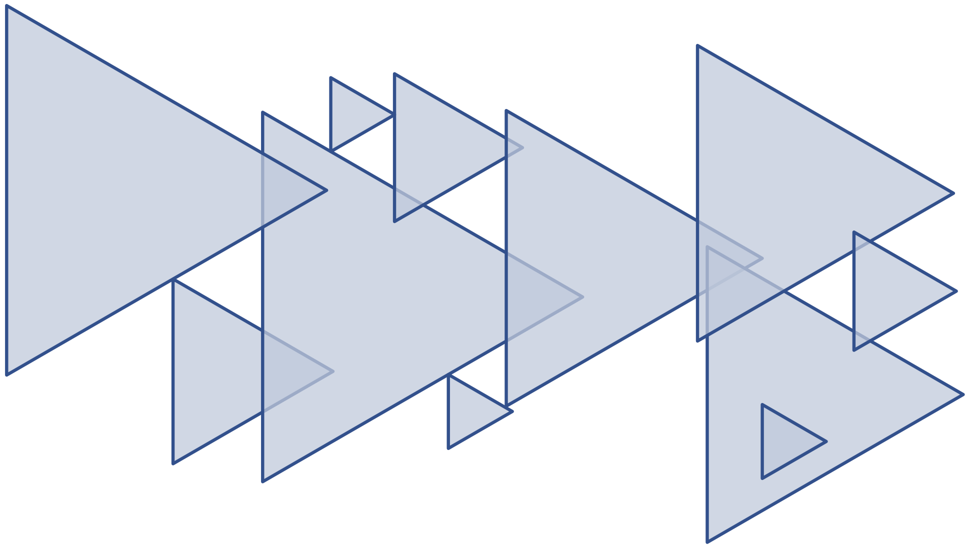
[Hickingbotham and Wood]

Where is the border between product structure and no product structure?

- Large cliques $\implies$ **no** product structure.
- Large treewidth in neighborhood $\implies$ **no** product structure.
- **No** linear local treewidth $\implies$ **no** product structure.

Intersection Graphs of Homothetic n-Gons



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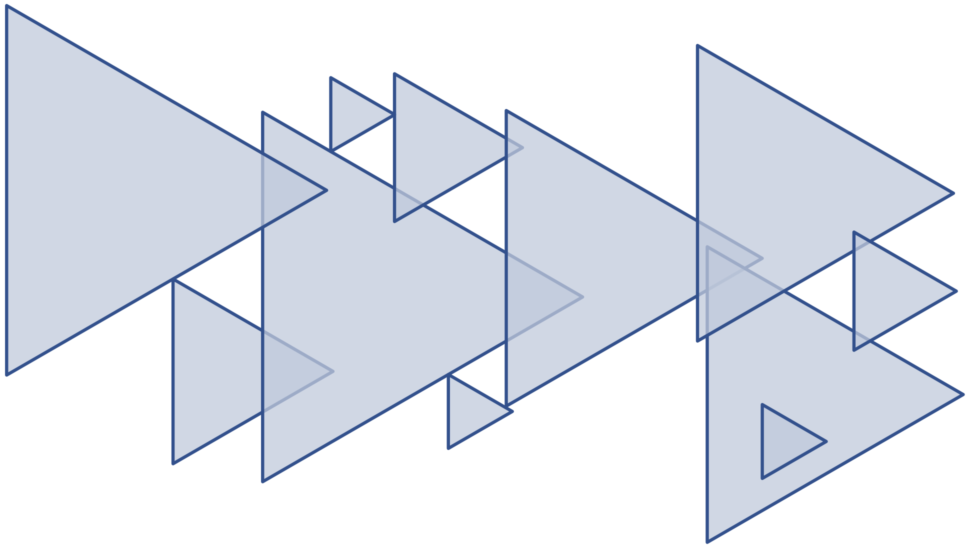

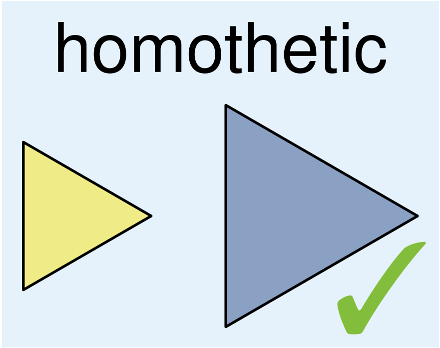

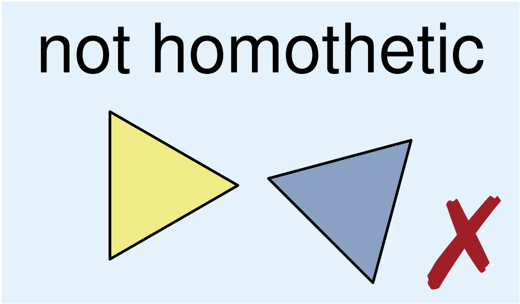

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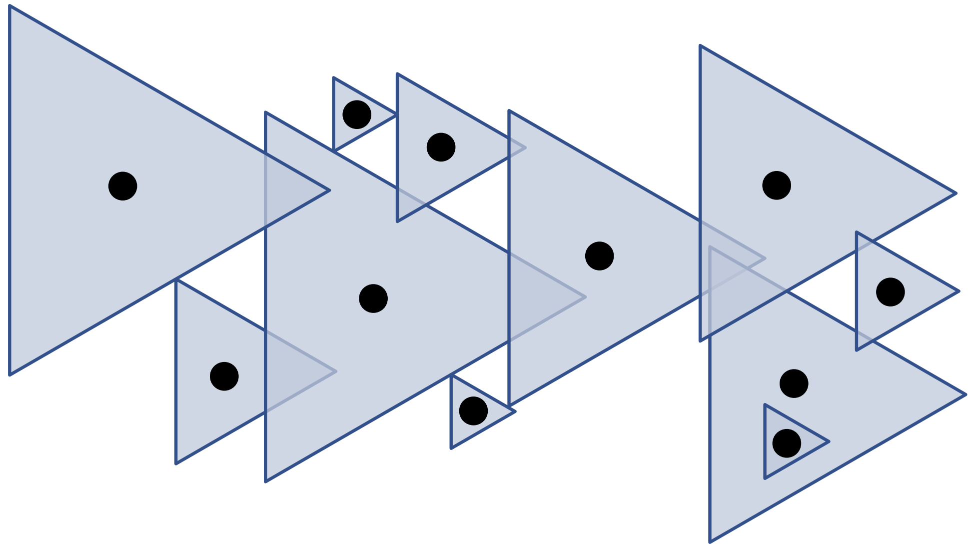

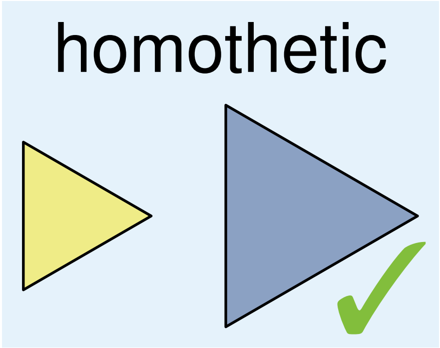

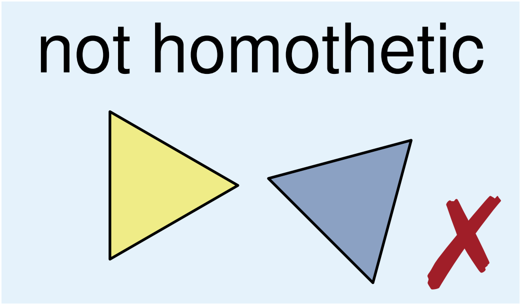

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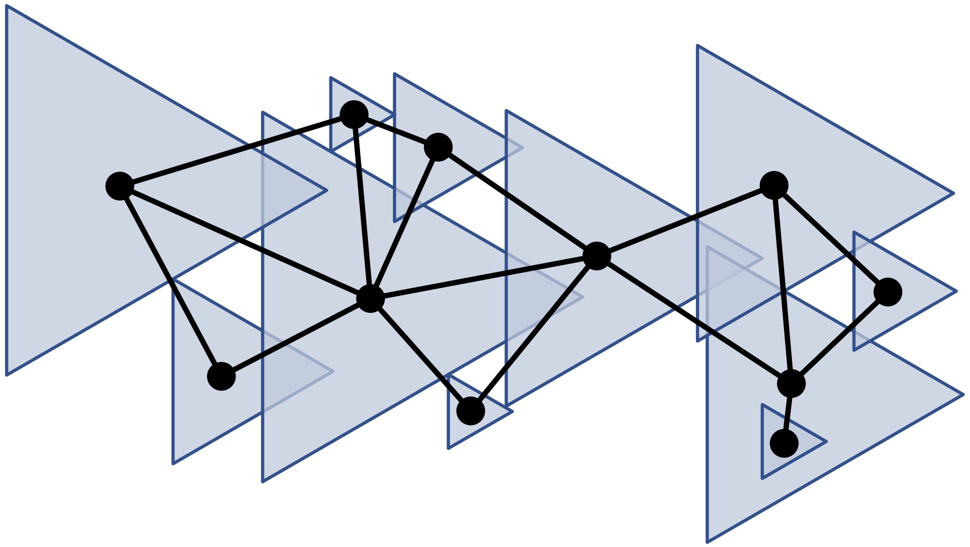

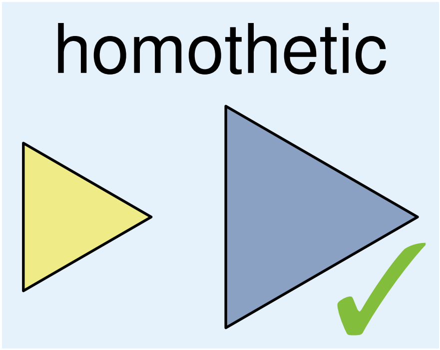

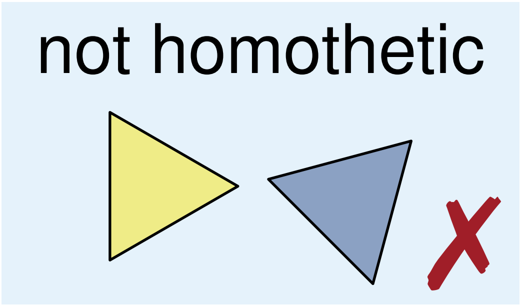

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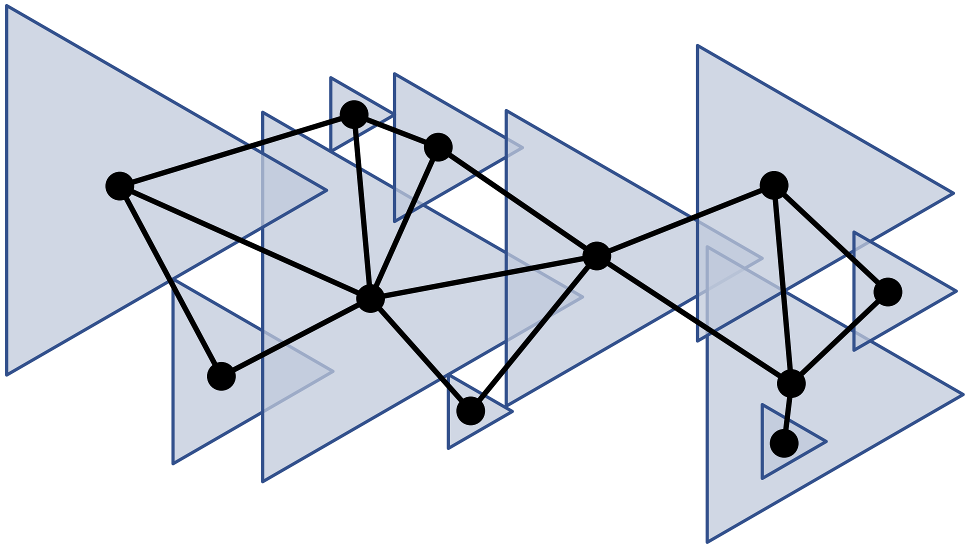
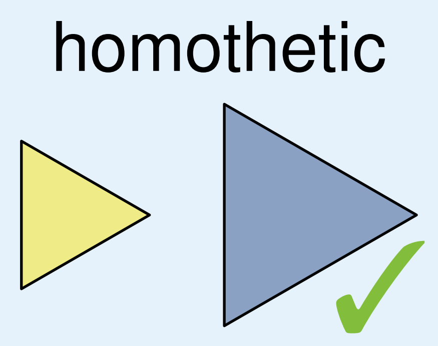
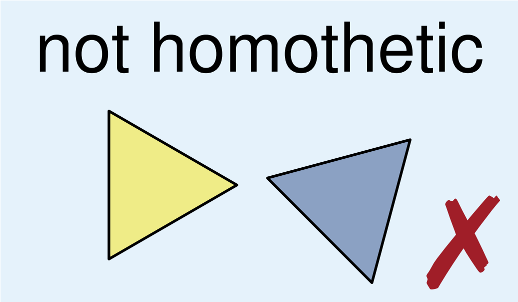
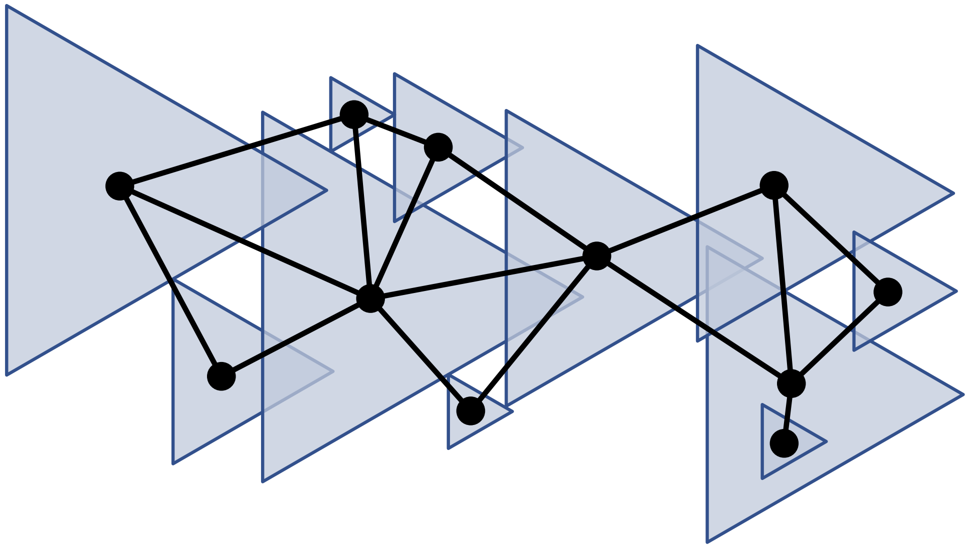


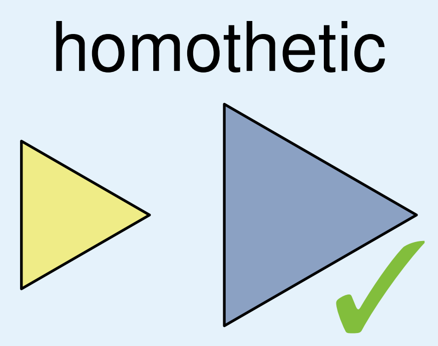


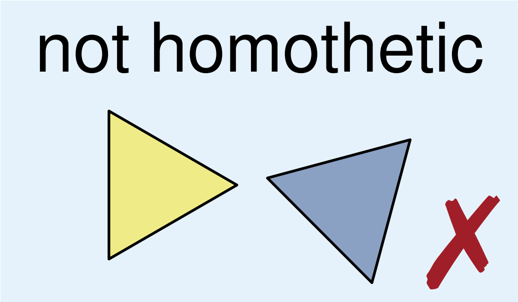


Problems for product structure:

Intersection Graphs of Homothetic n-Gons







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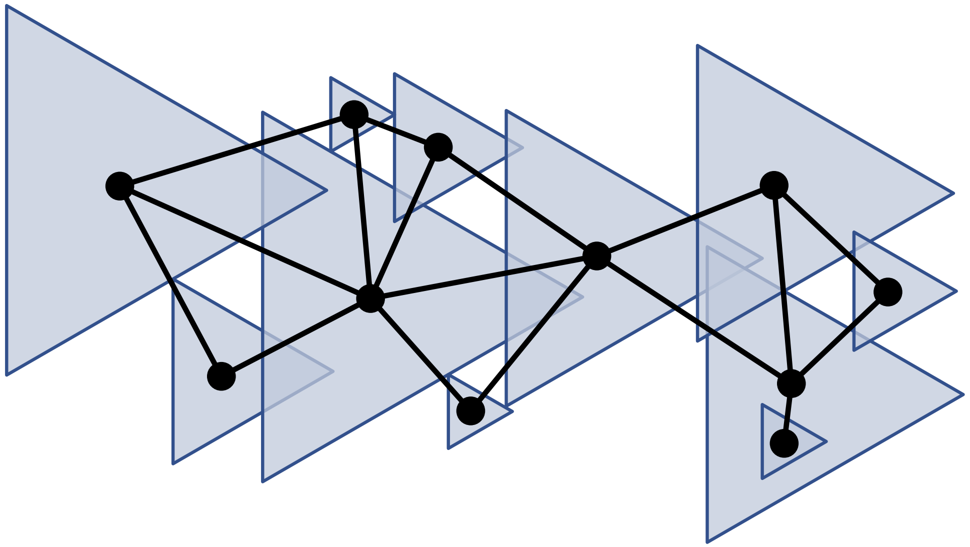
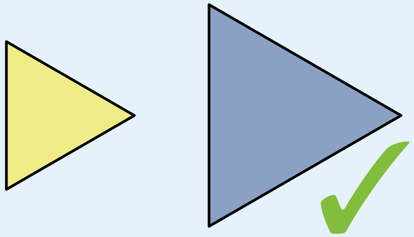
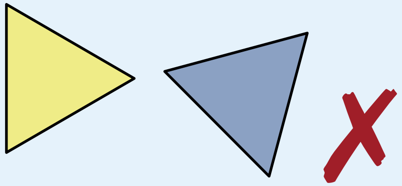


homothetic



not homothetic



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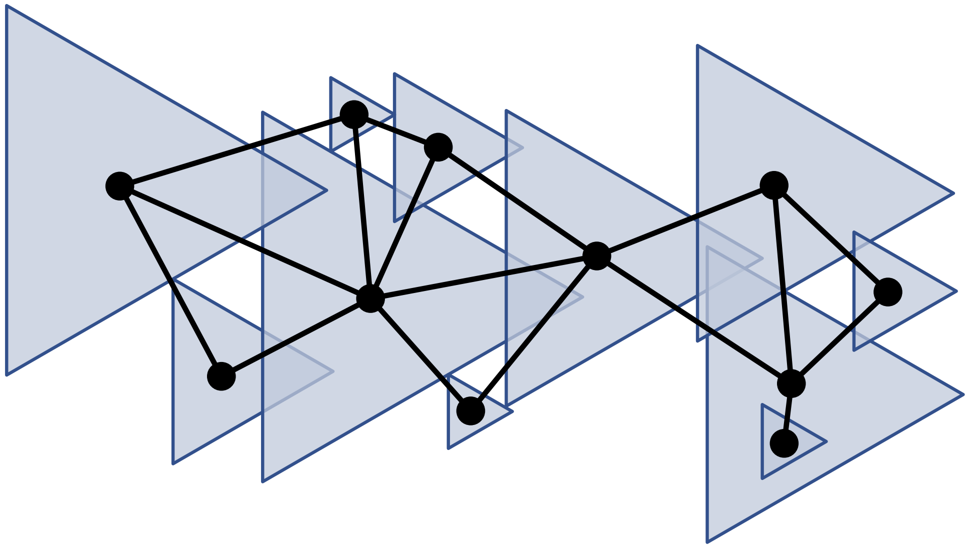

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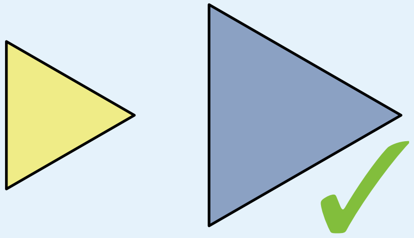

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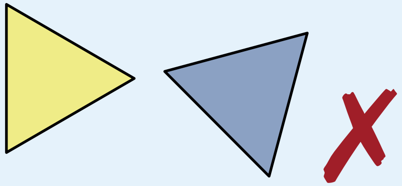

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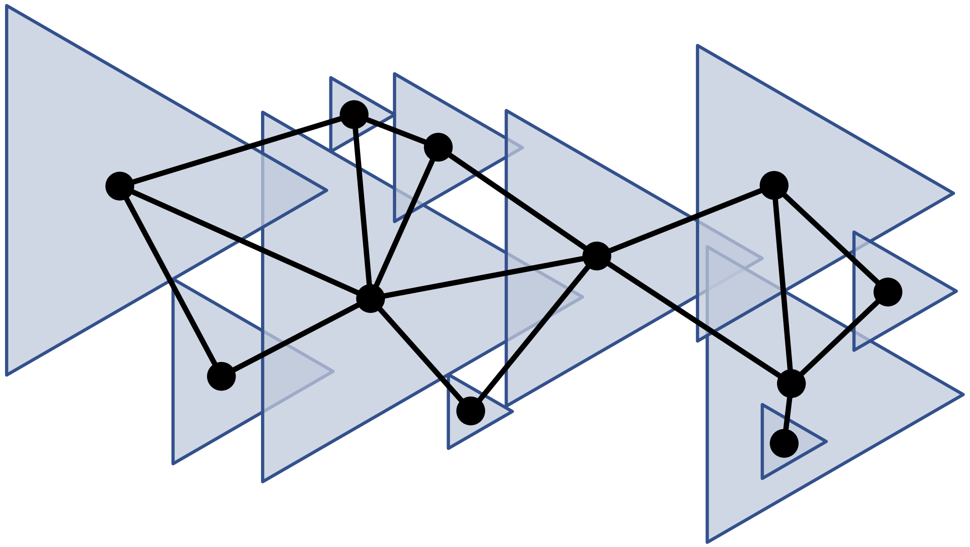

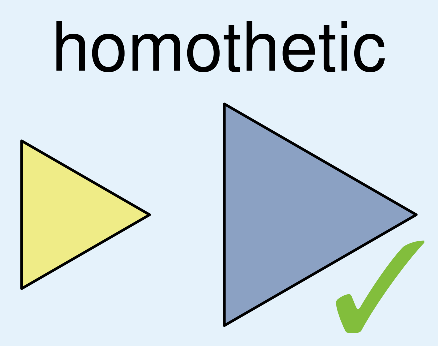

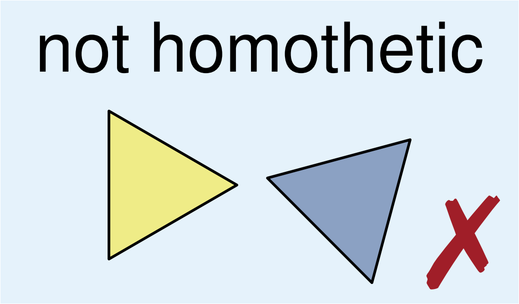

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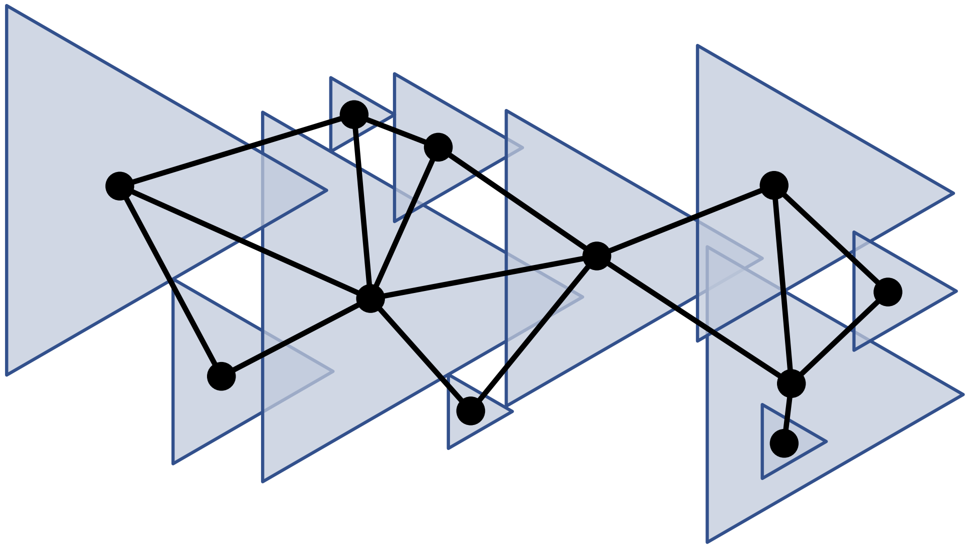

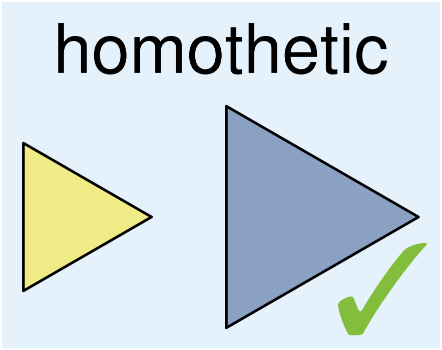

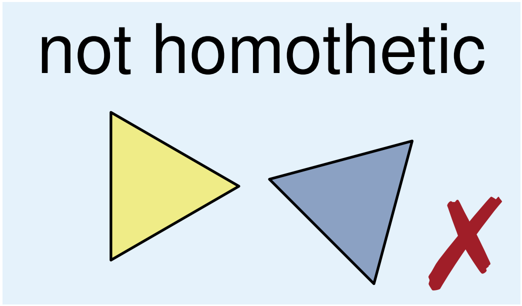

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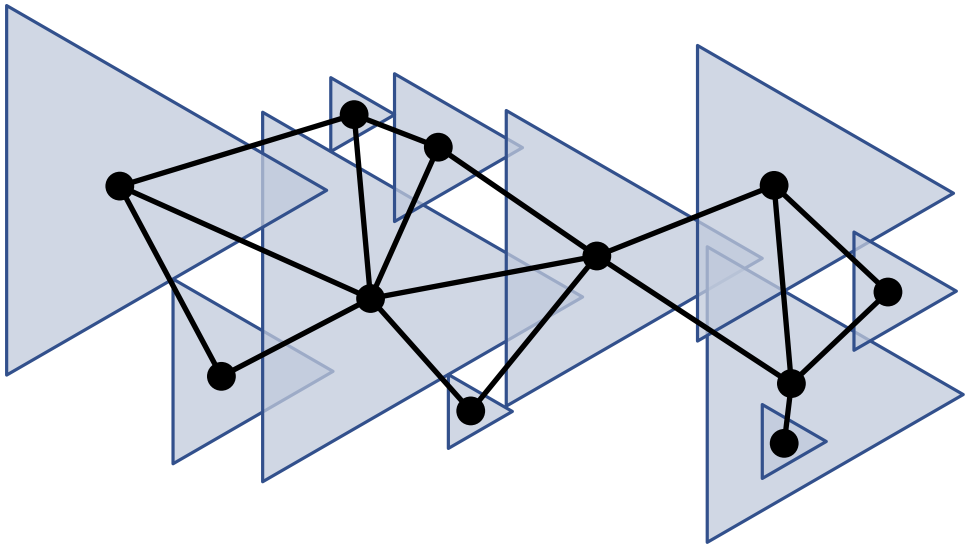

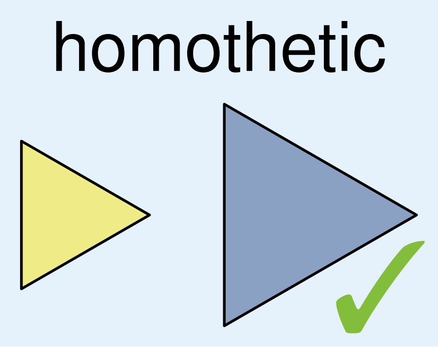

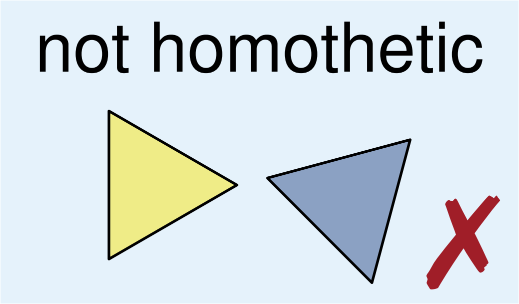

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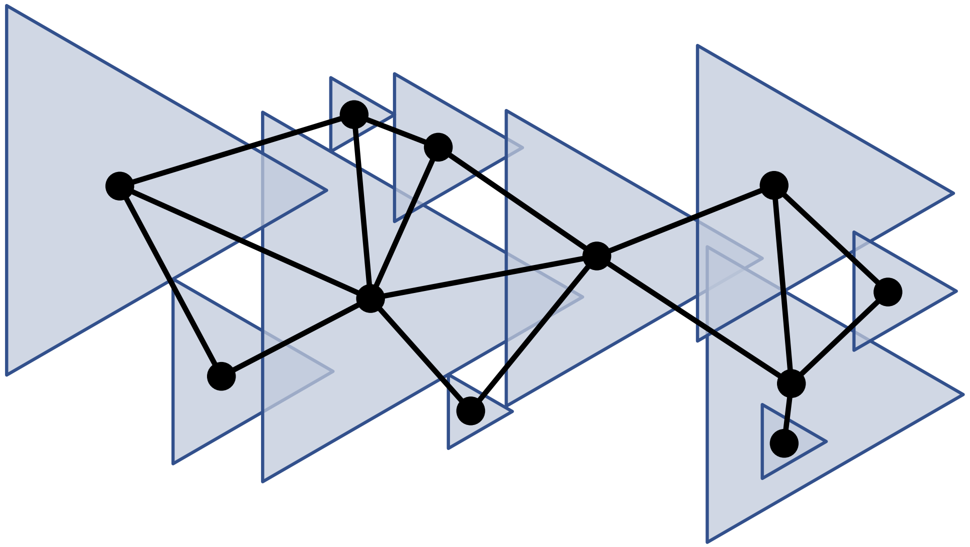

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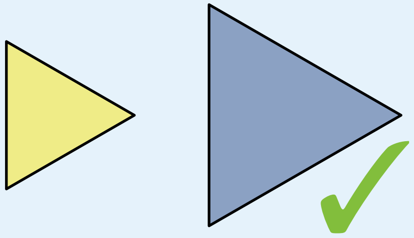
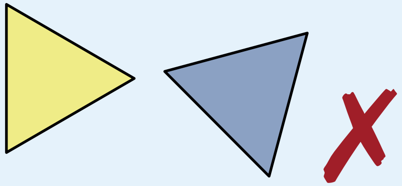


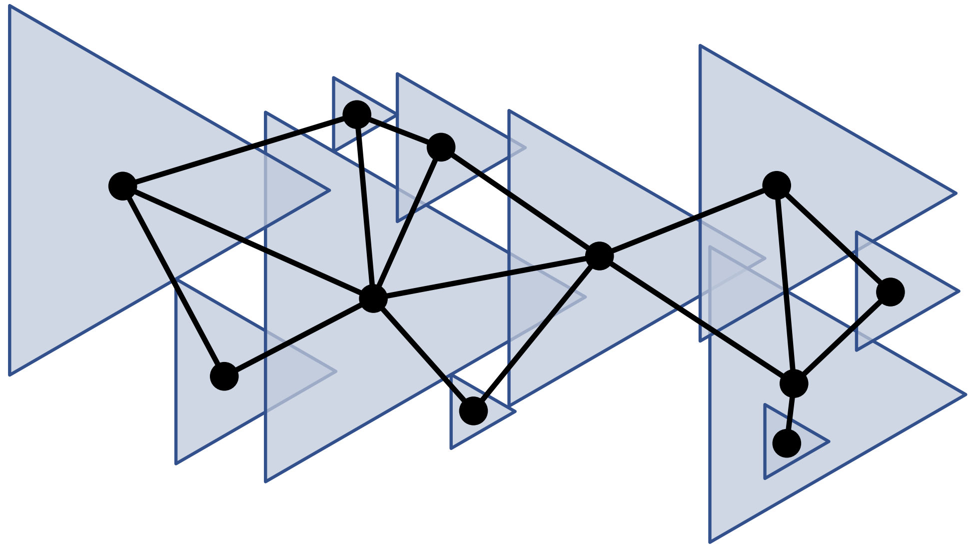
not homothetic

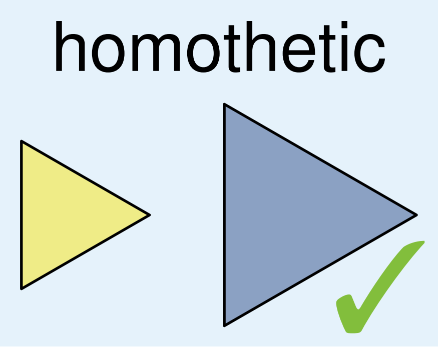


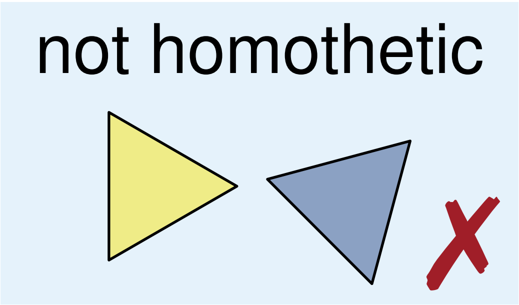
Problems for product structure:

large cliques

Intersection Graphs of Homothetic n-Gons







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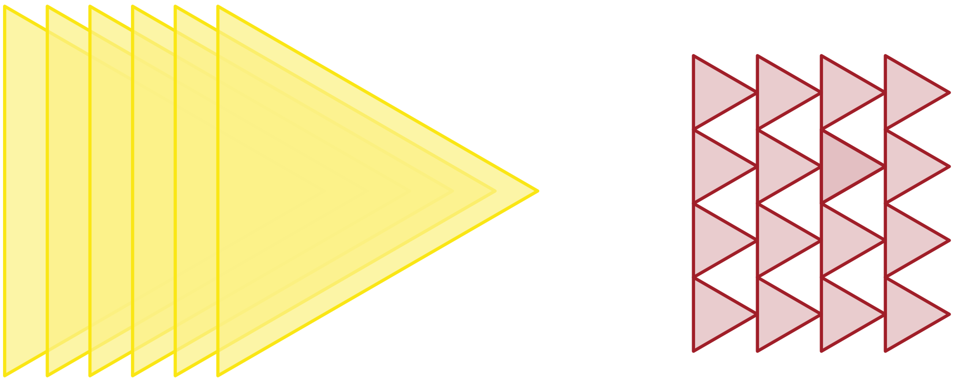

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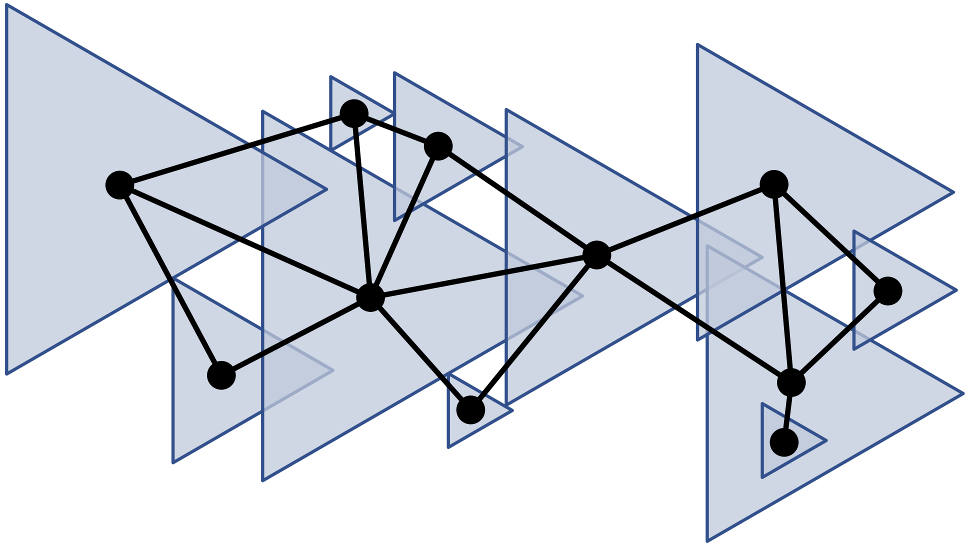

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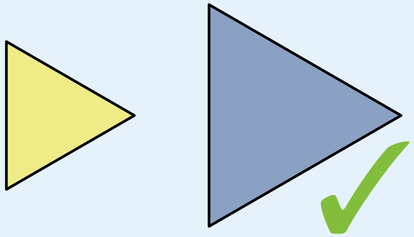

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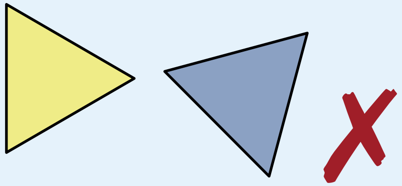
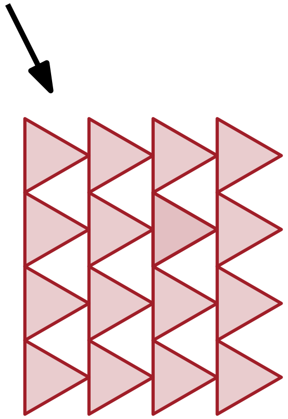


Problems for product structure:

large treewidth



large cliques

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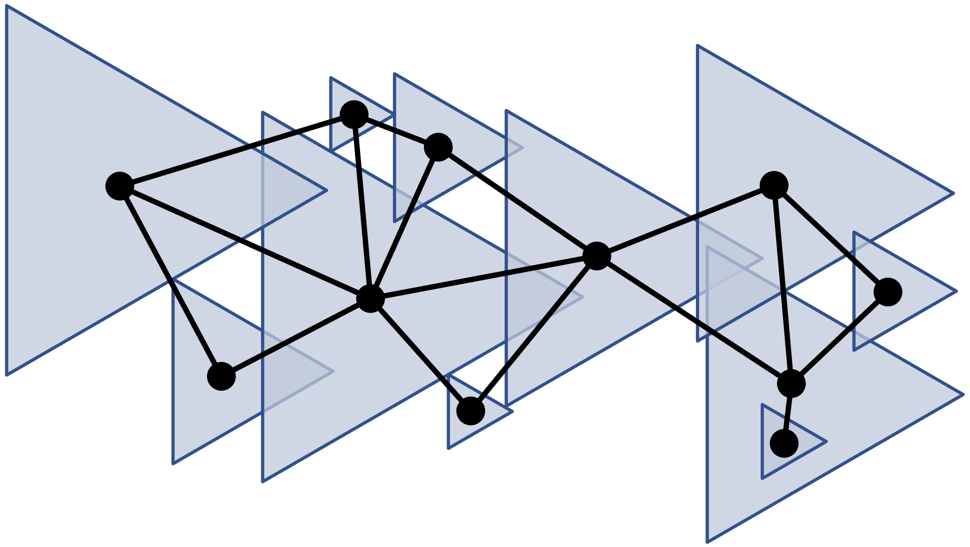

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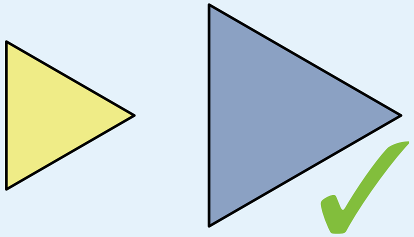

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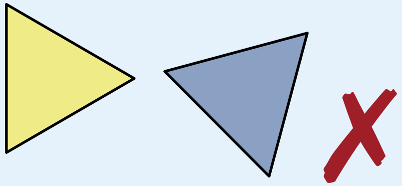

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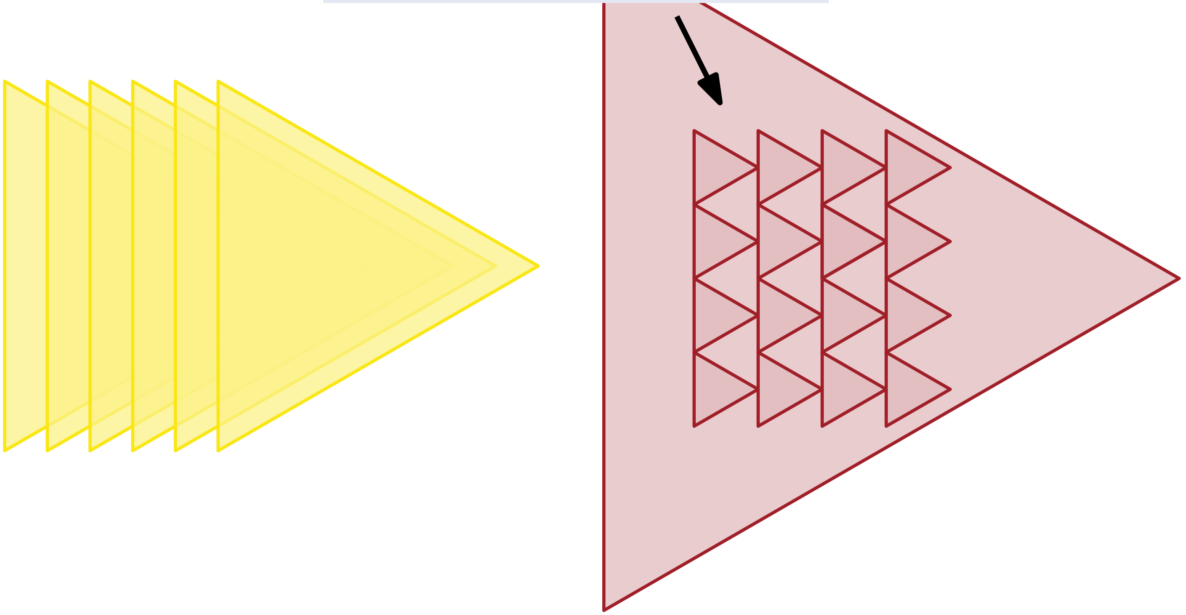

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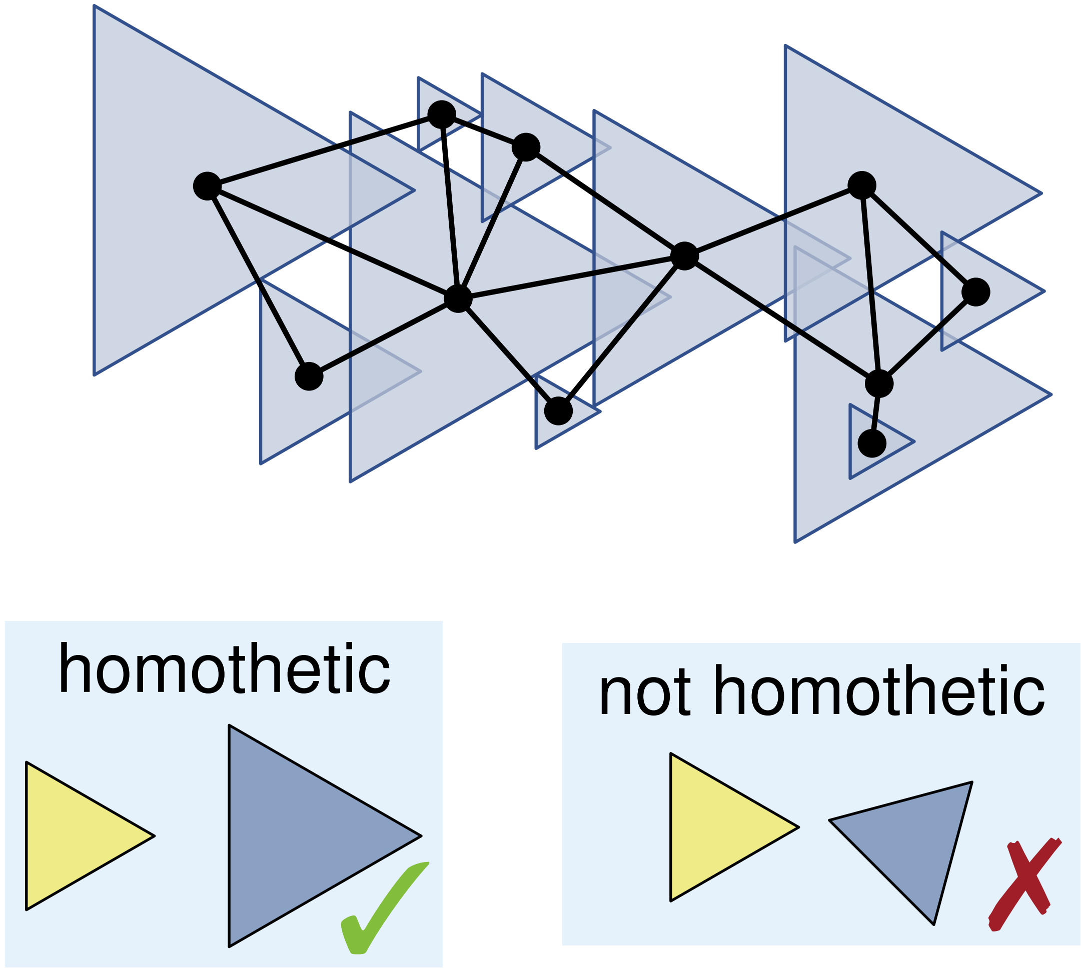

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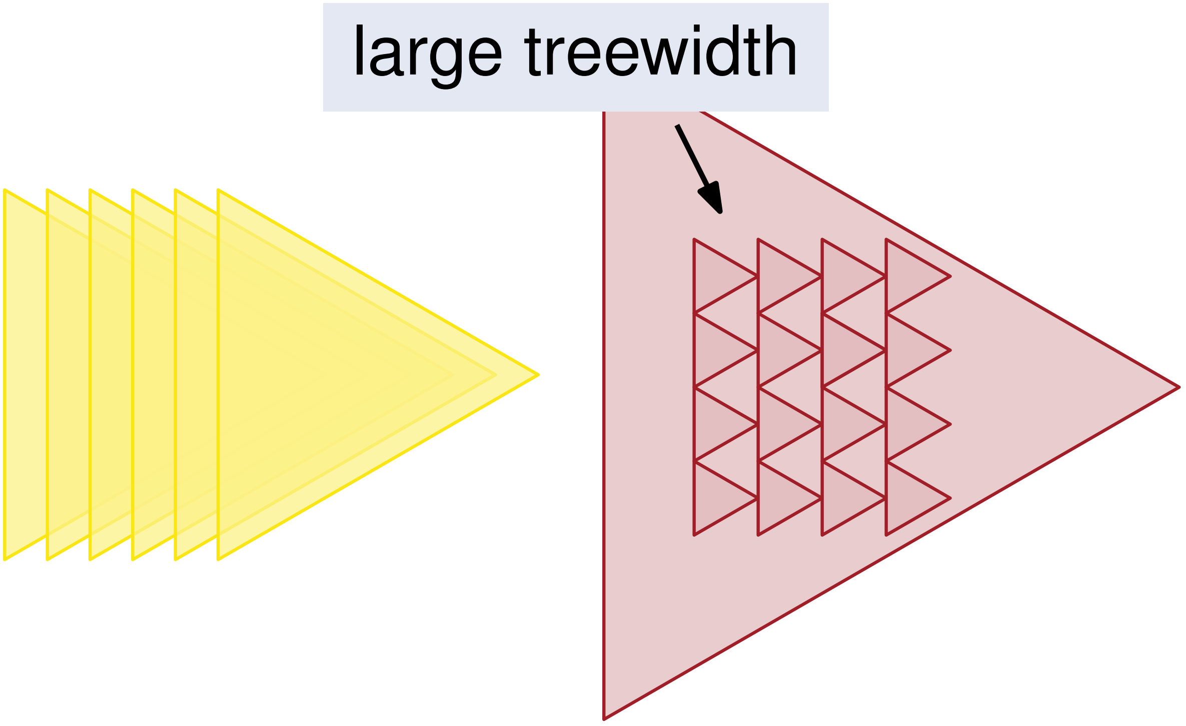

α-free Intersection Graphs

A set $\mathcal{S}$ of shapes in the plane is α-free with $\alpha \in [0, 1]$ if every shape $S \in \mathcal{S}$ has at least α of its area disjoint from all other shapes.

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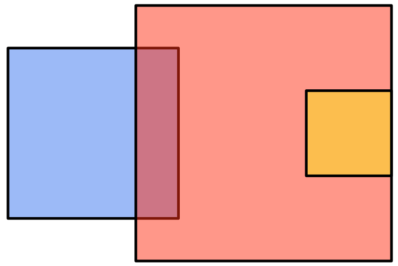

0-free

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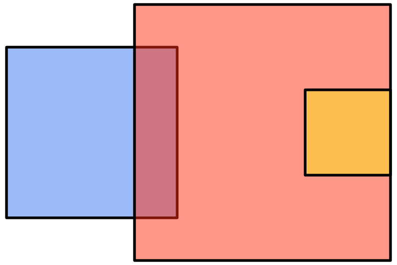

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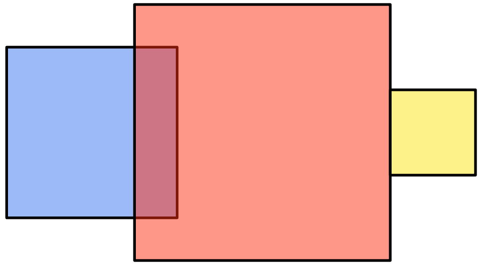

$\frac{3}{4}$-free

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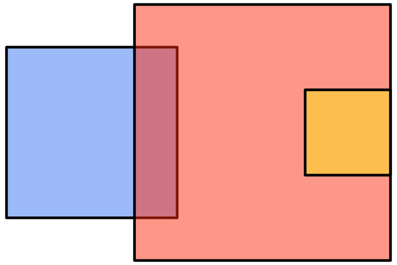

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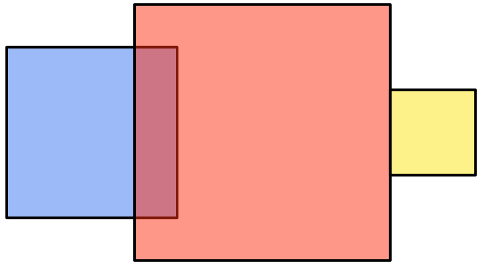

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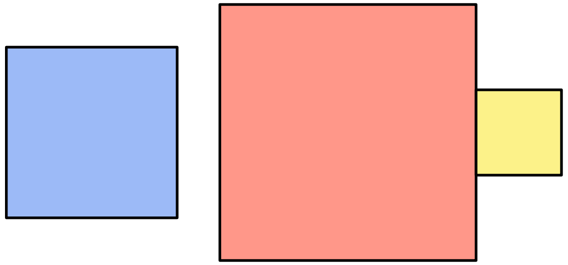

1-free

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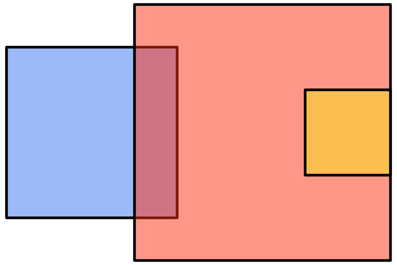
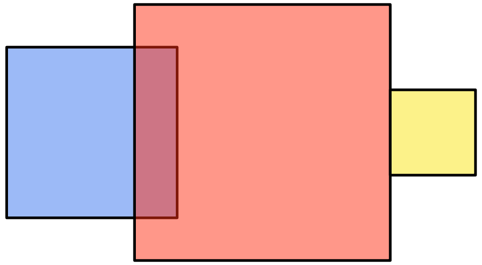


0-free



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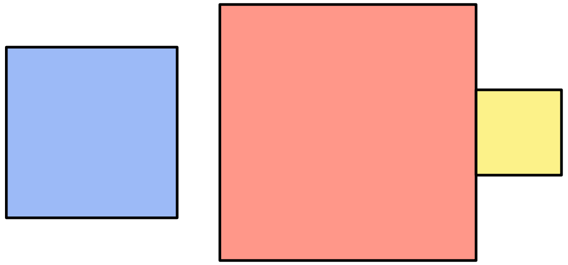

1-free

large cliques

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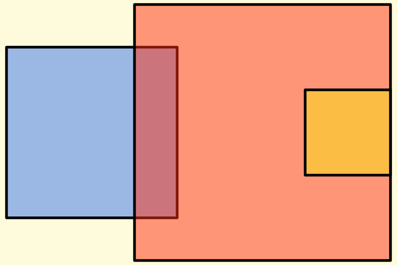

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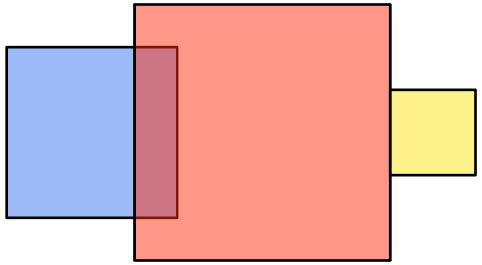

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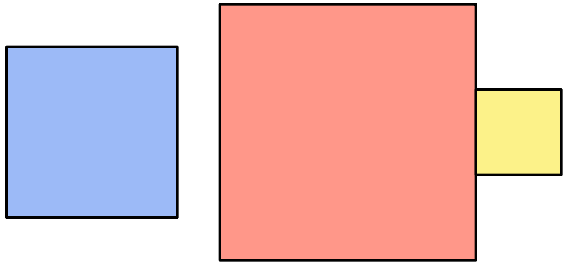

1-free

no product structure

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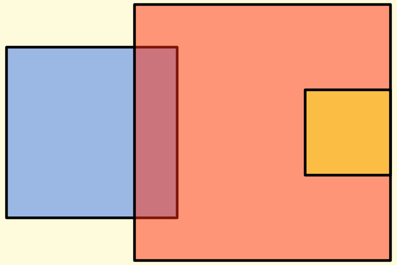

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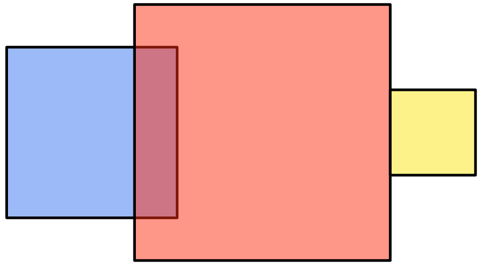

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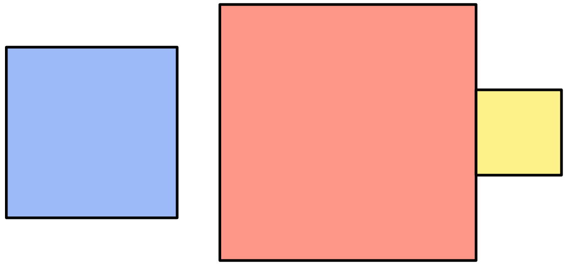

1-free

1-planar

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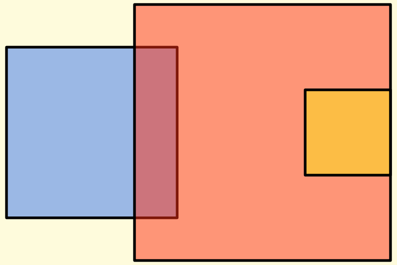
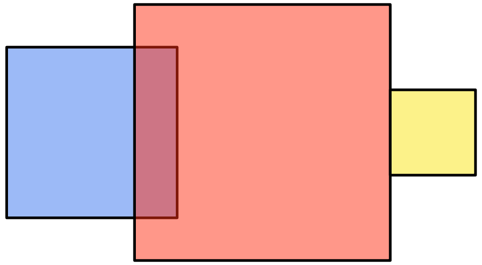


0-free

large cliques



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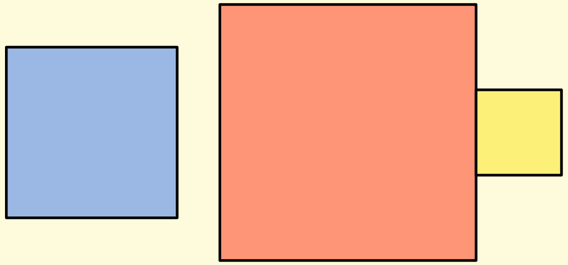

1-free

1-planar

no product structure

product structure

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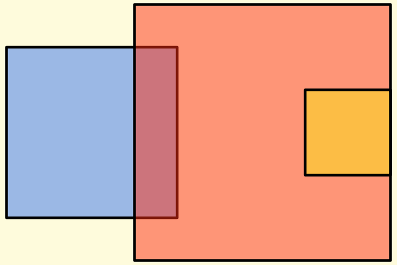

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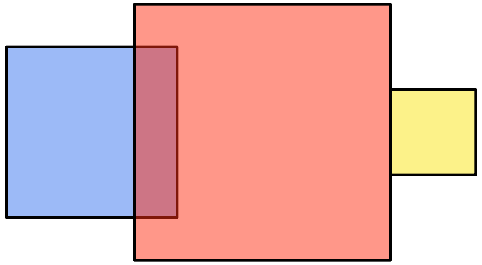

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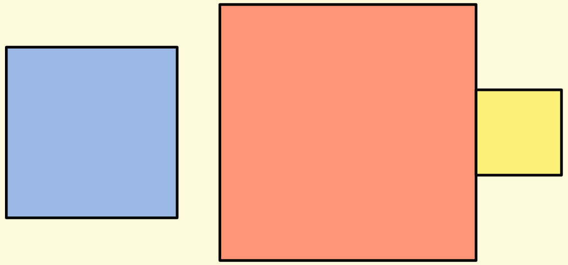
What about $\alpha \in (0, 1)$?

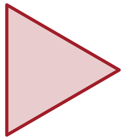
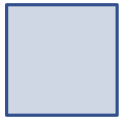


1-free

1-planar

product structure

Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.

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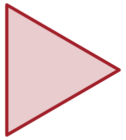
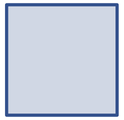
- For  and  : **no** product structure for $\alpha < 1$.
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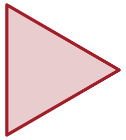
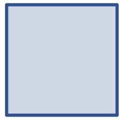
- For  and  : **no** product structure for $\alpha < 1$.
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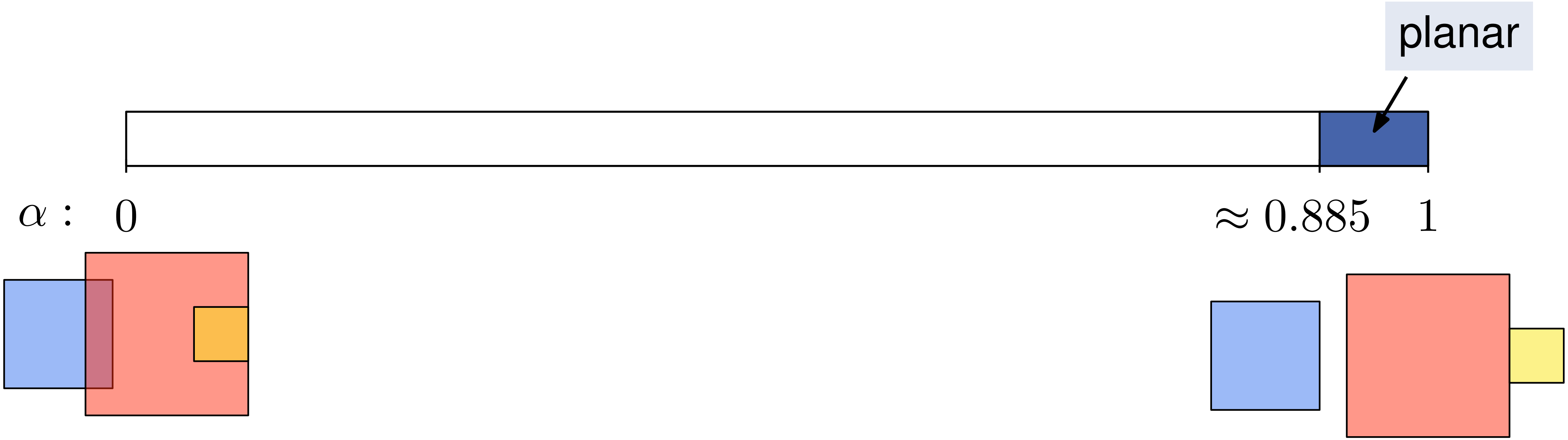
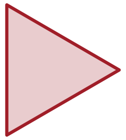
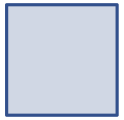
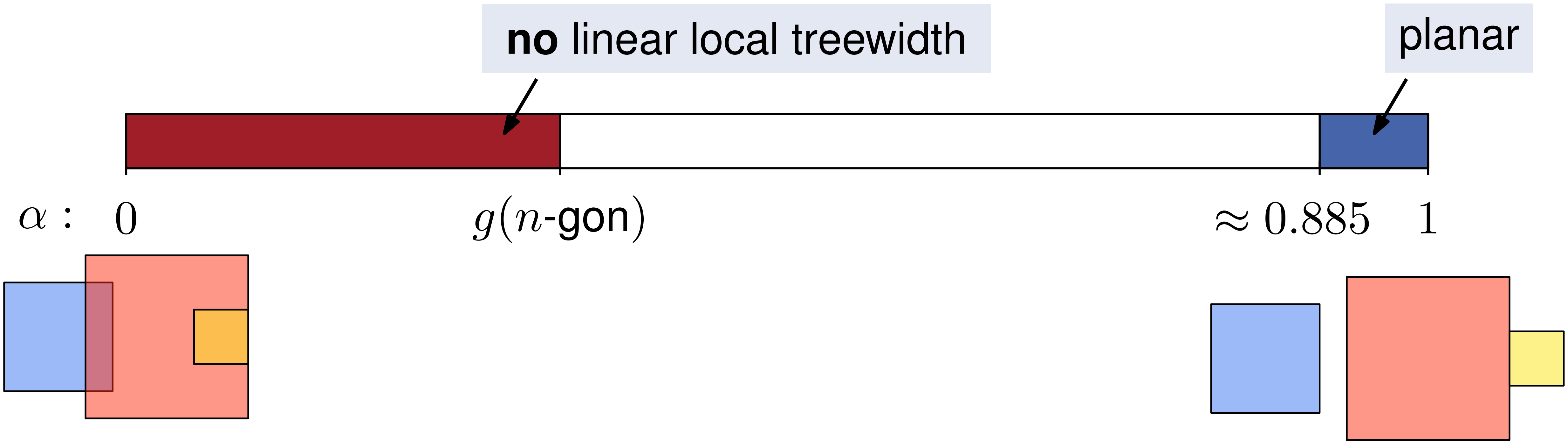


Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.
- For even $n \geq 6$:



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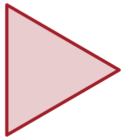
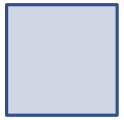
Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.
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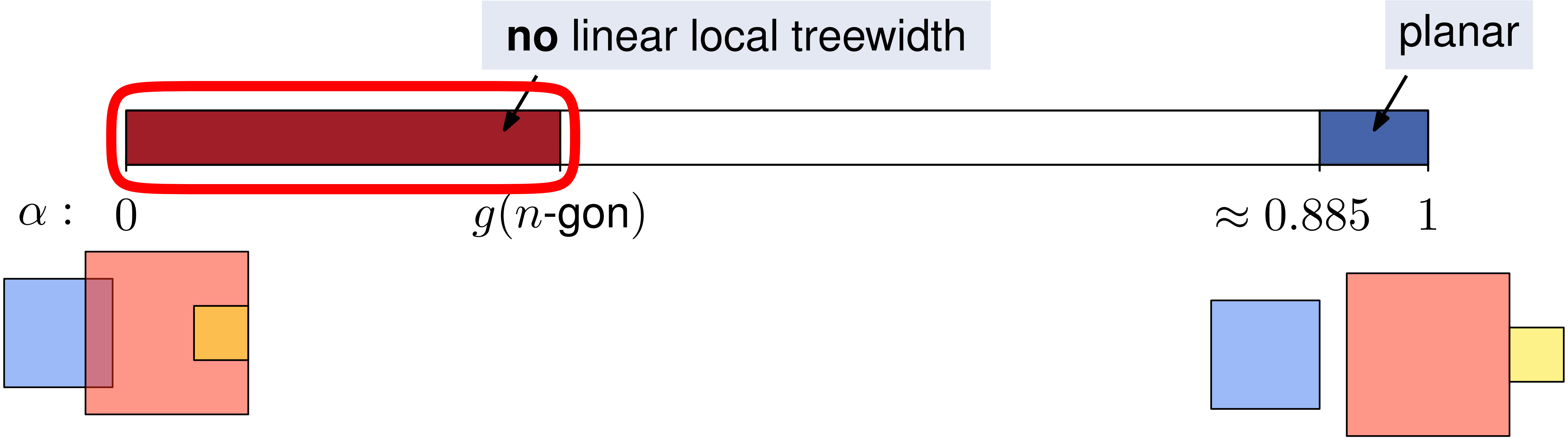

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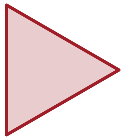
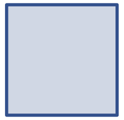
- For  and  : **no** product structure for $\alpha < 1$.
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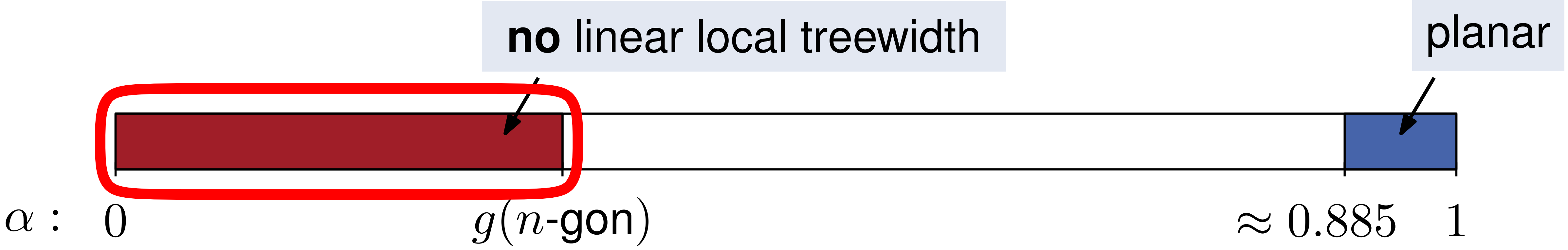

$\mathcal{G}$ has **linear local treewidth** $\Longrightarrow$ graphs in $\mathcal{G}$ have **treewidth linear in their radius**

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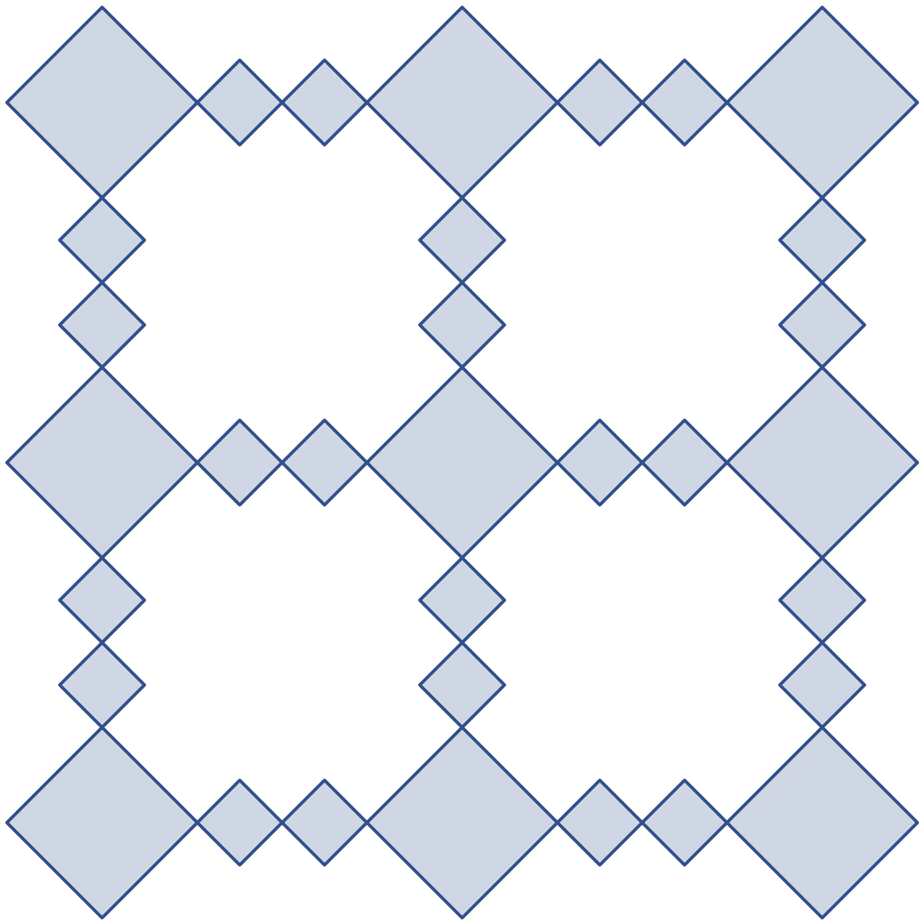
Constructing Graphs with Radius $\mathcal{O}(k)$ and Treewidth $\Omega(k^2)$



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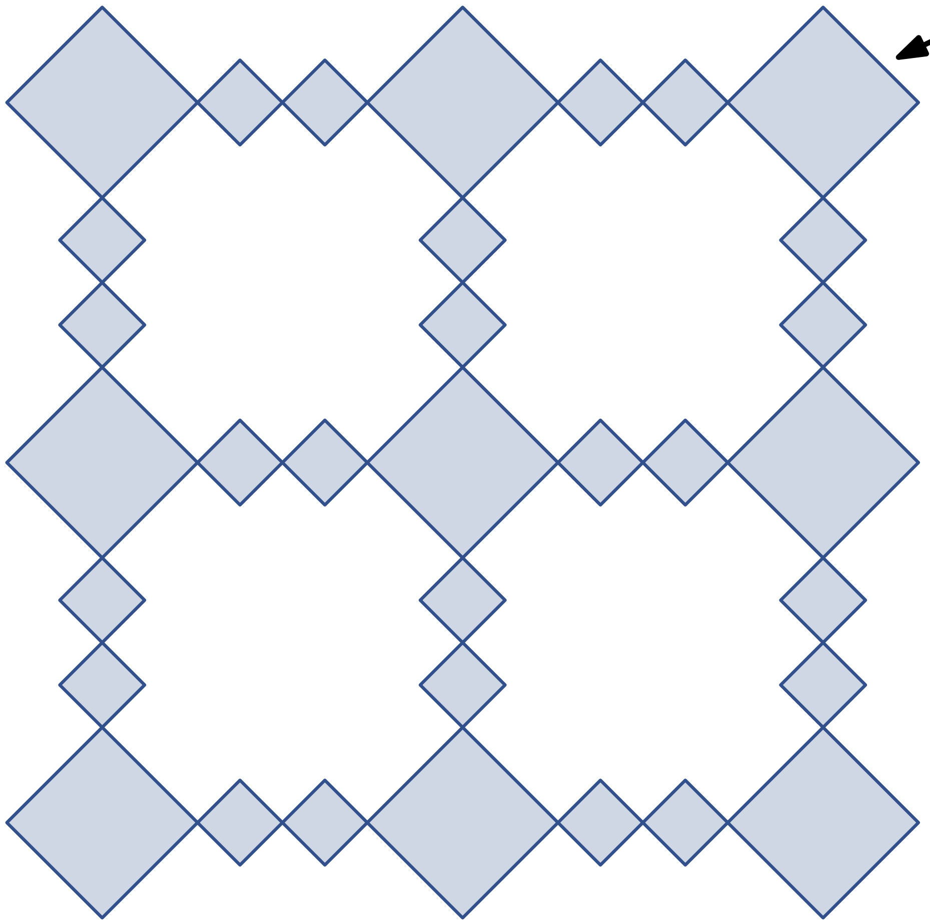

$(k+1) \times (k+1)$-grid

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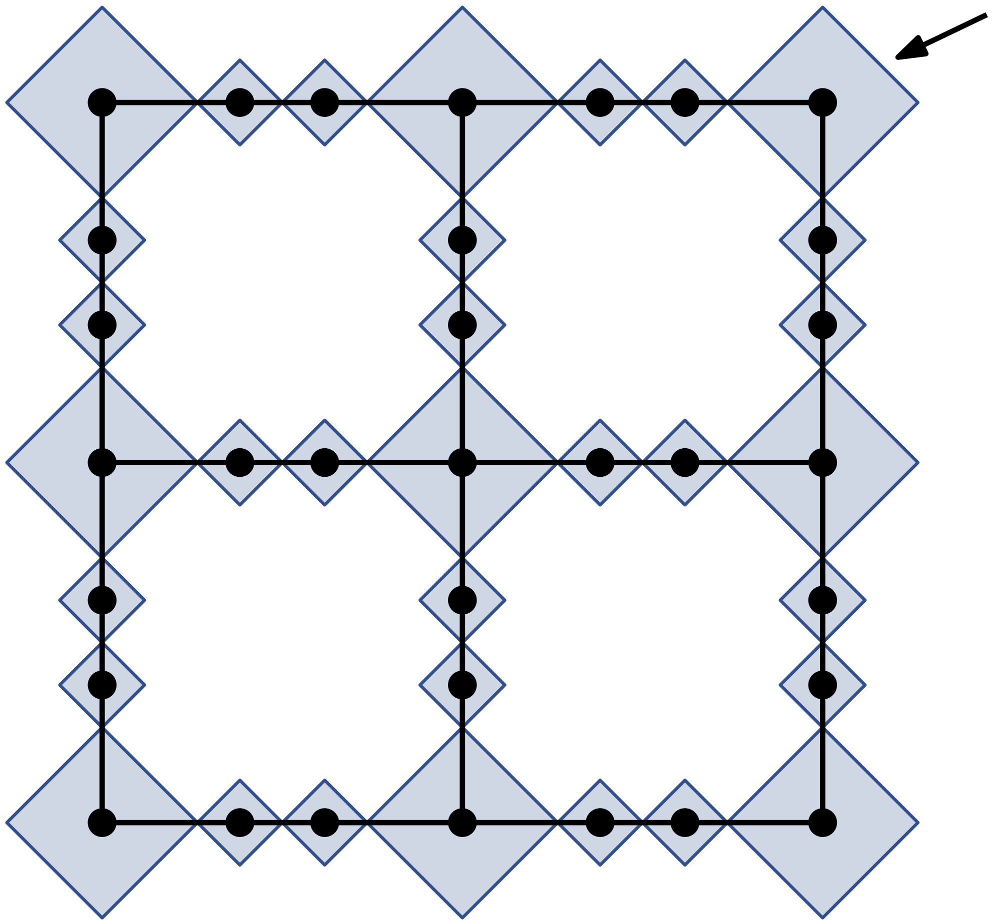

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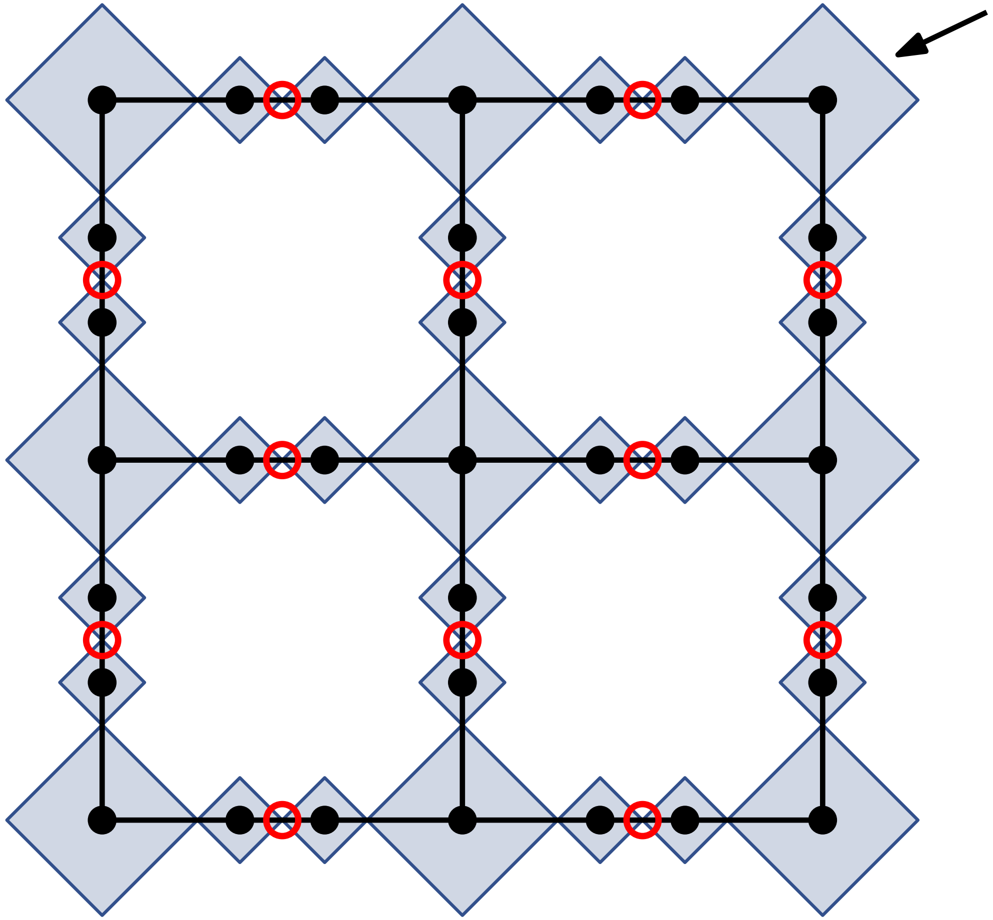

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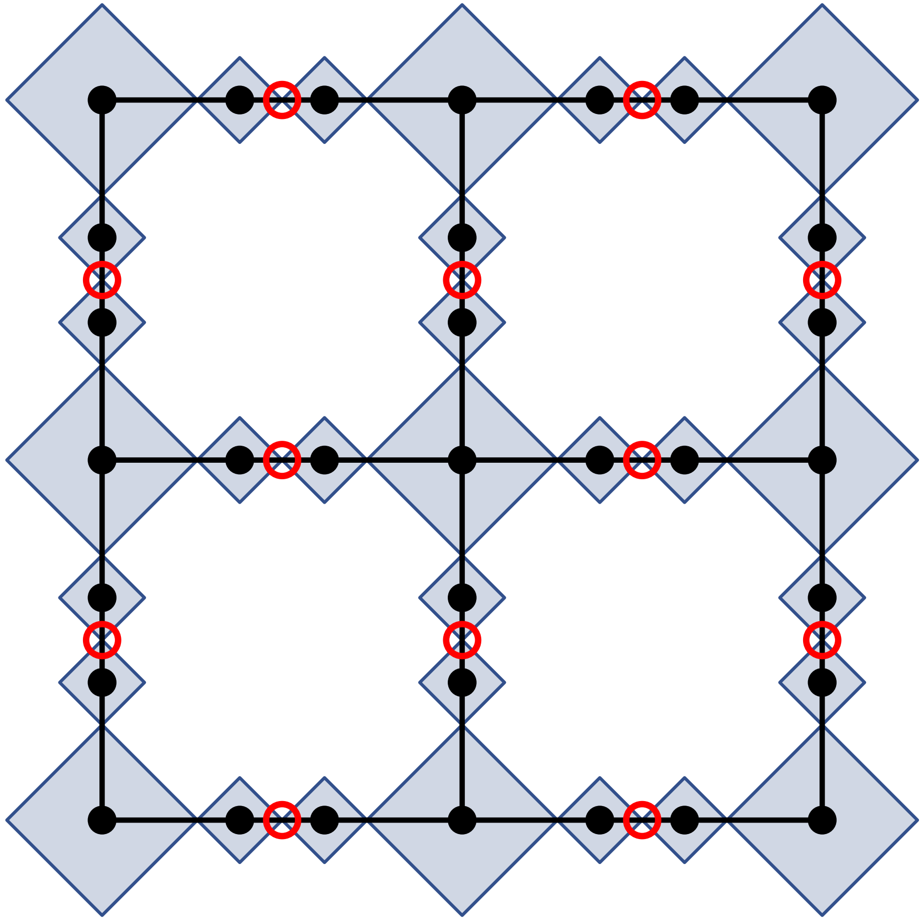

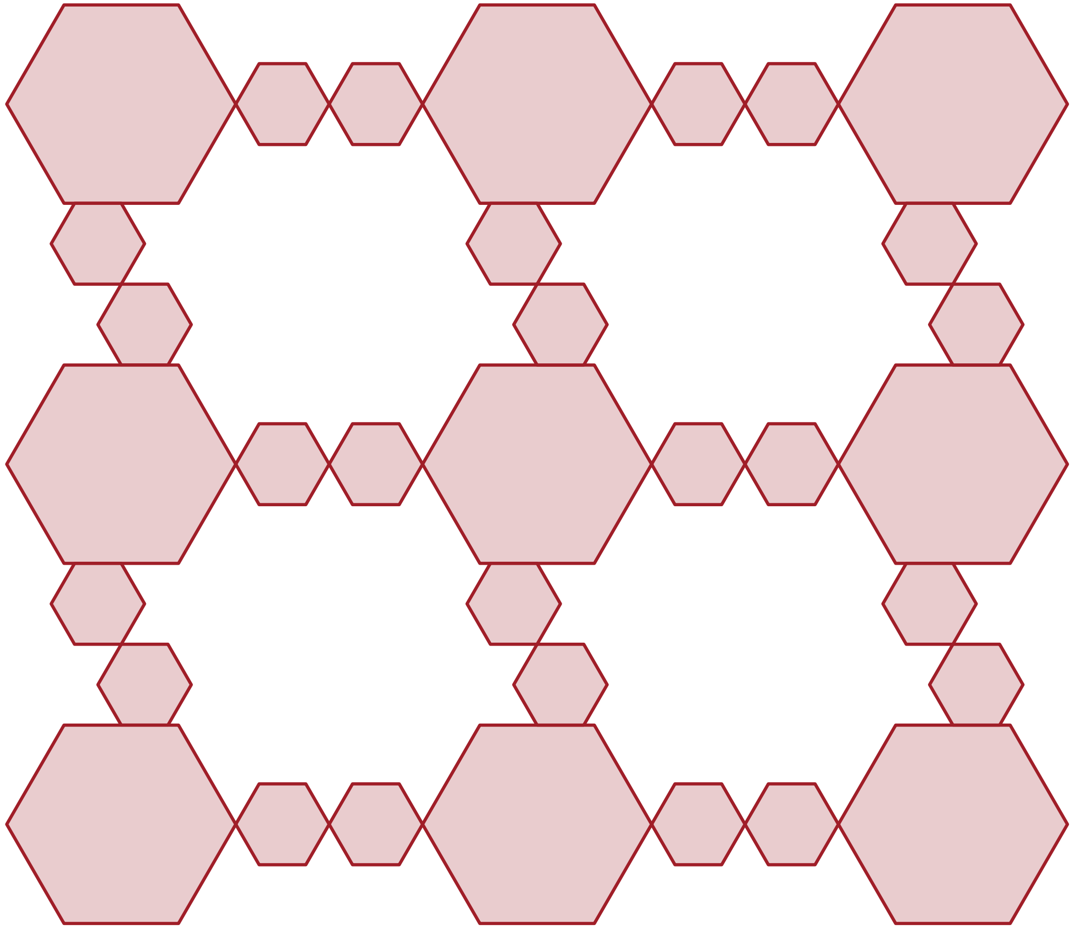

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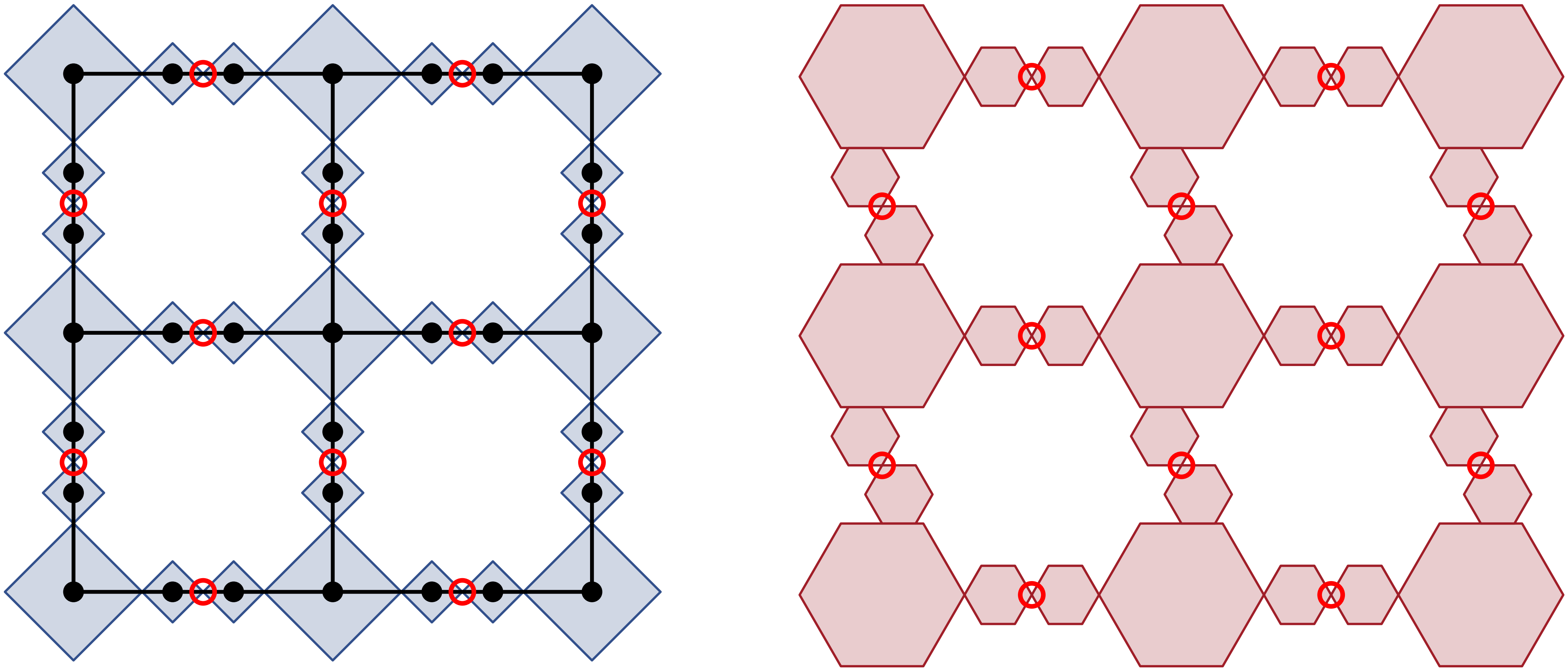

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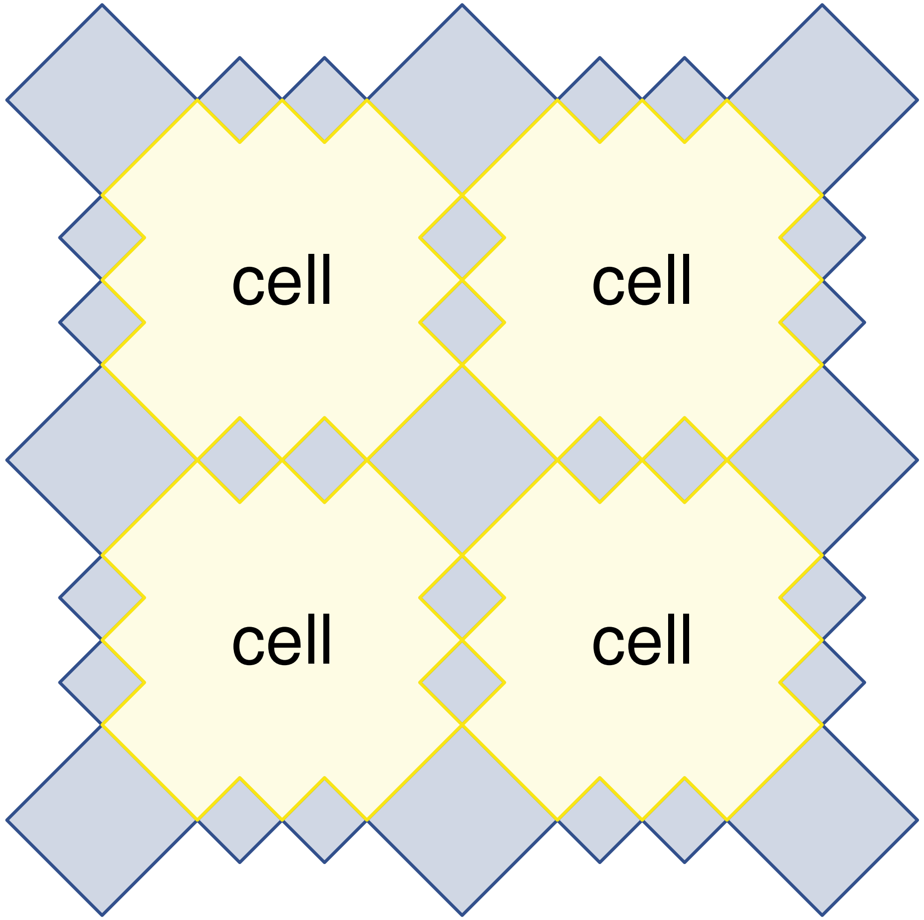

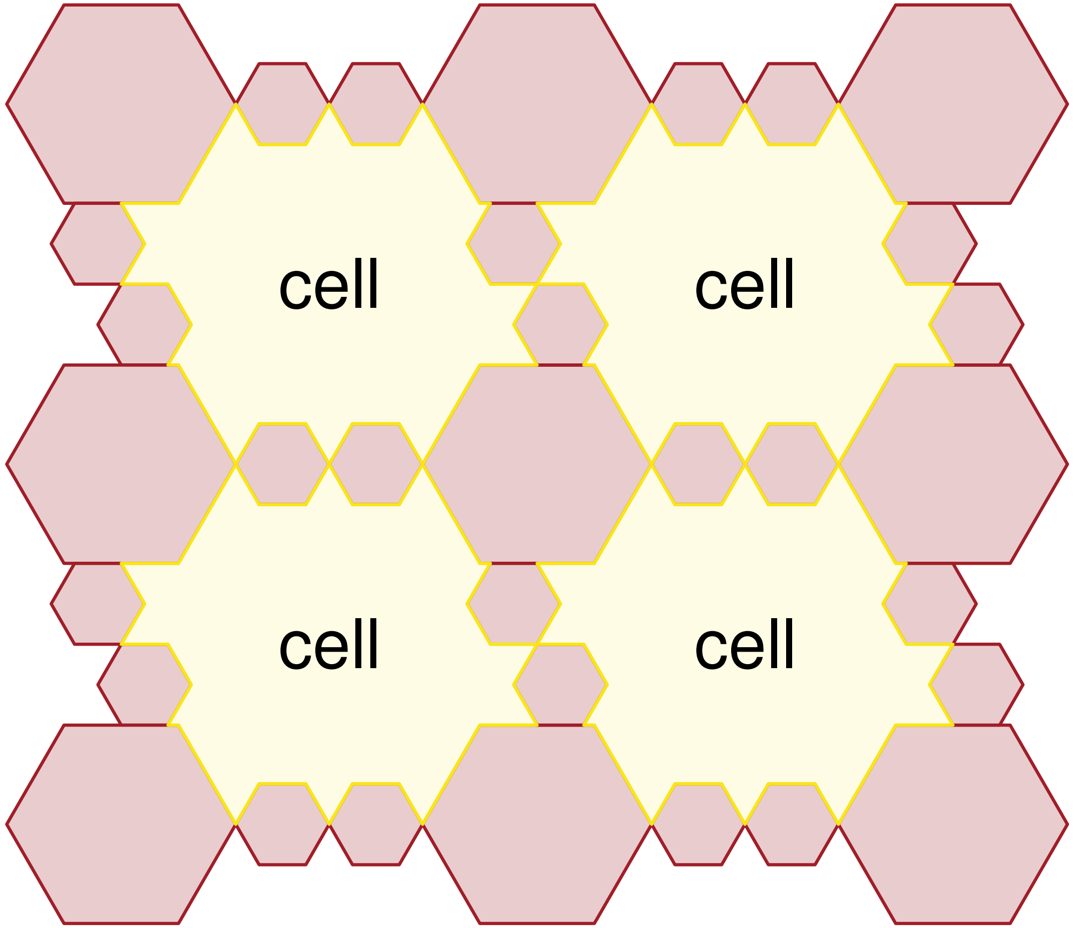

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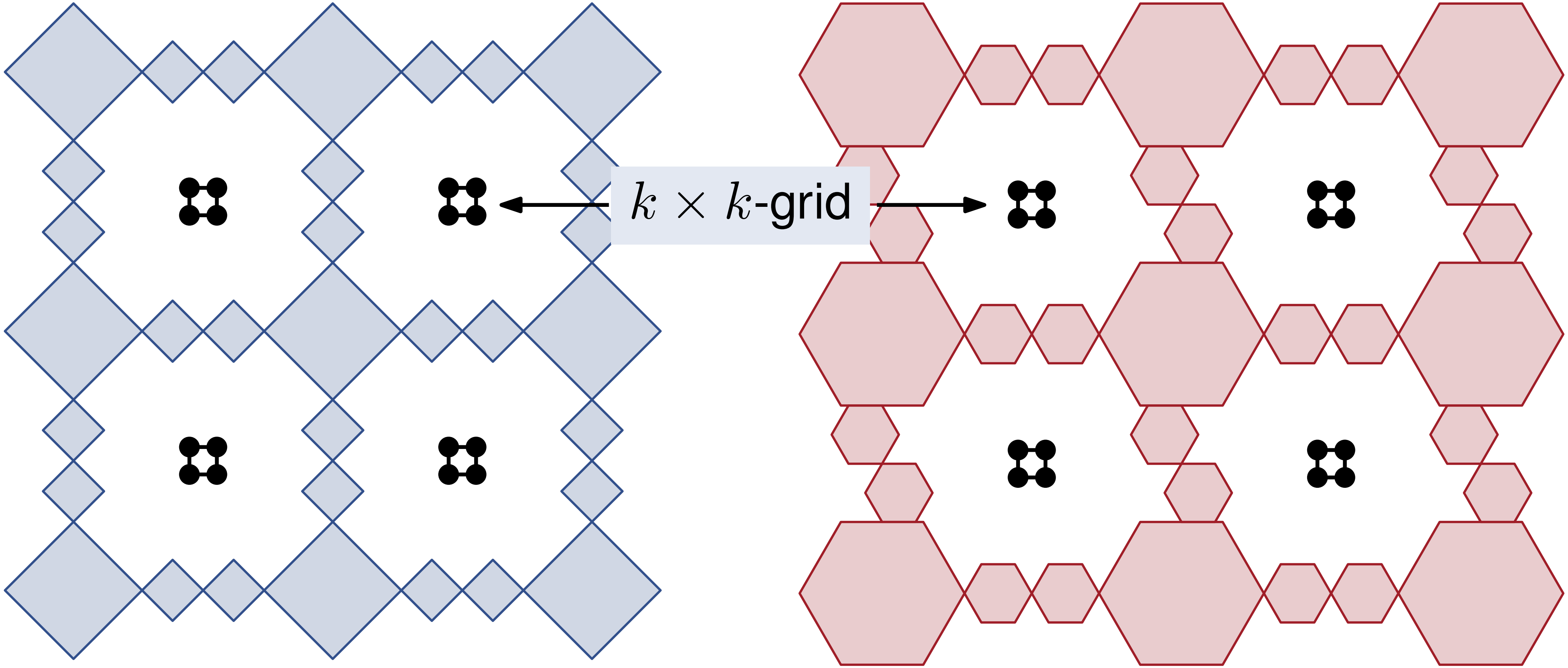

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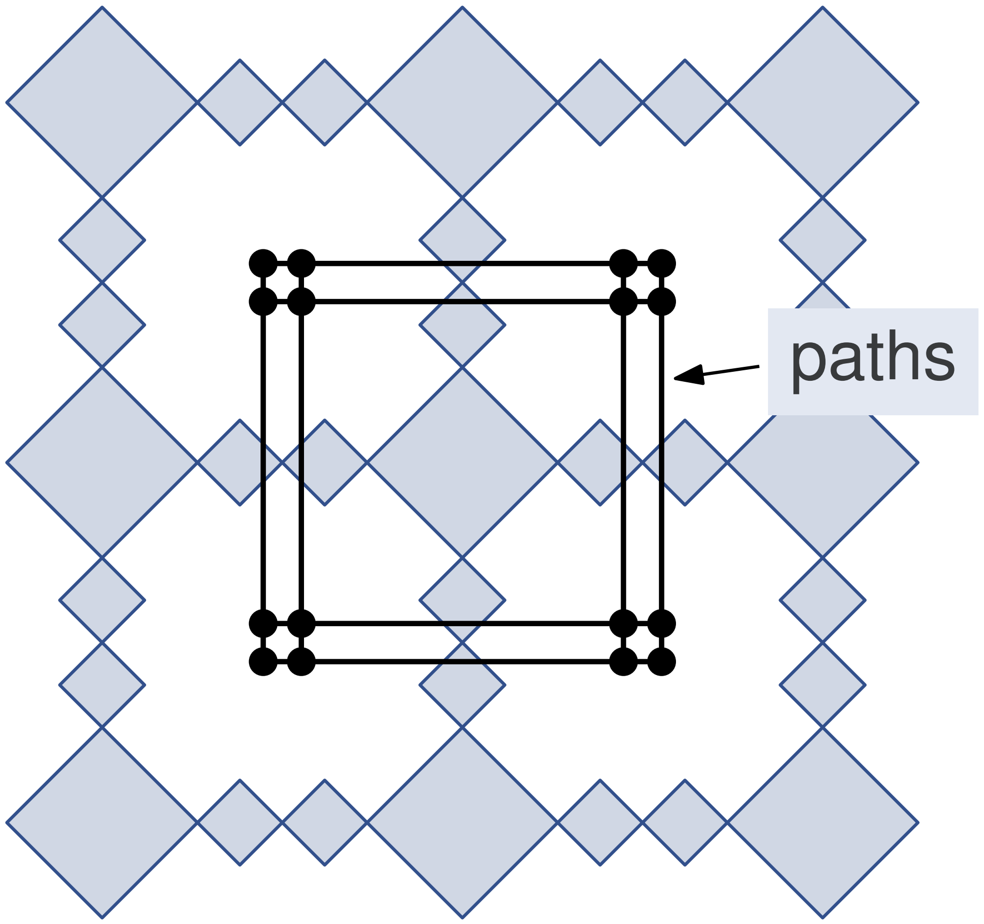

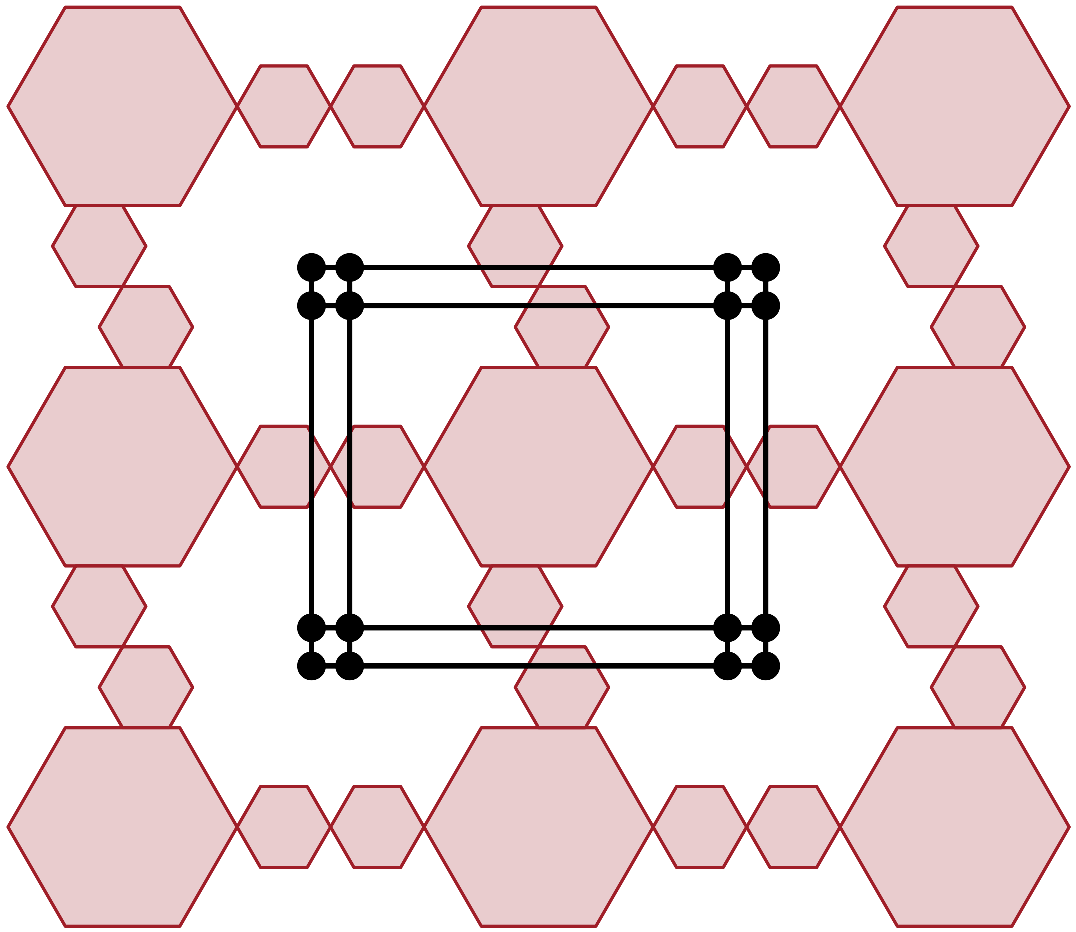

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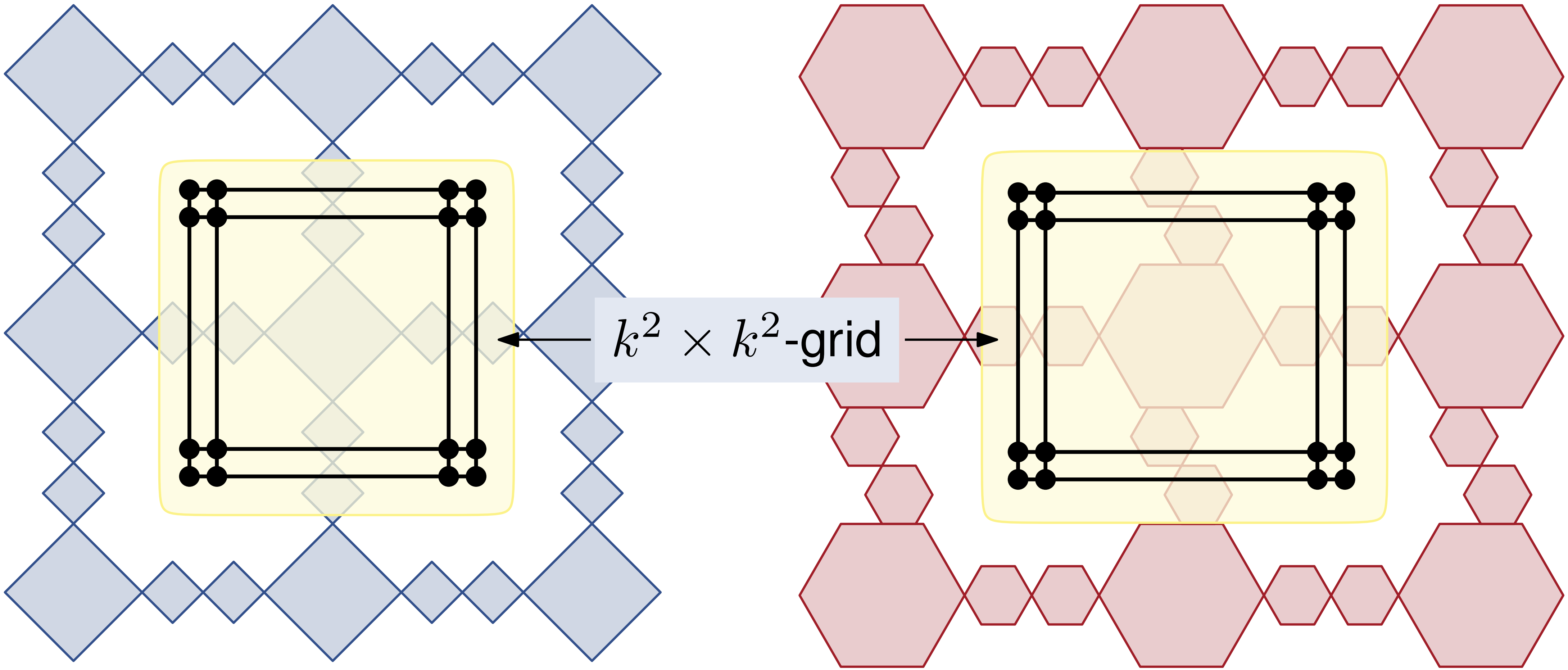

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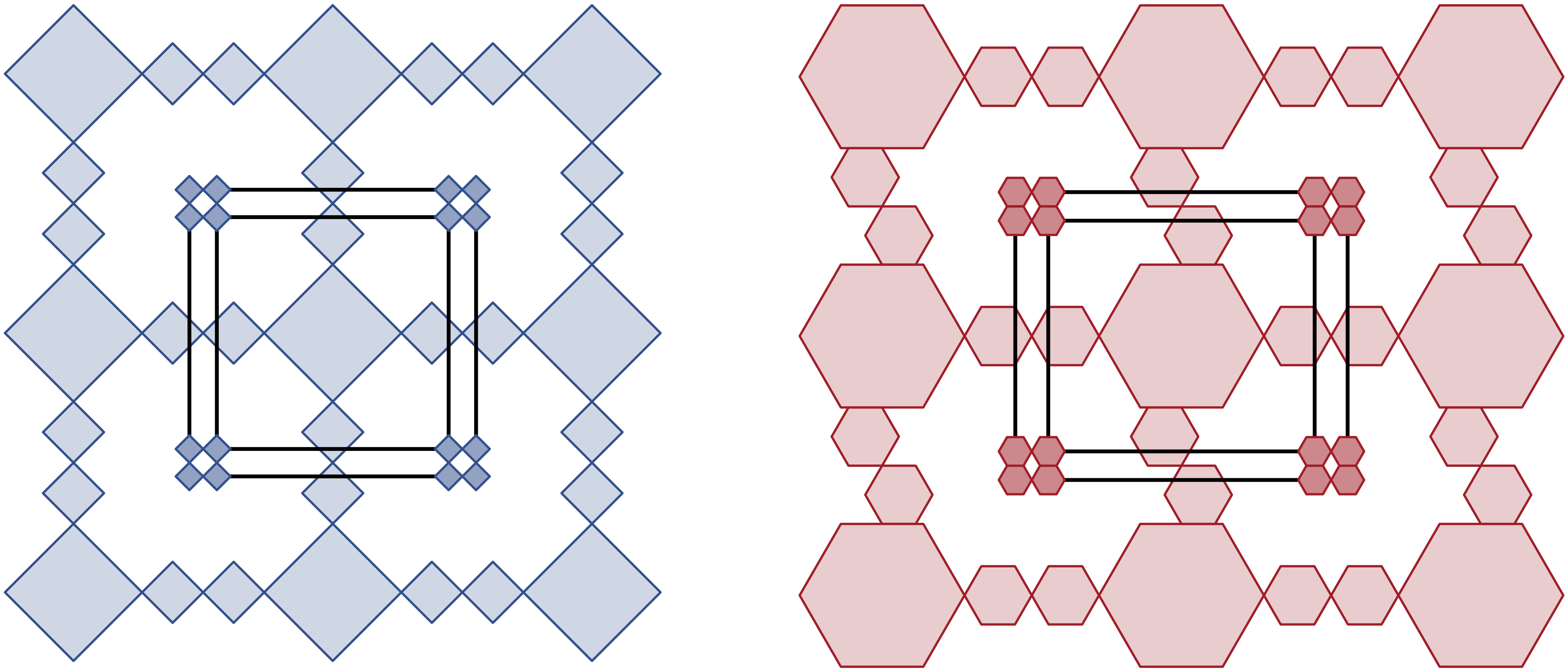

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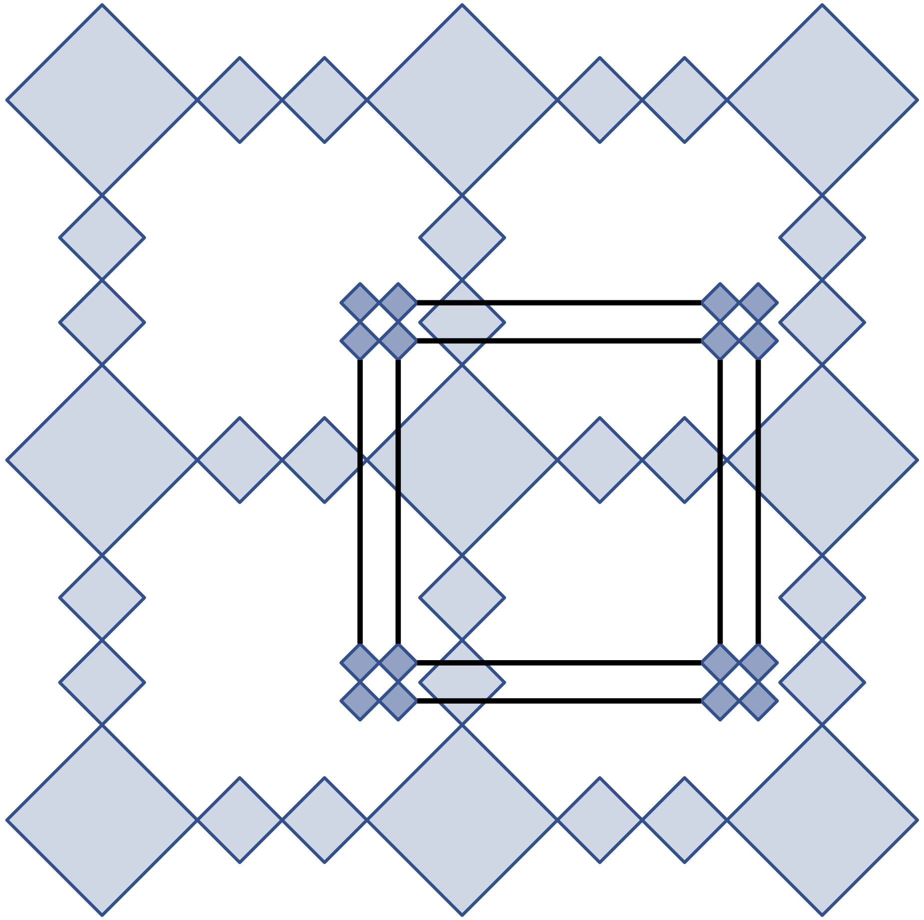

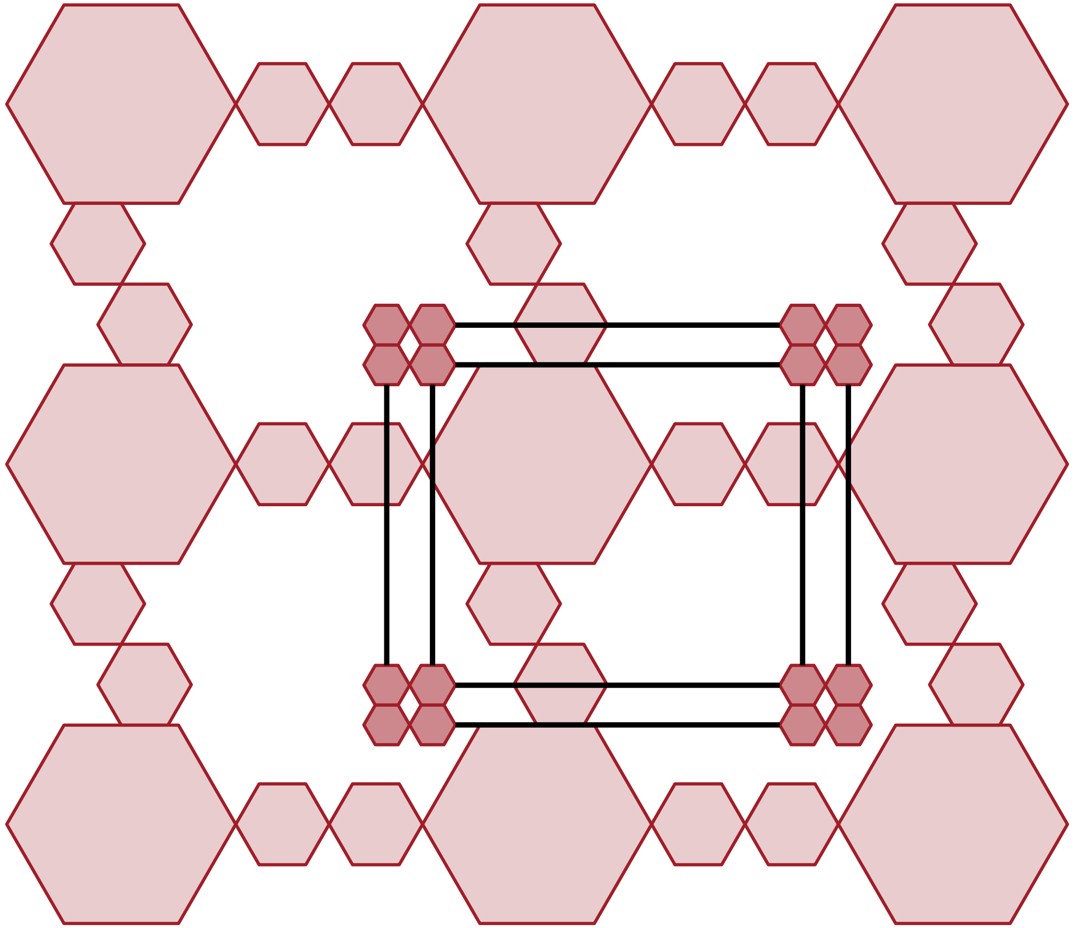

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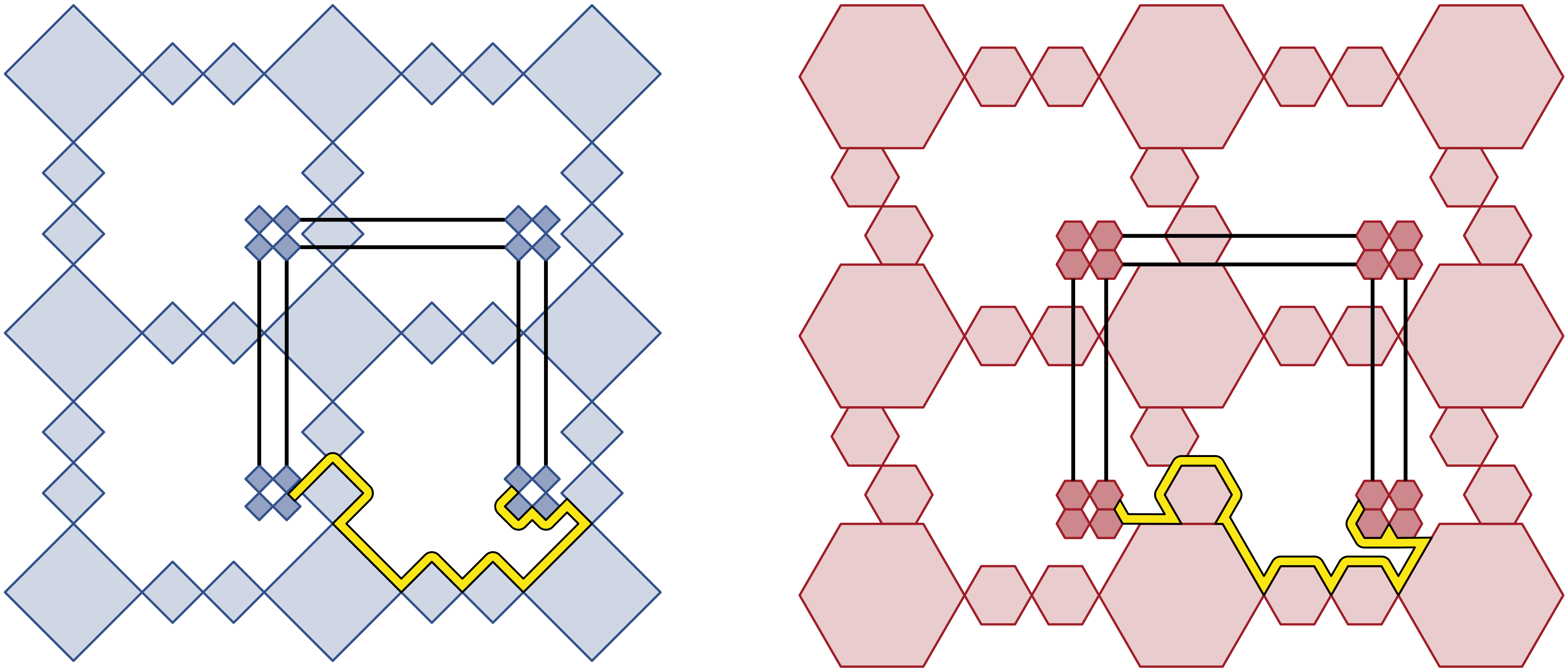

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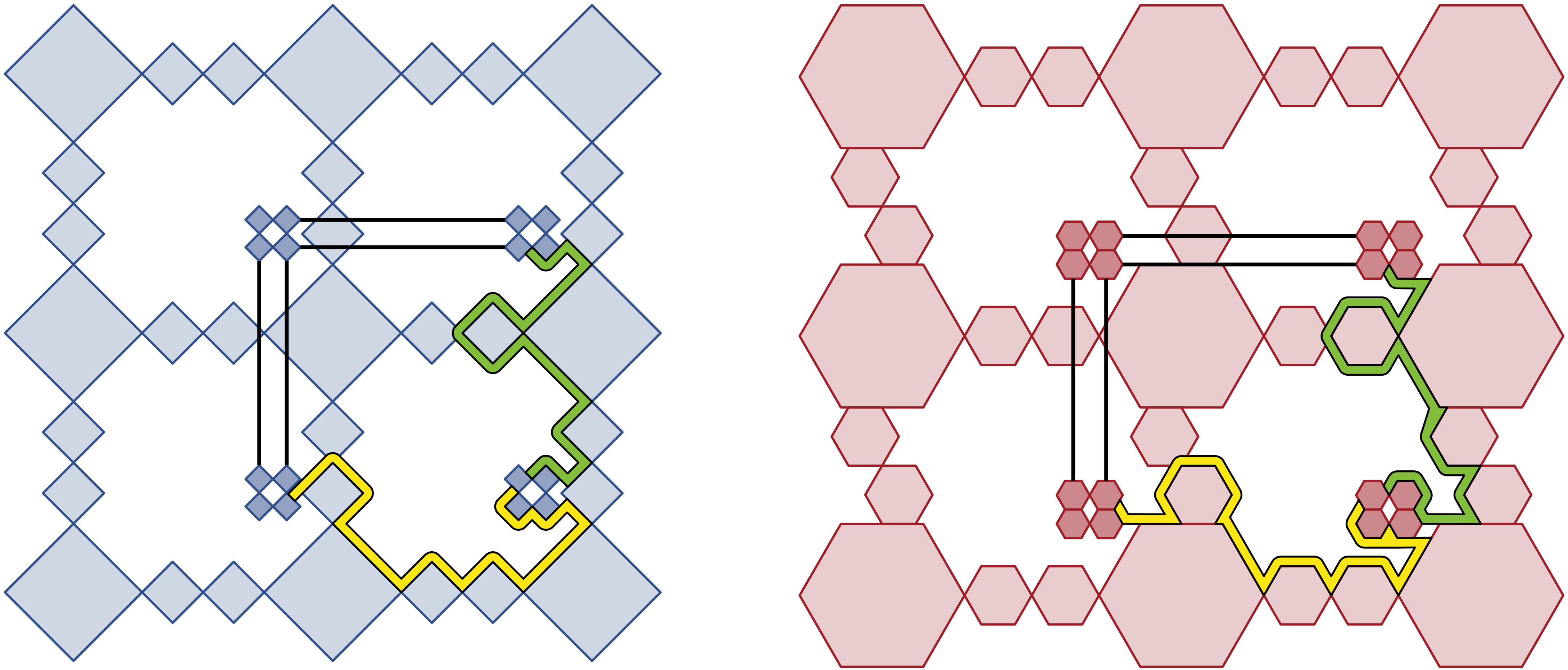

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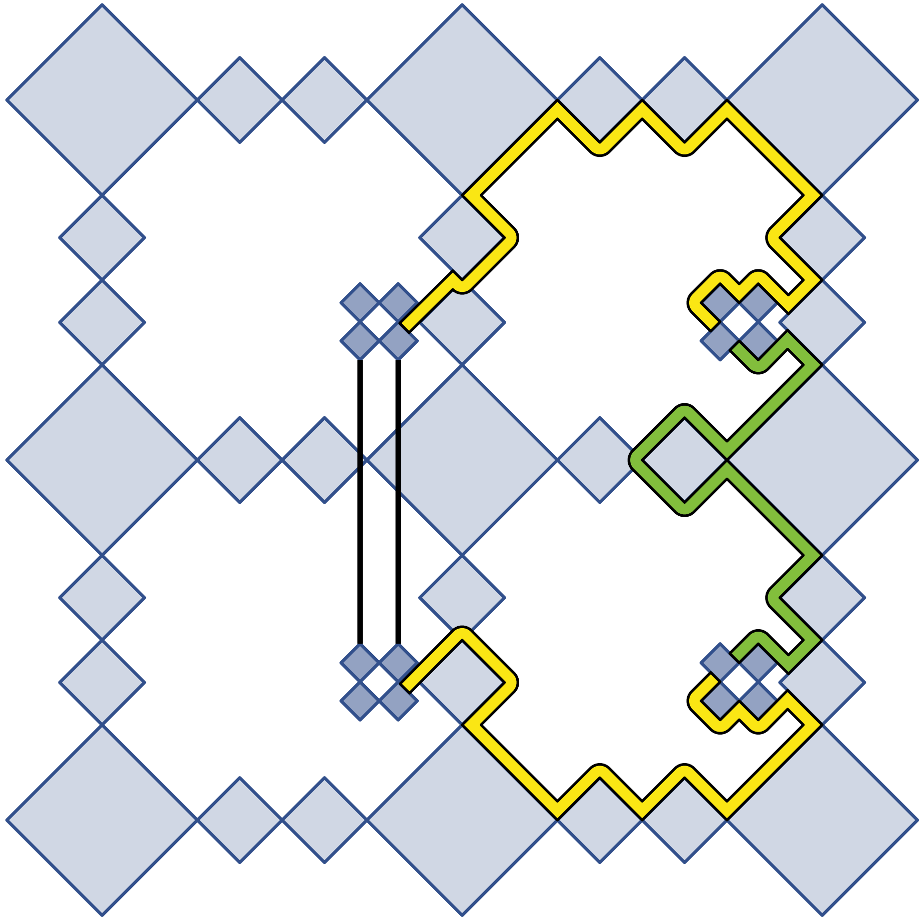

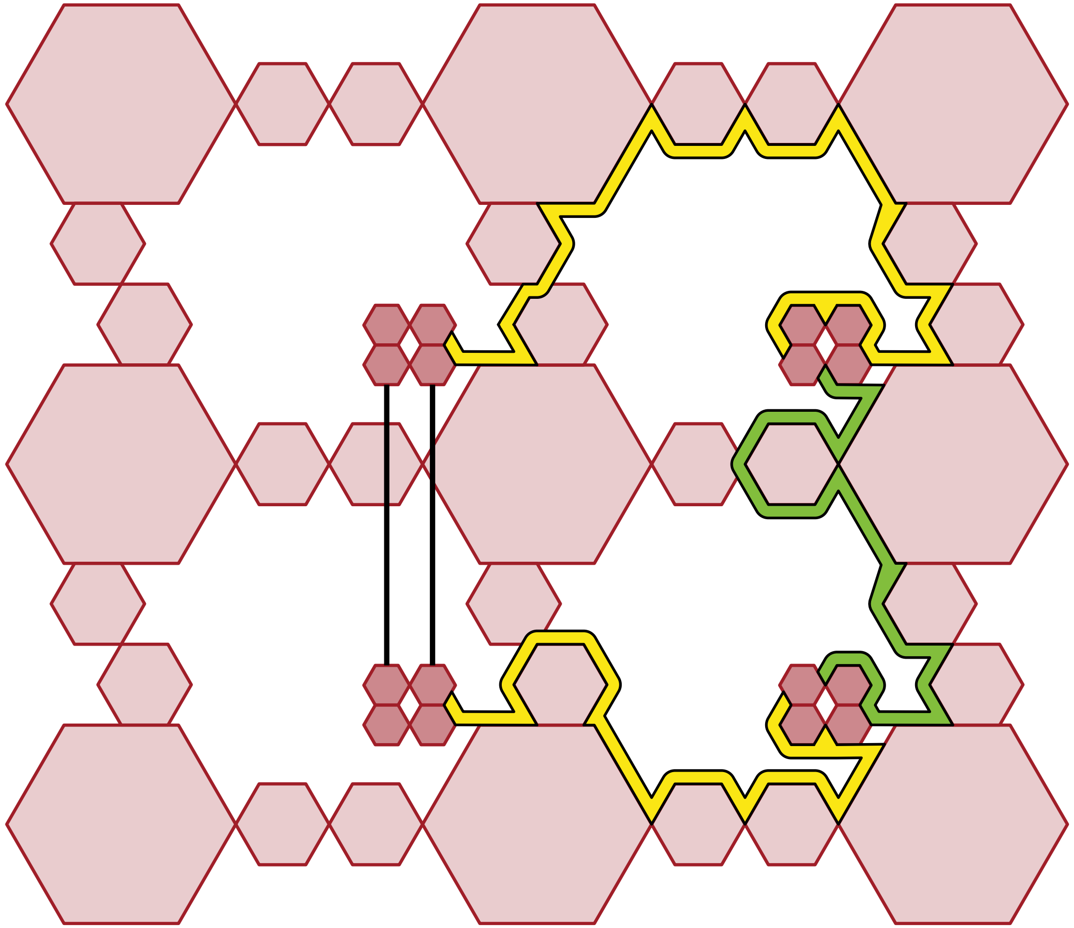

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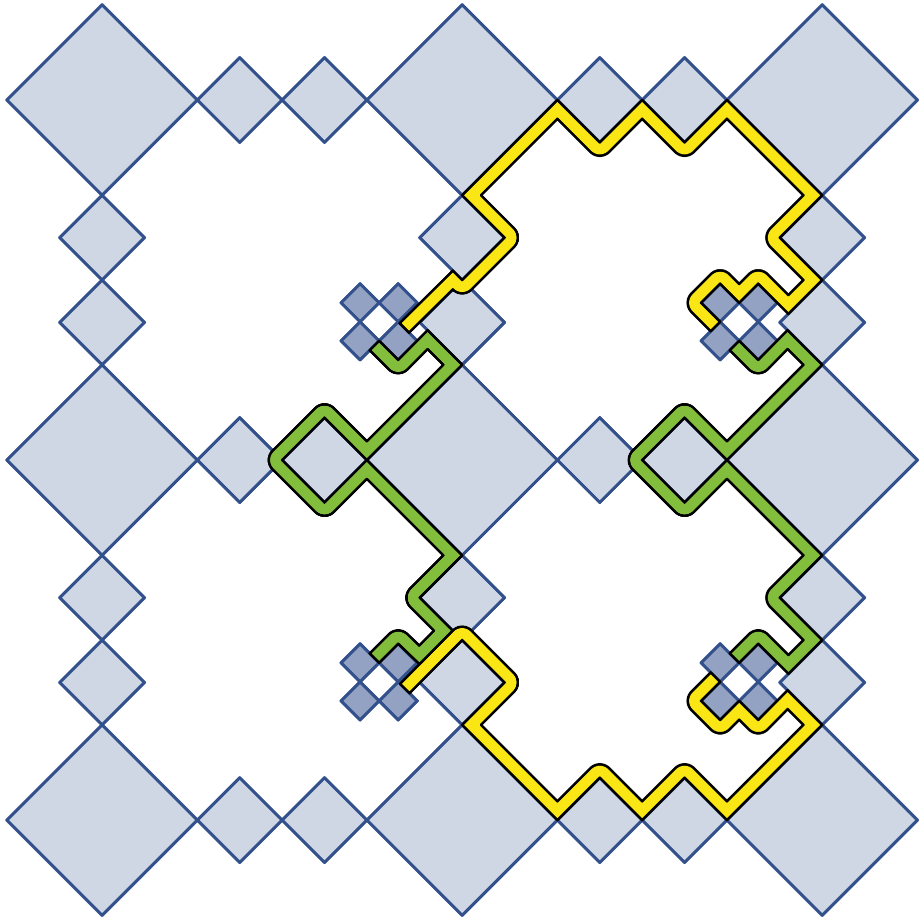

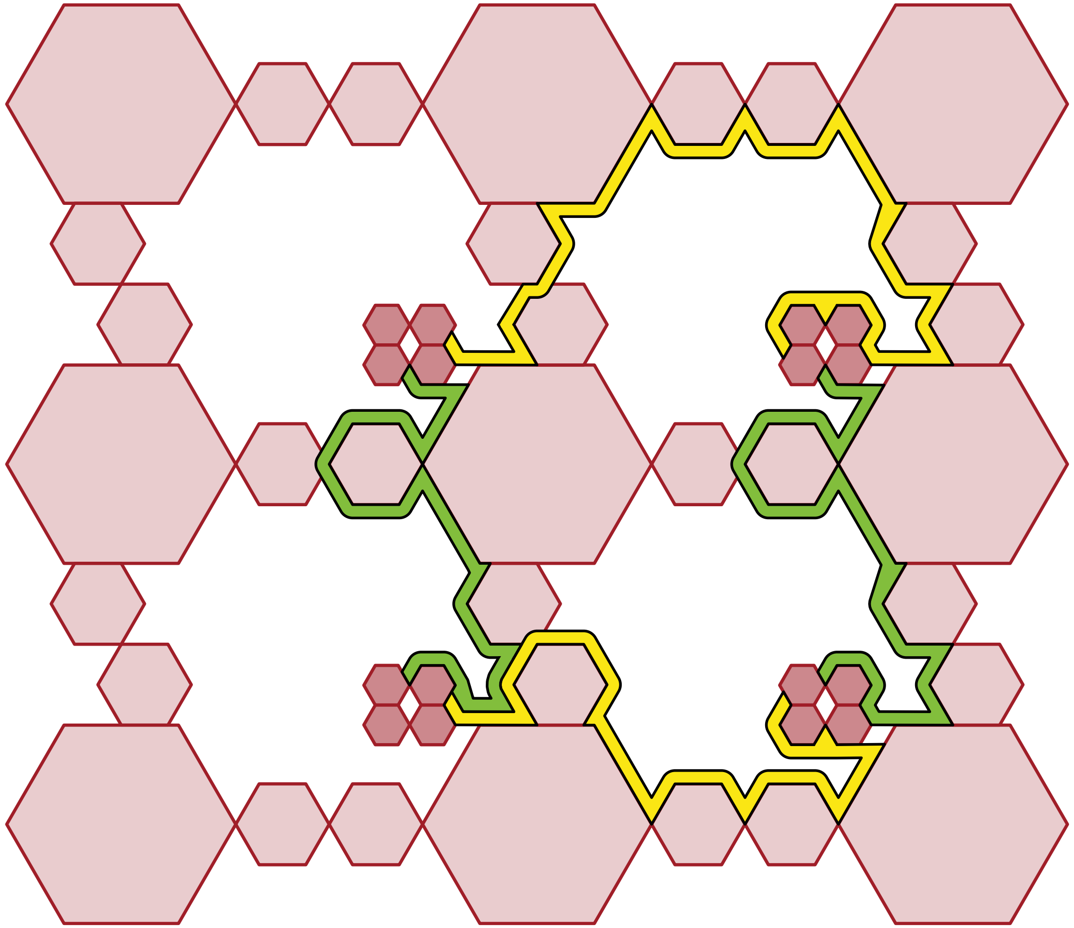

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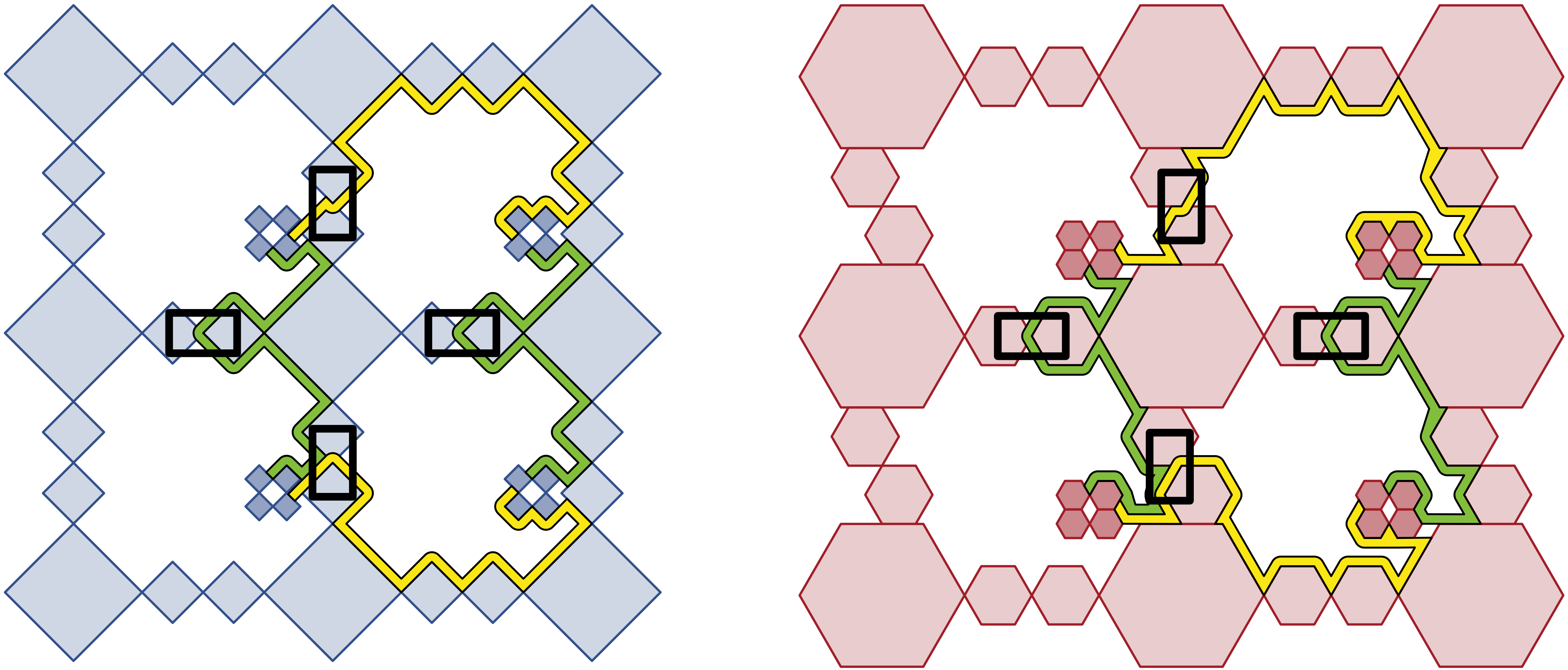

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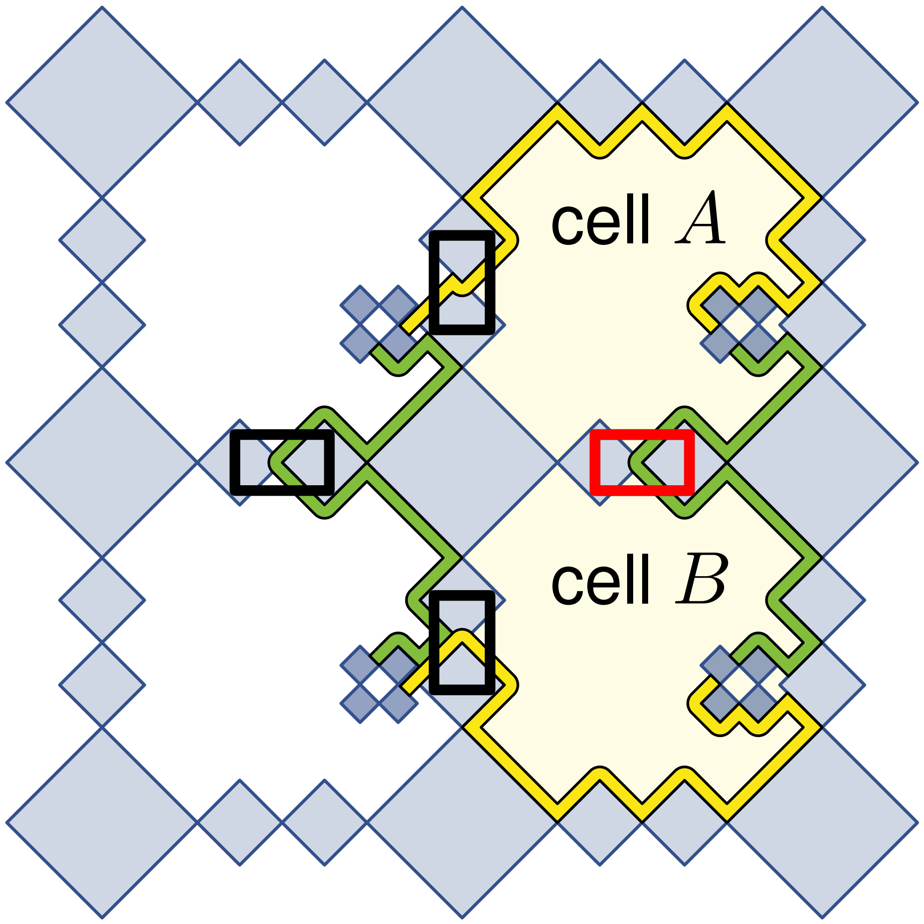
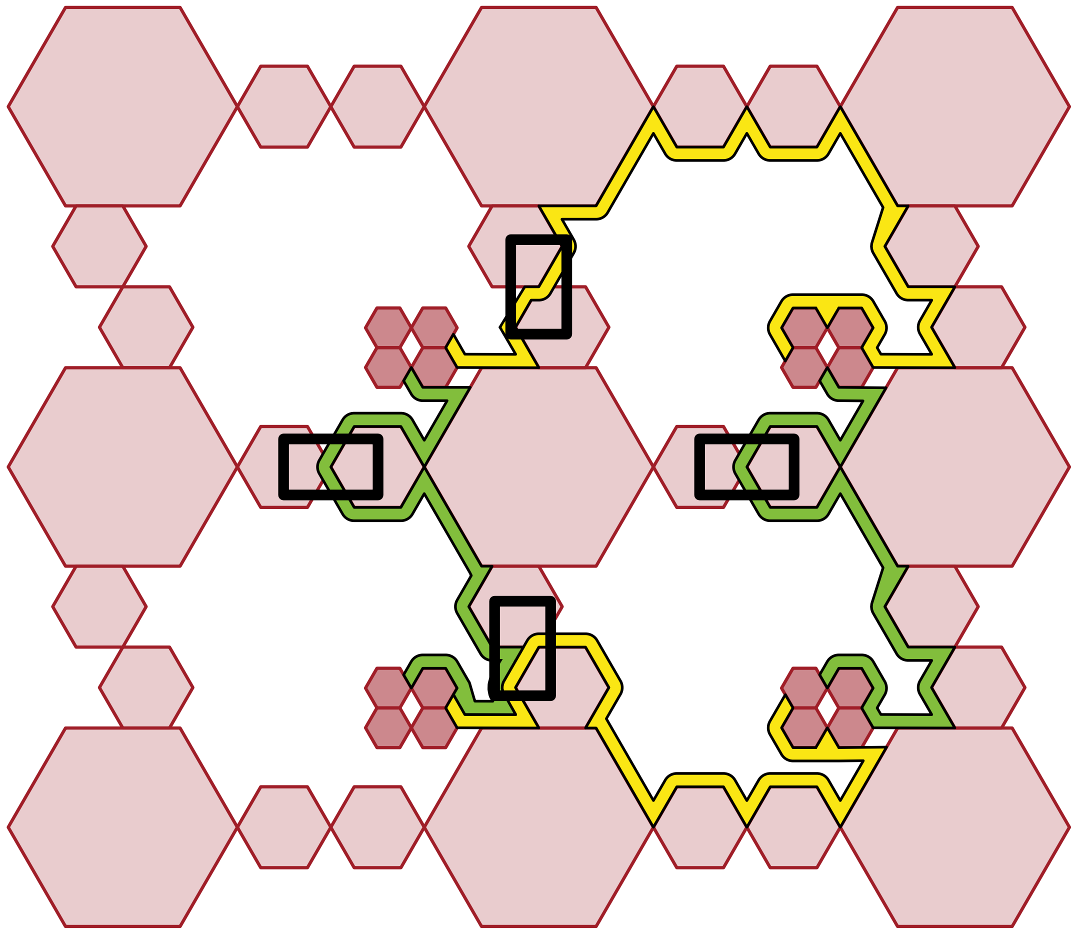
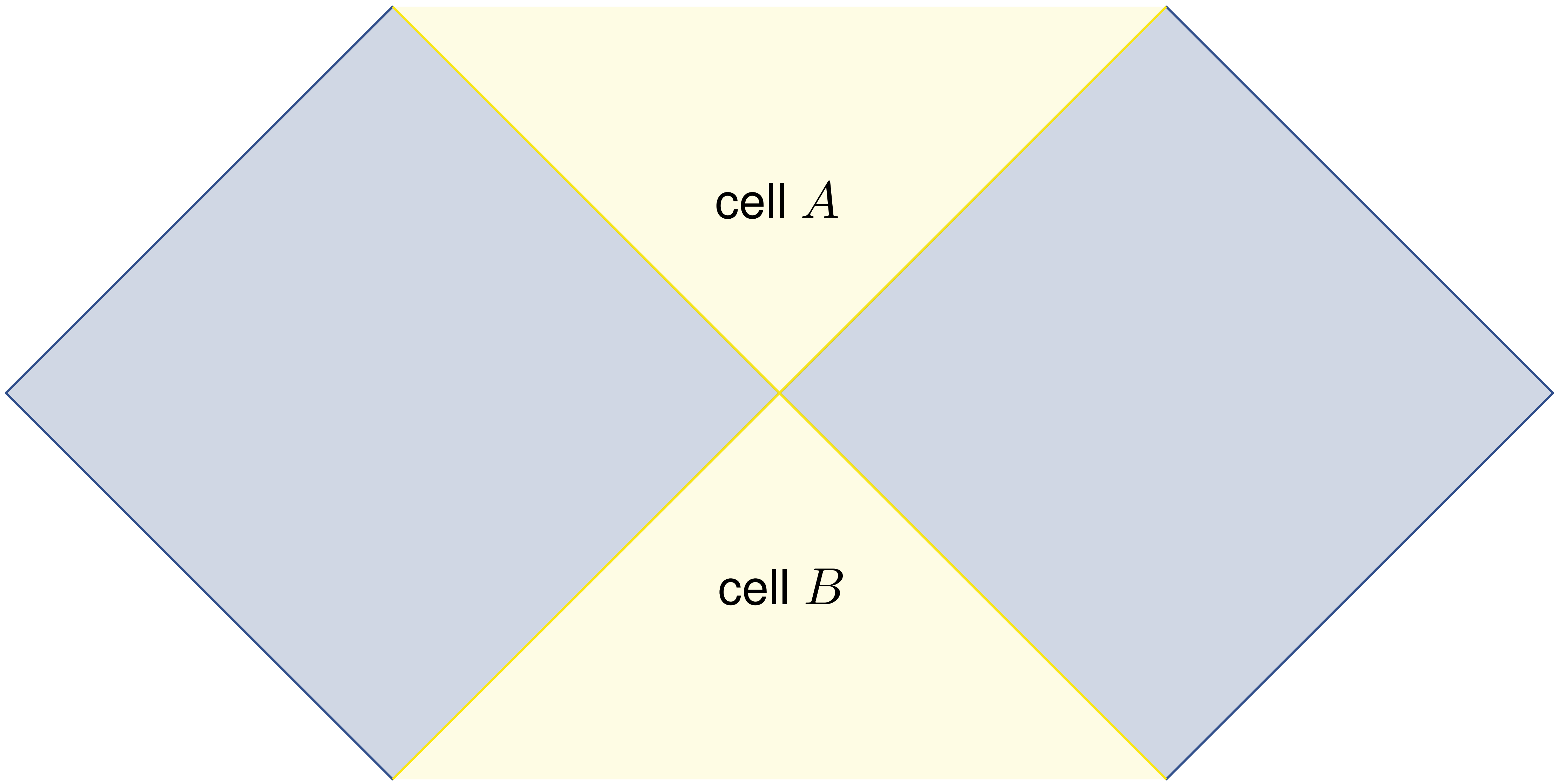




Independent Edges Between Cells: Rectangles



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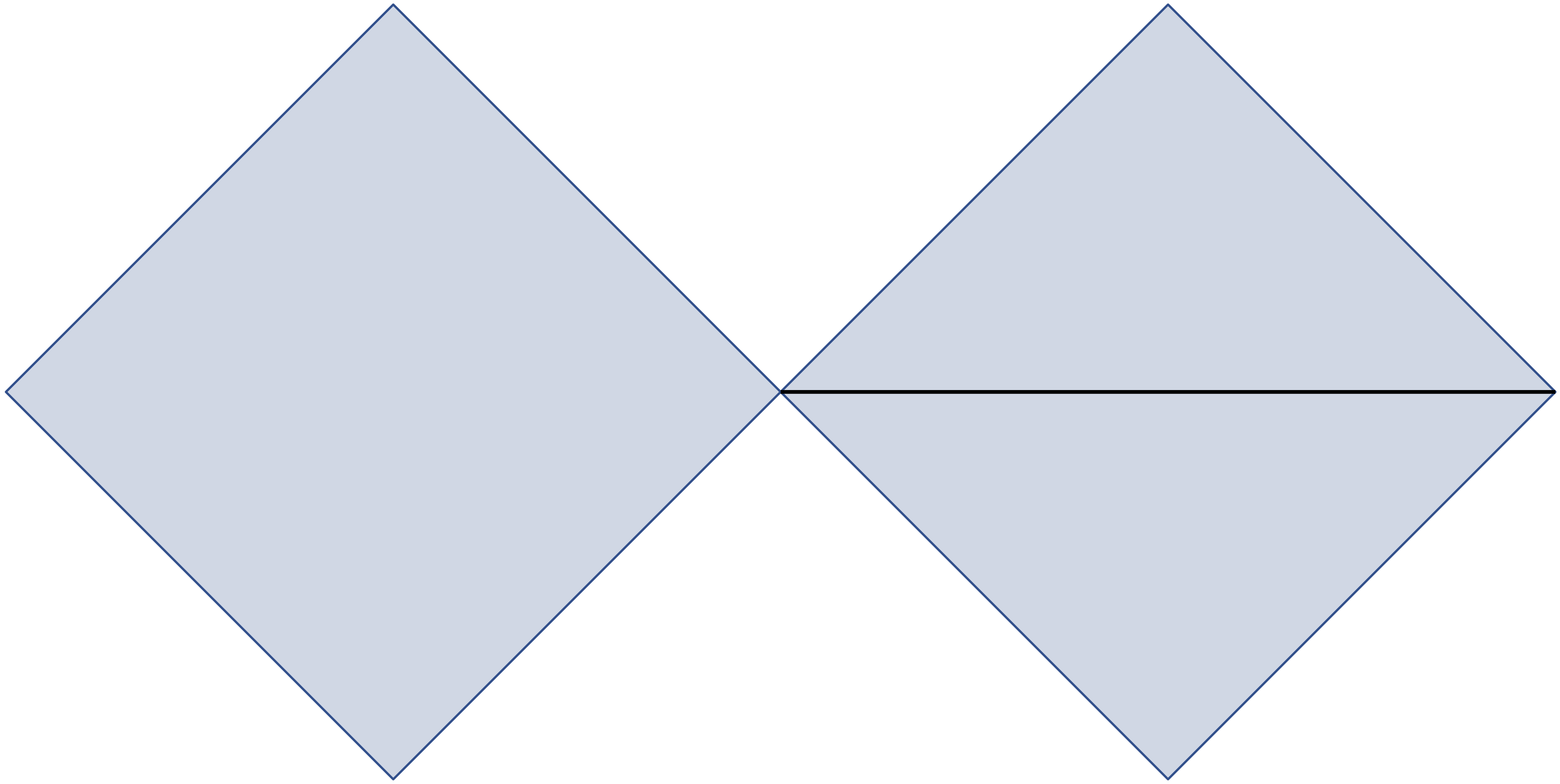

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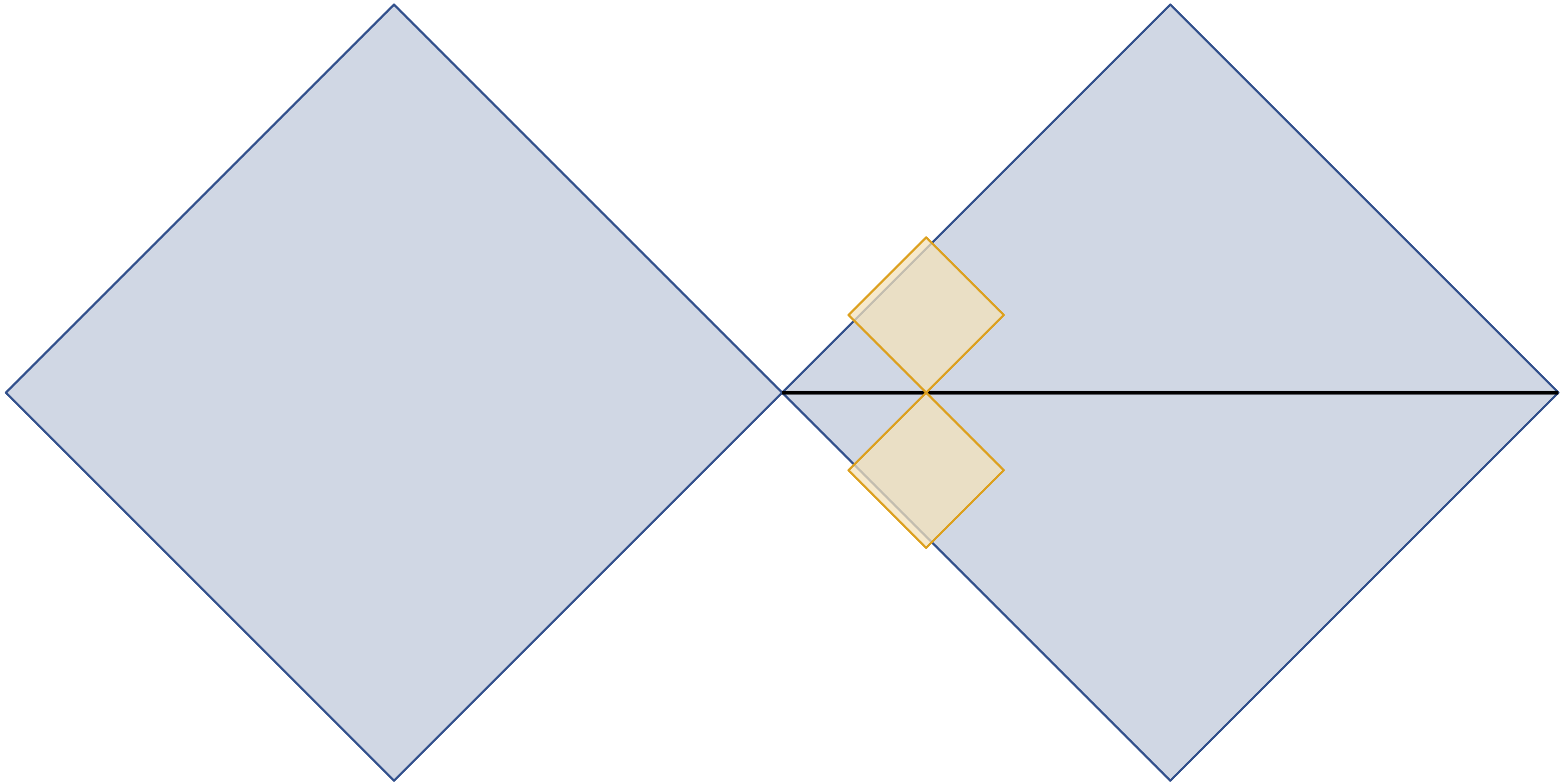

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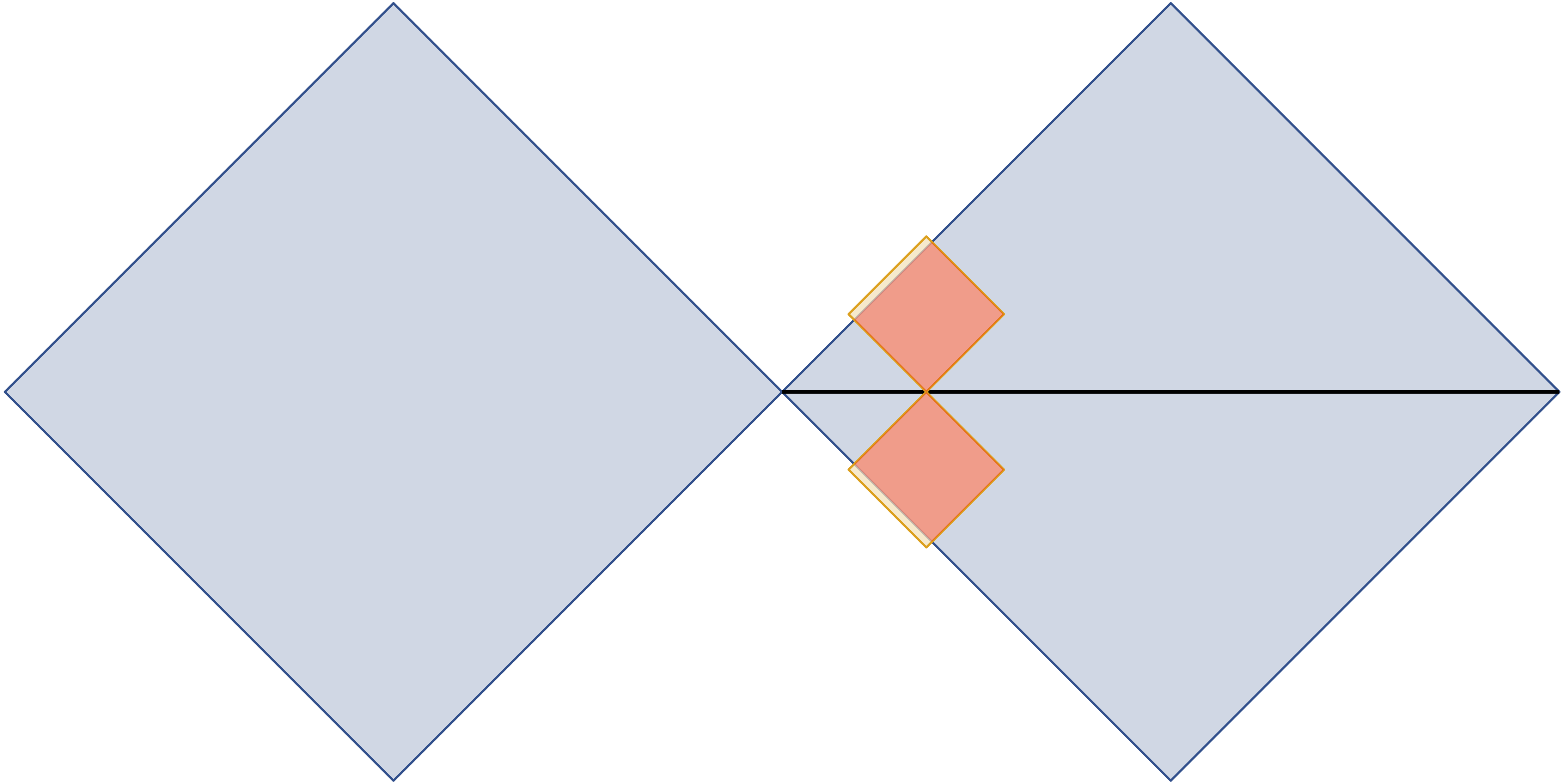

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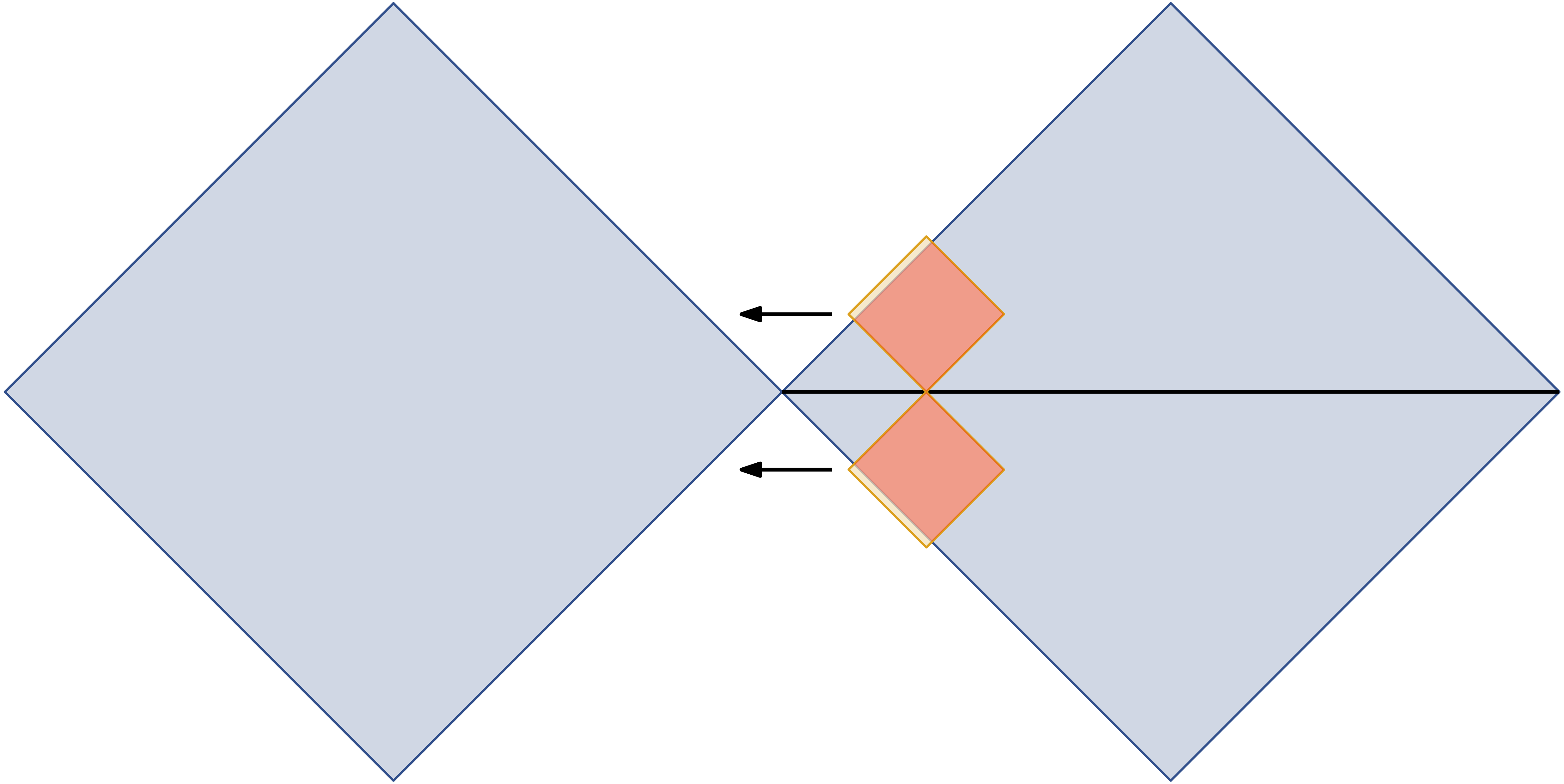

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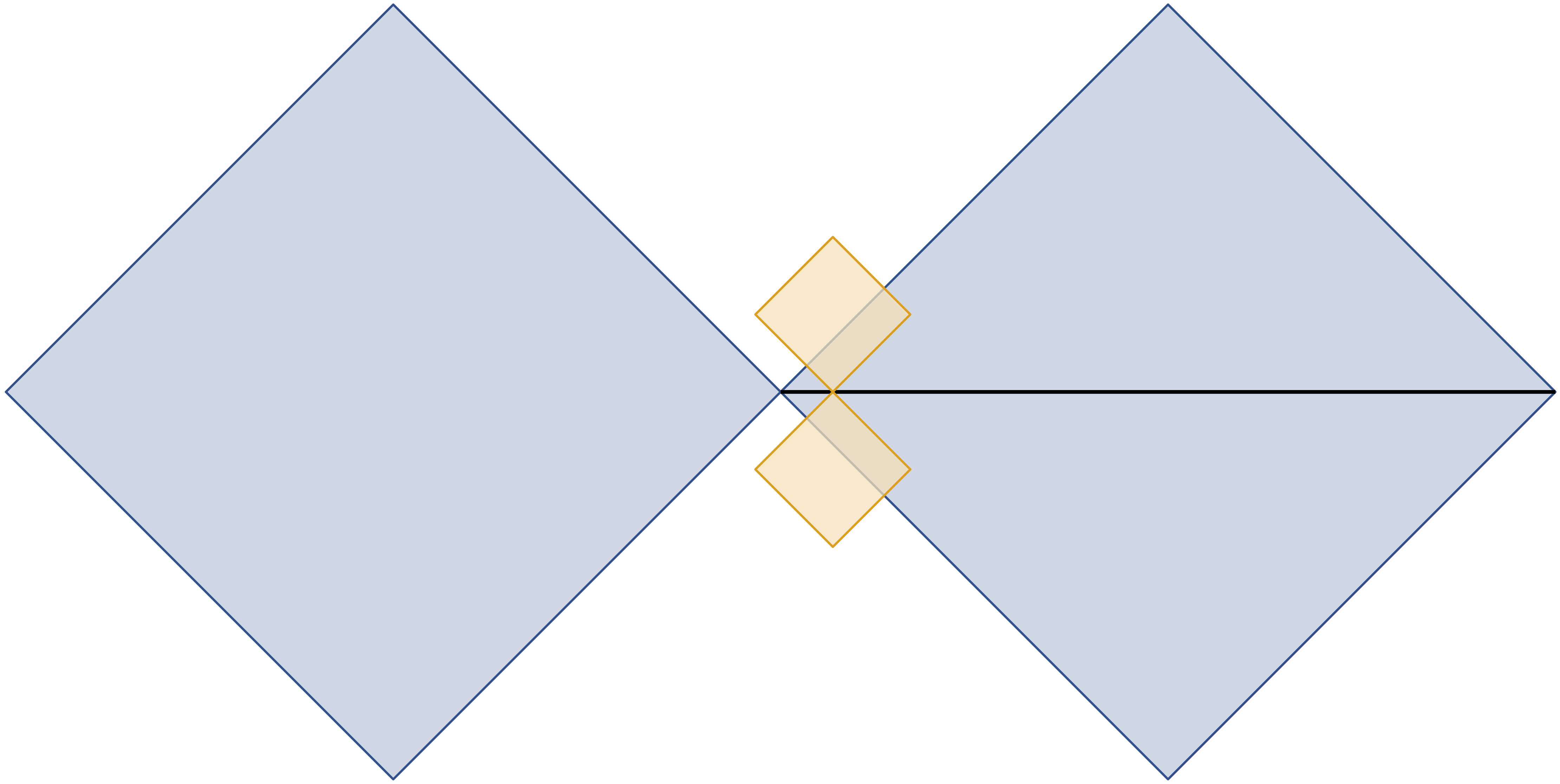

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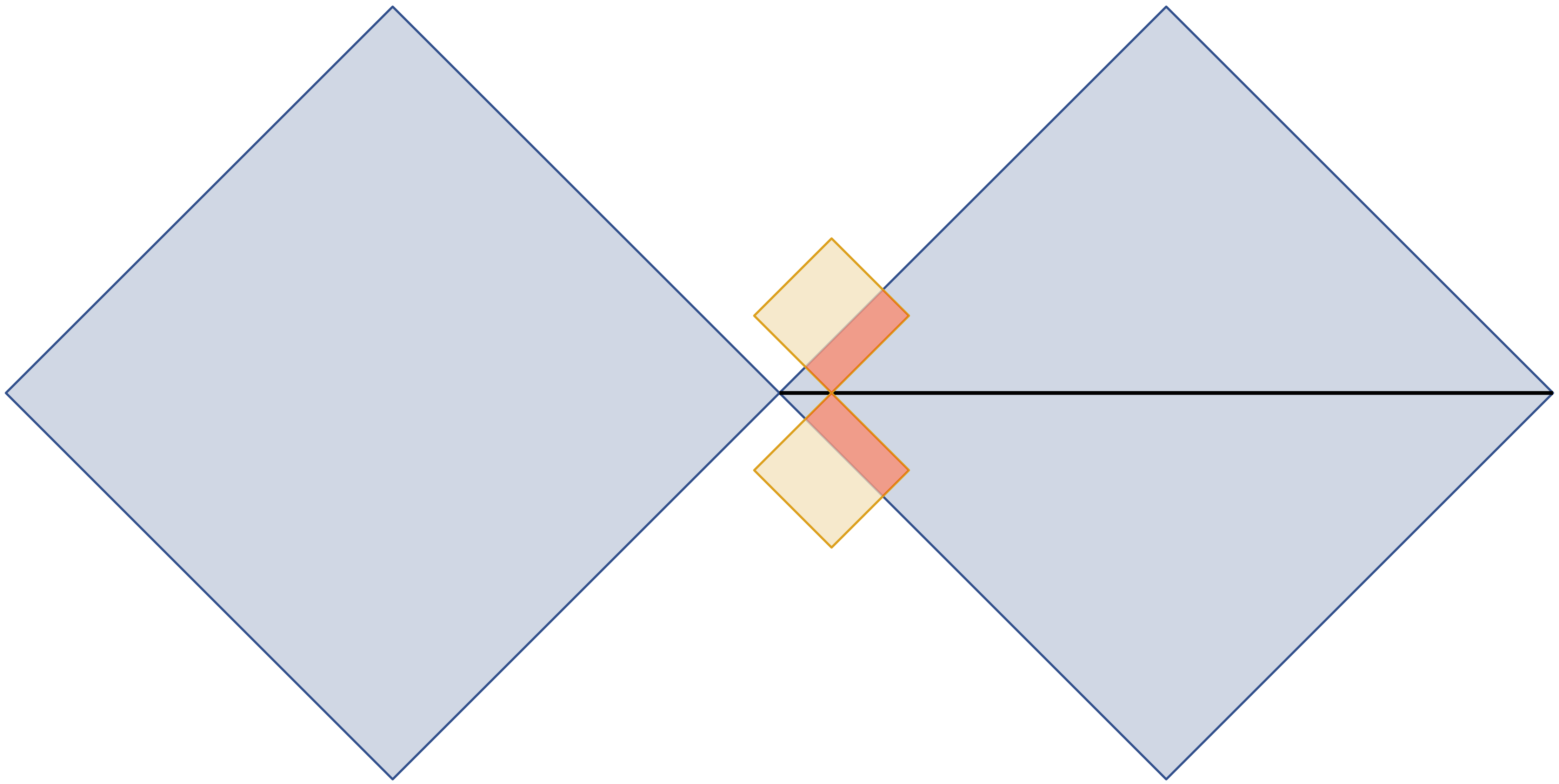

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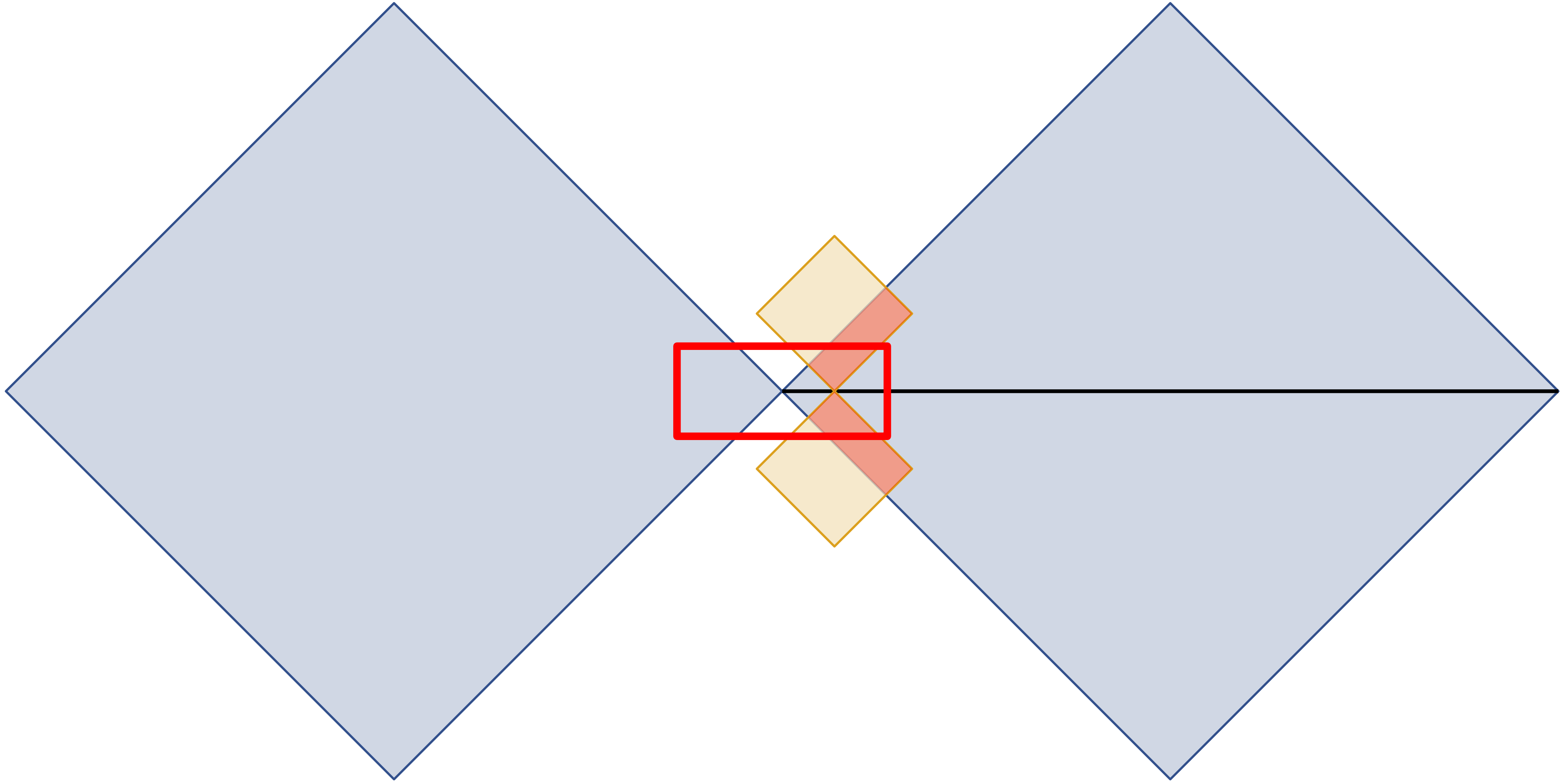

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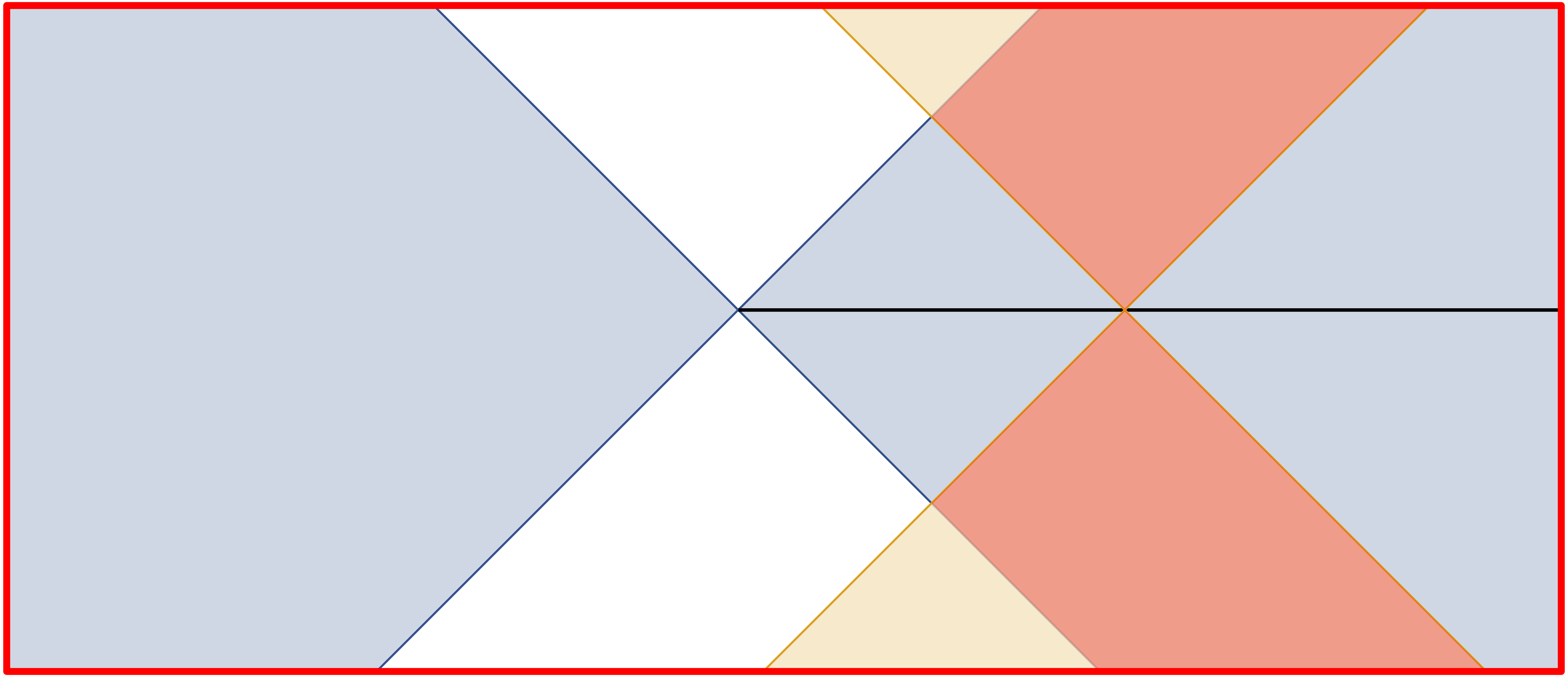

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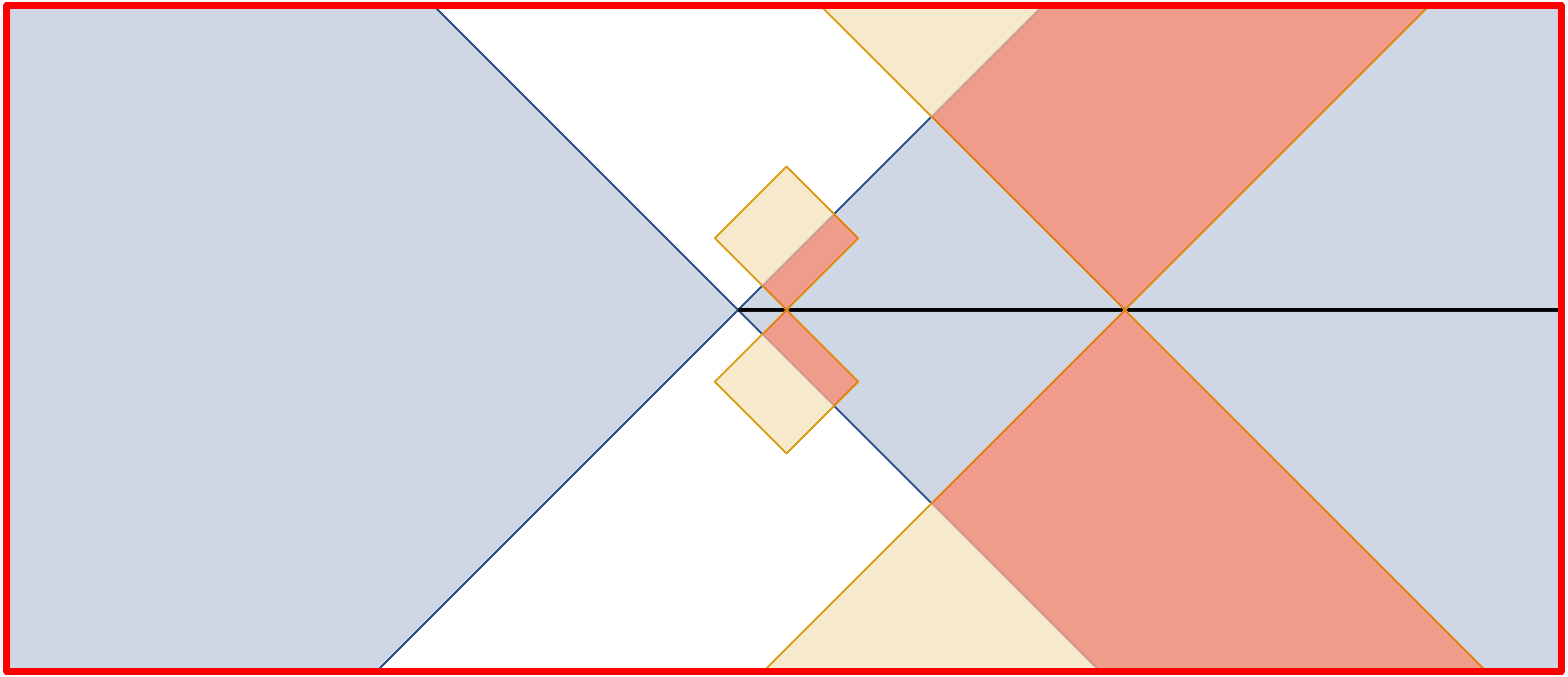

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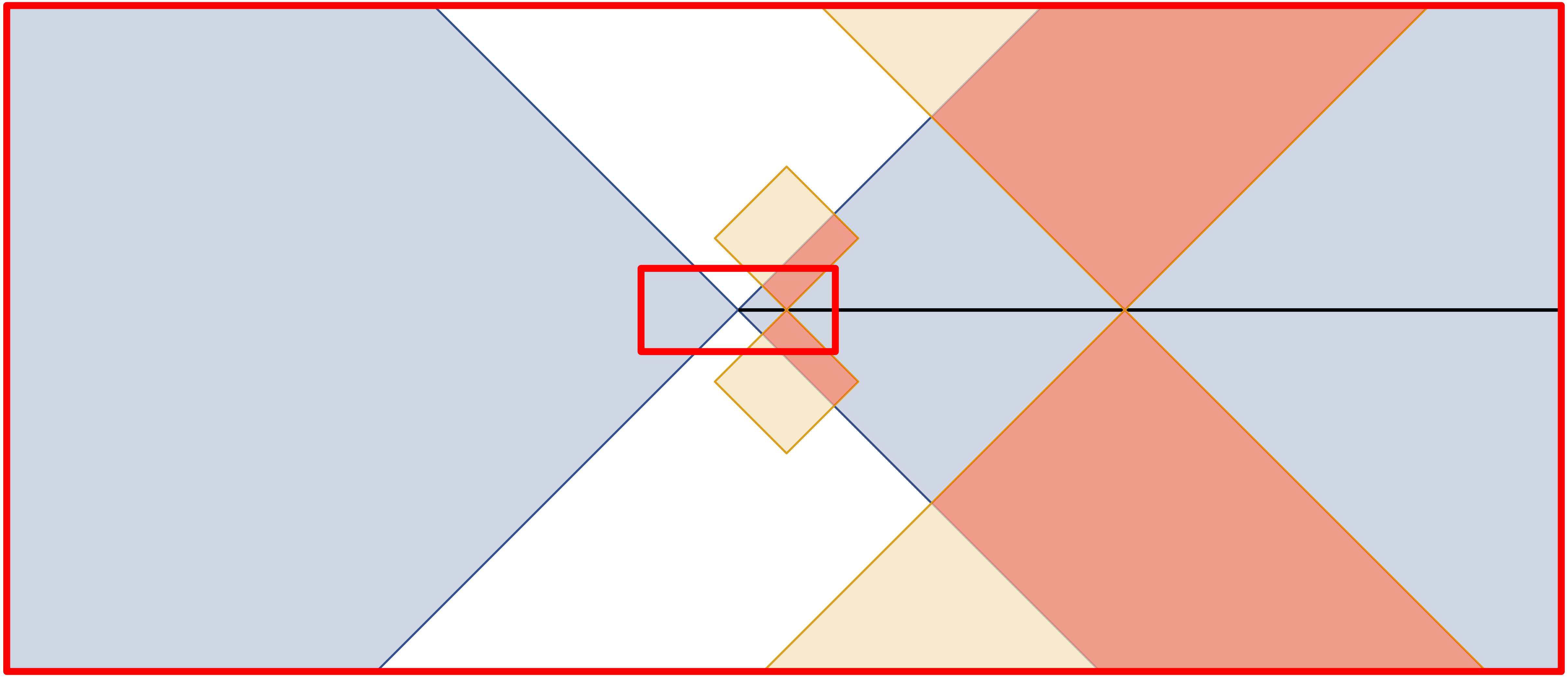

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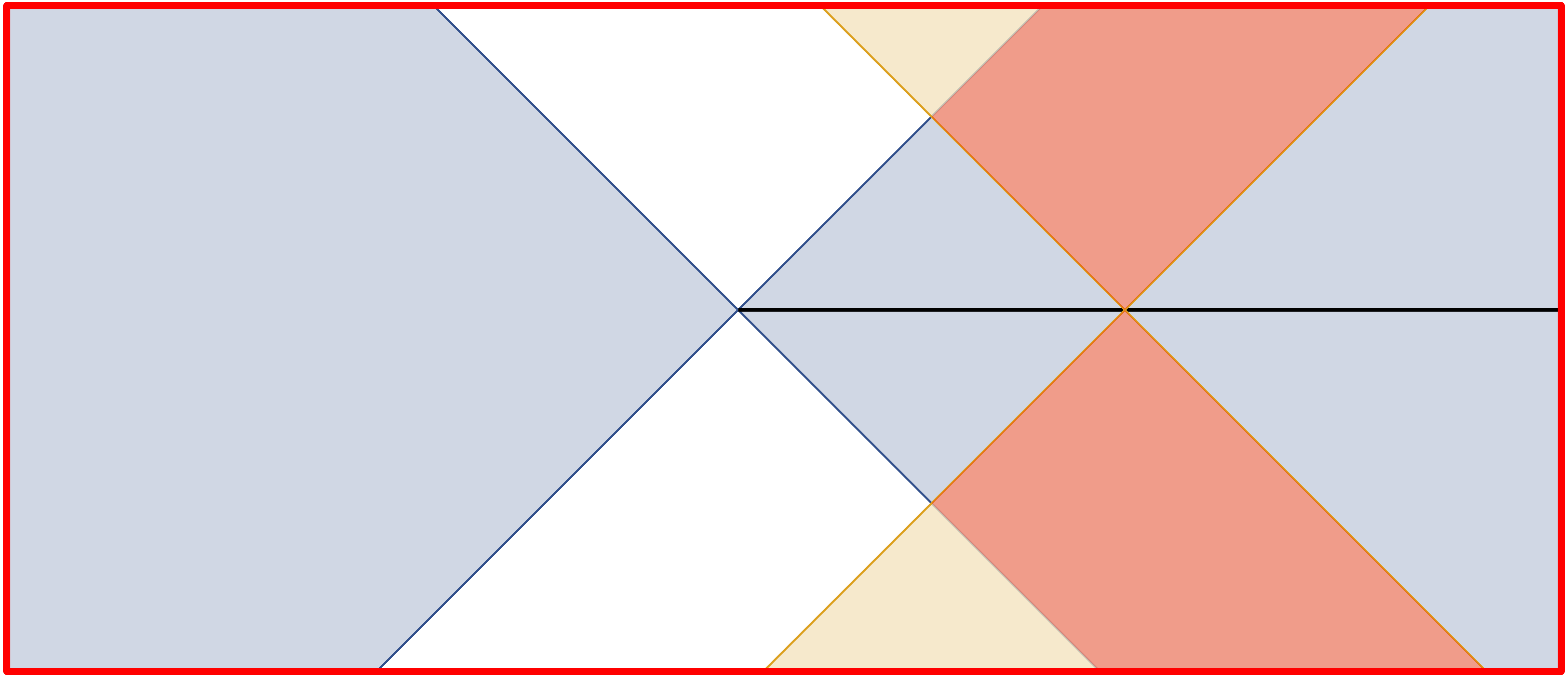

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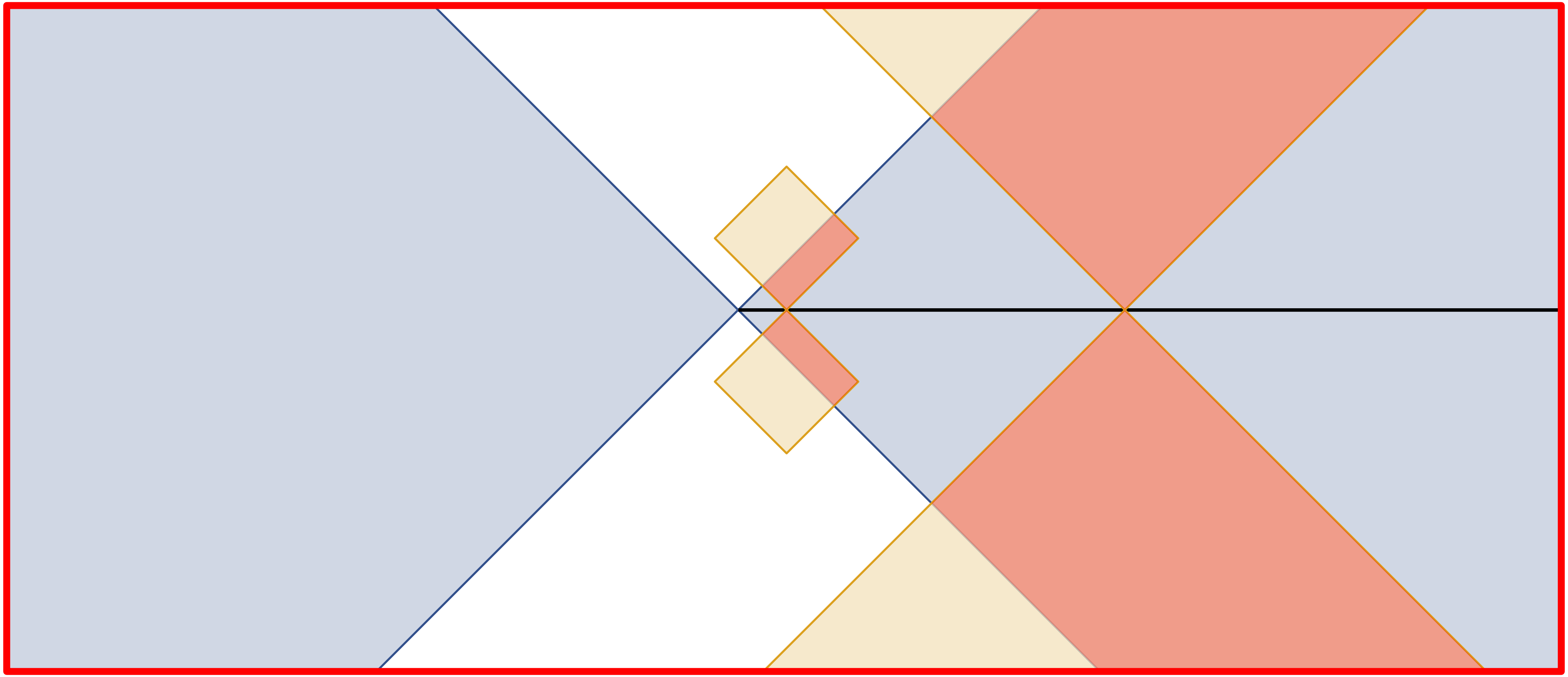

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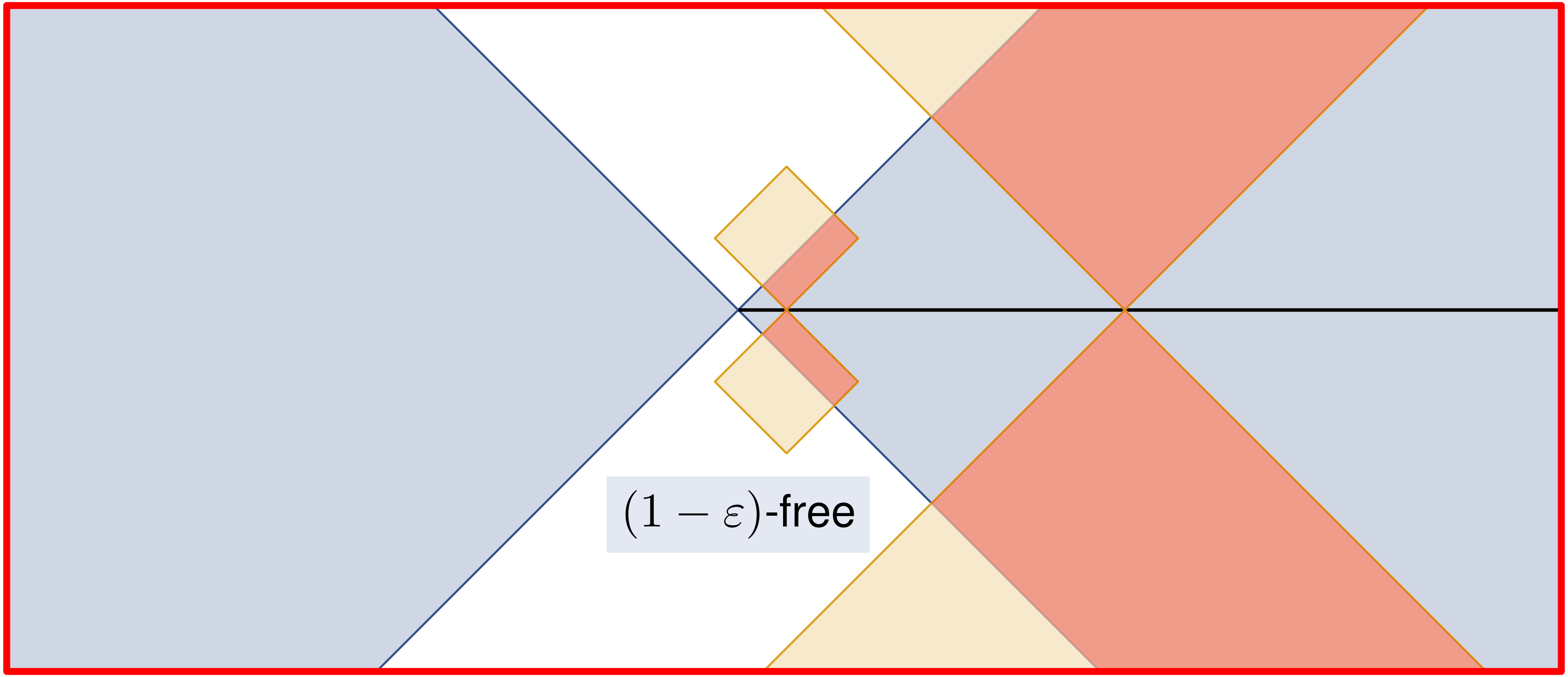
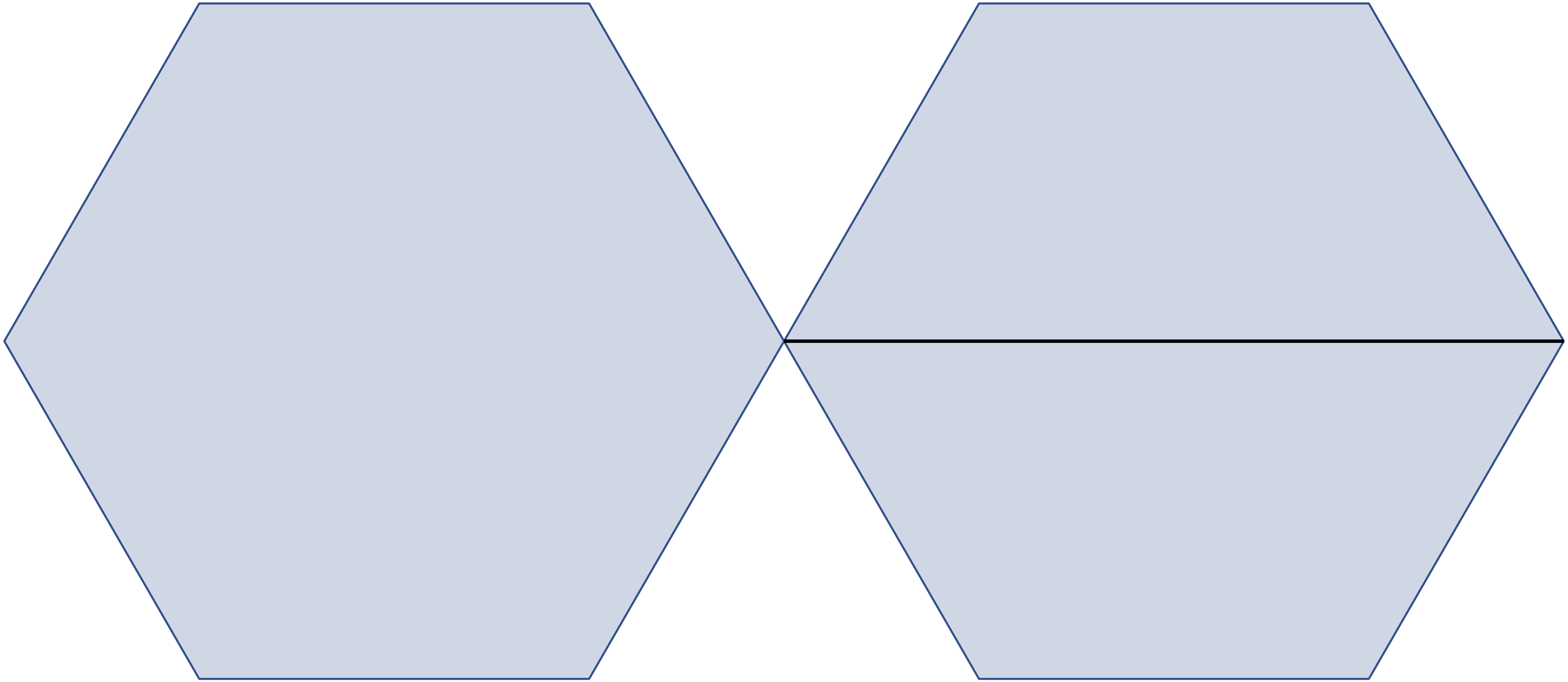


Independent Edges Between Cells: Hexagons



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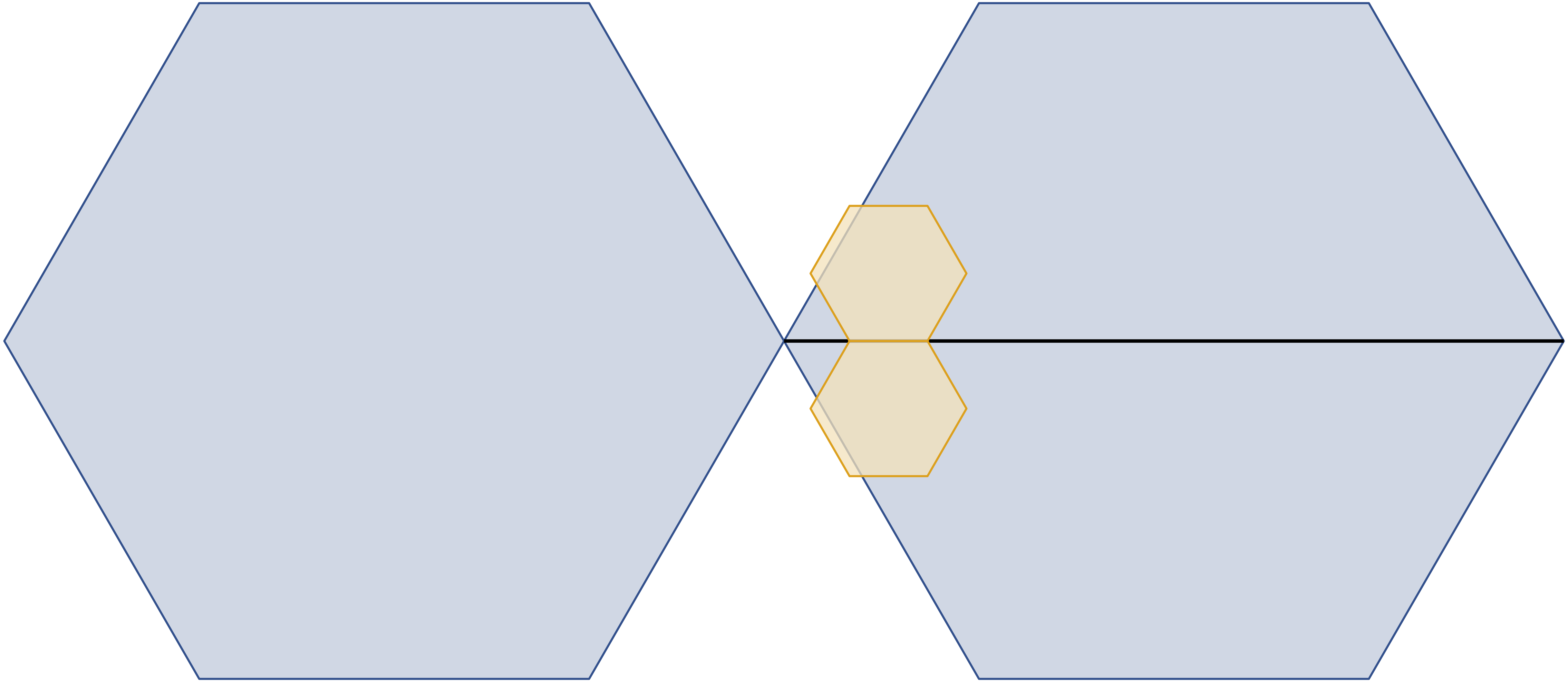

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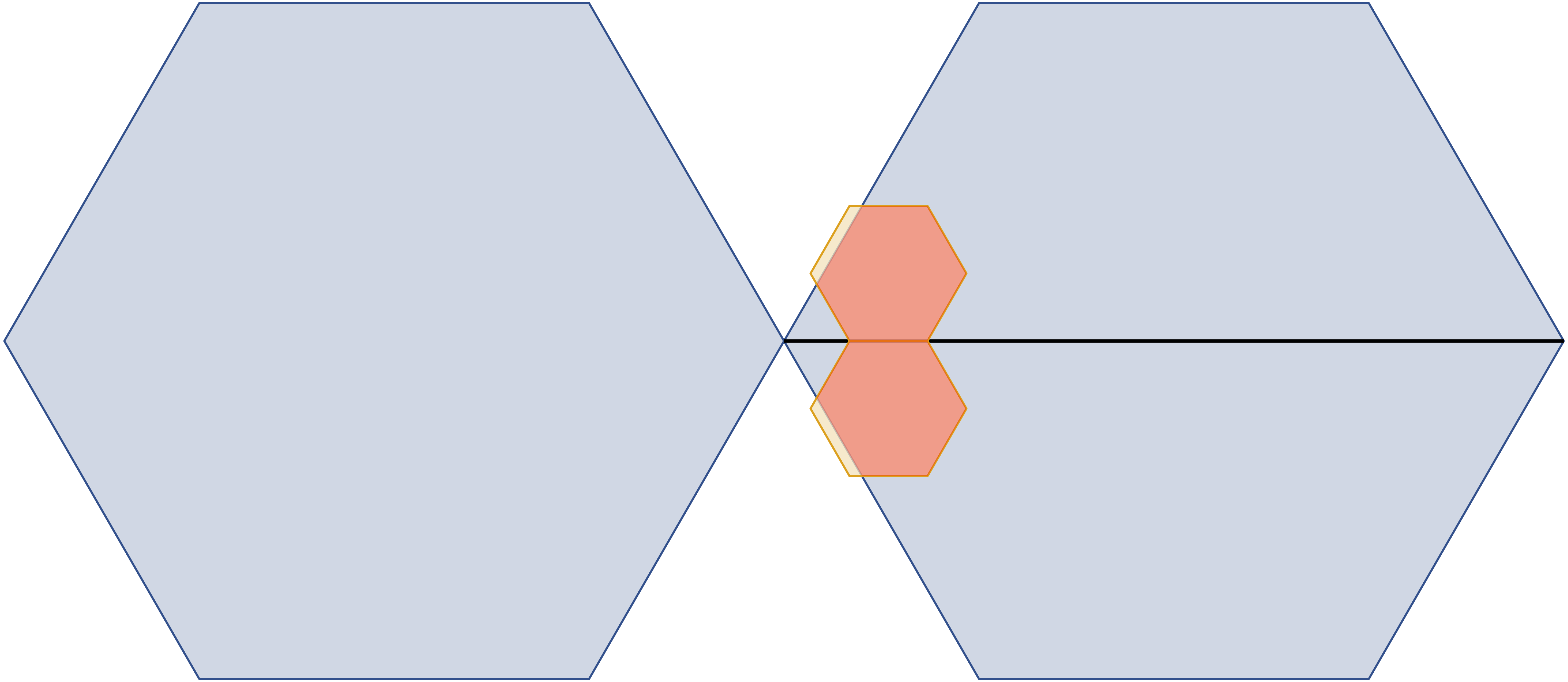

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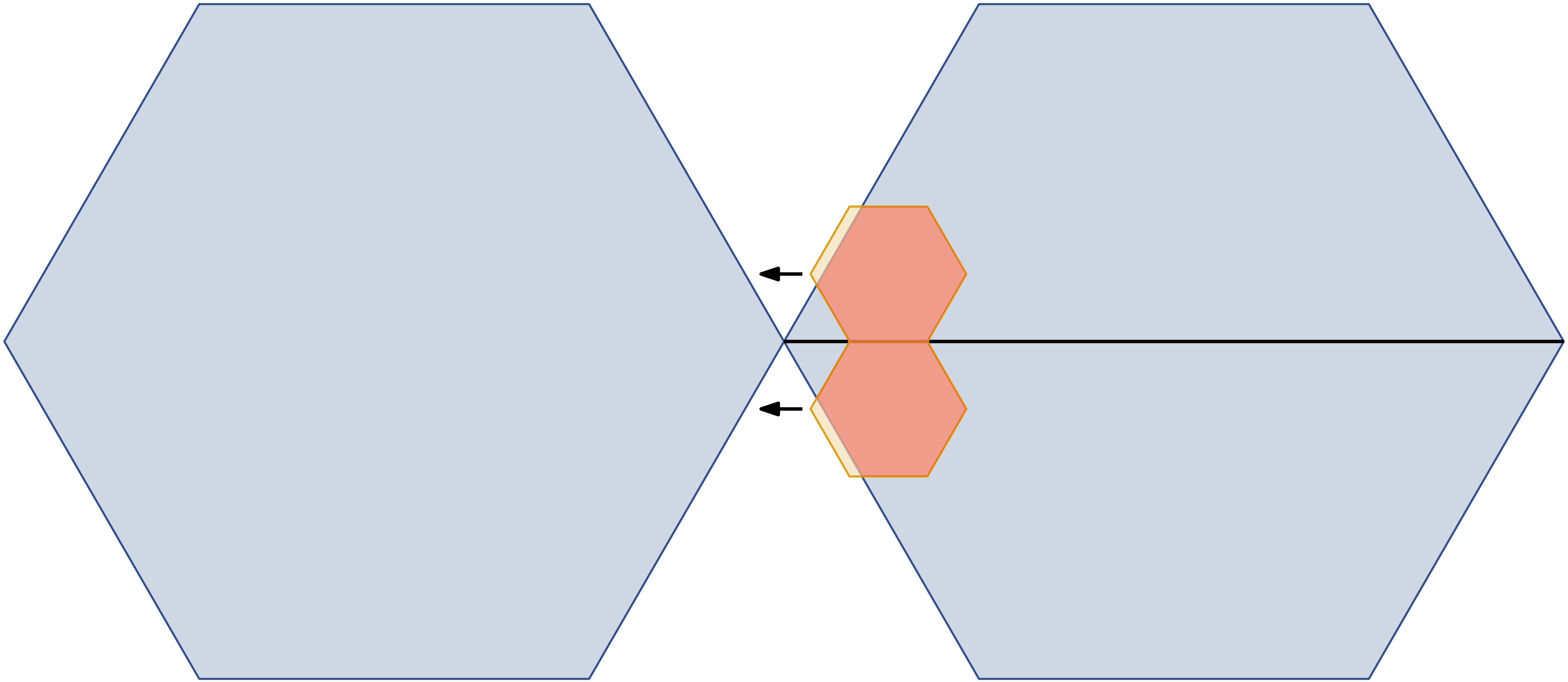

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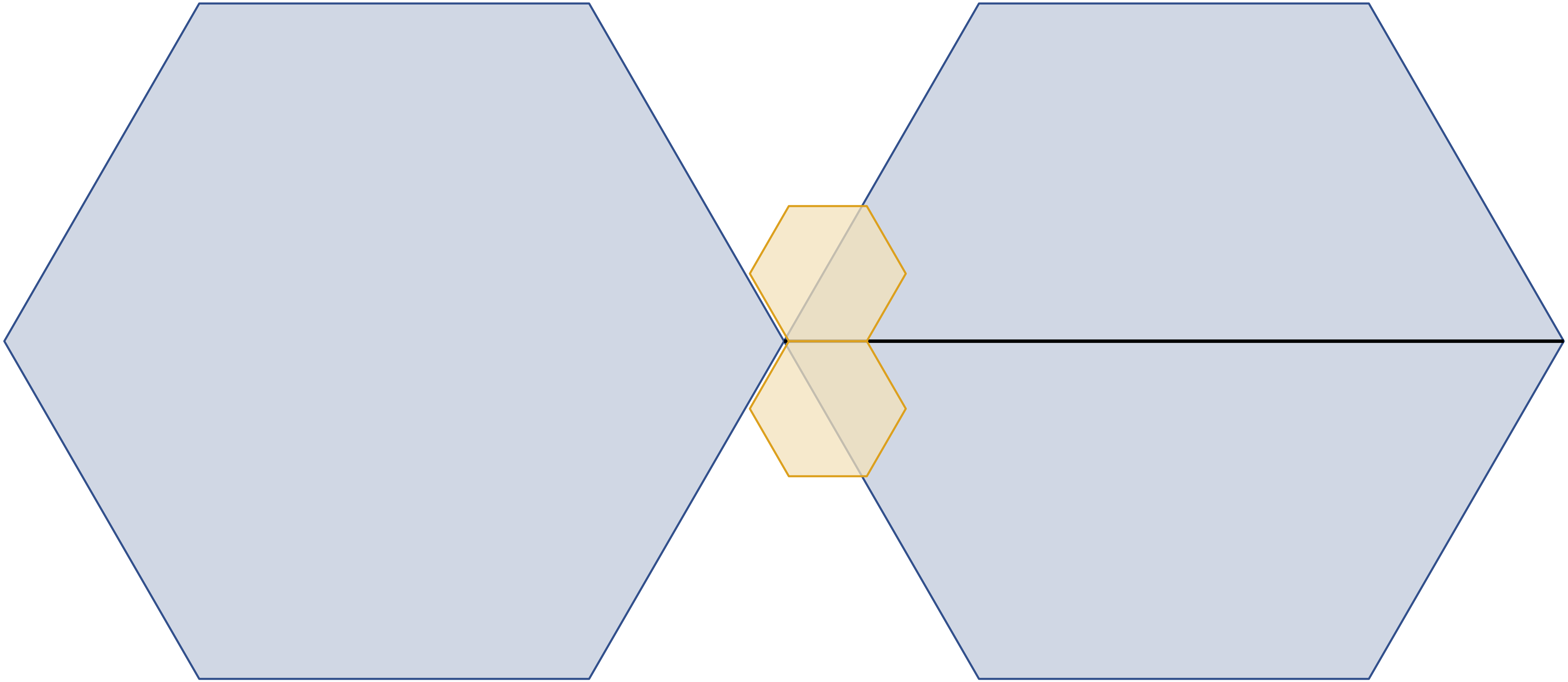

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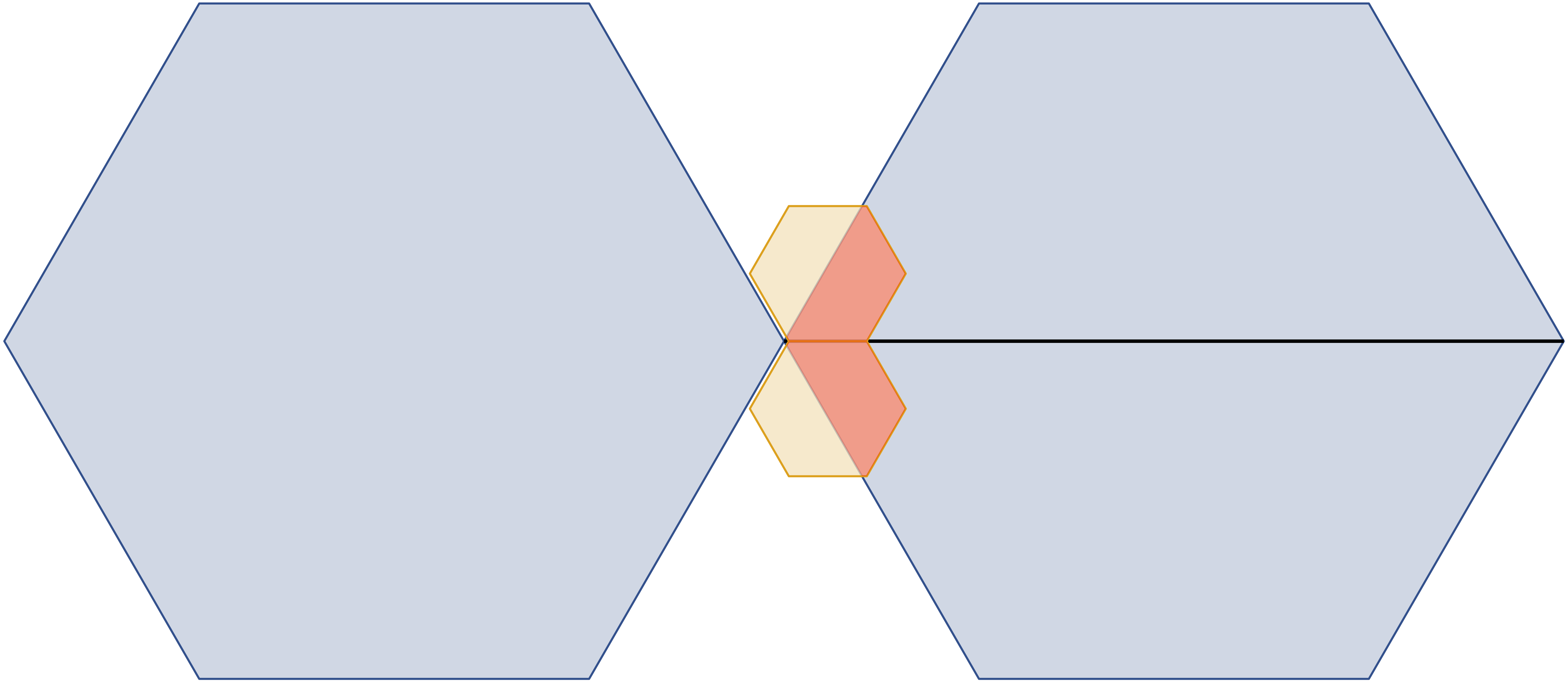

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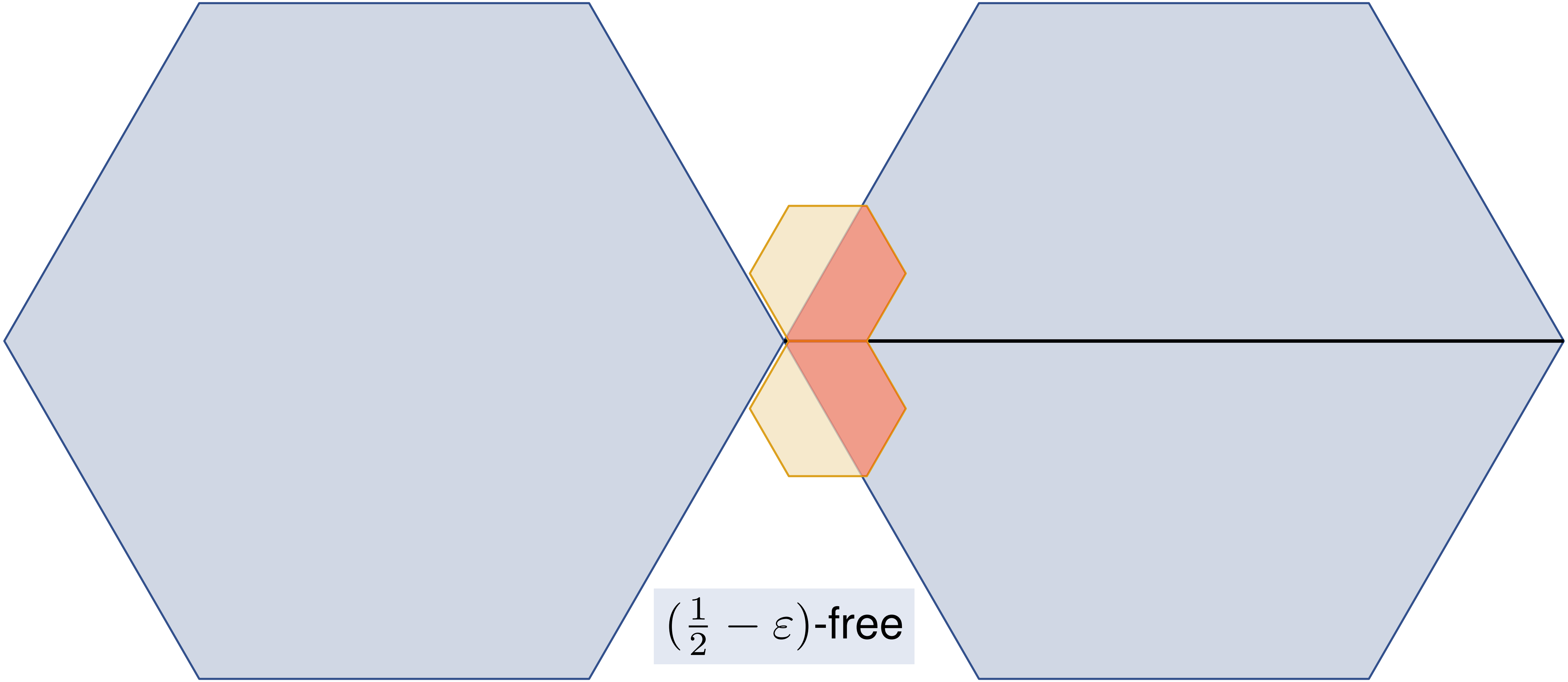
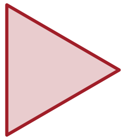
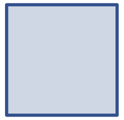


Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.
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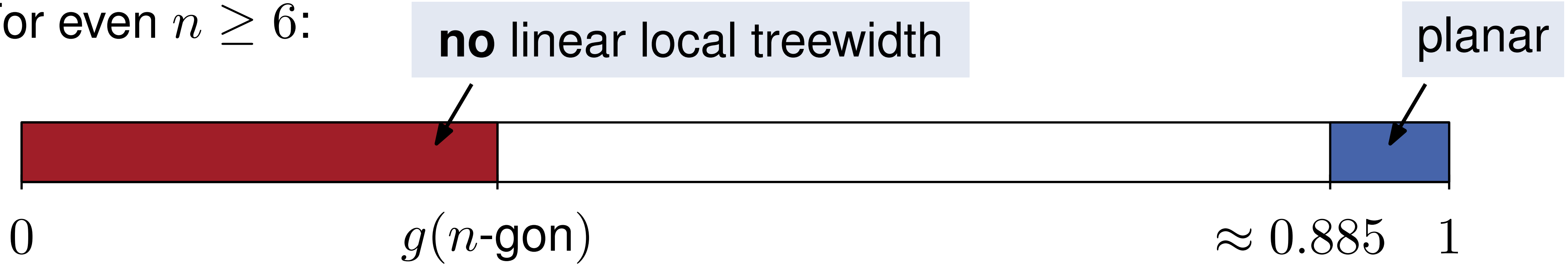

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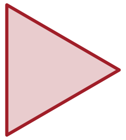
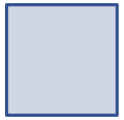
Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.
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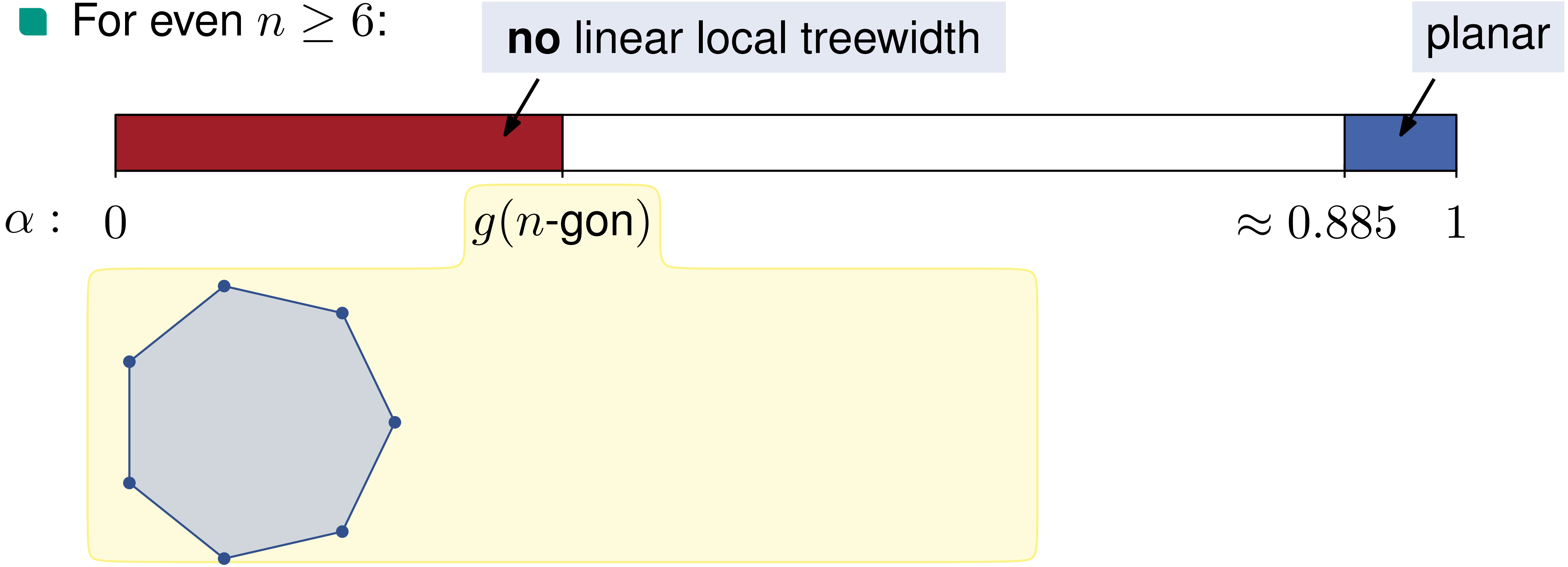

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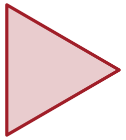
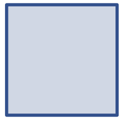
- For  and  : **no** product structure for $\alpha < 1$.
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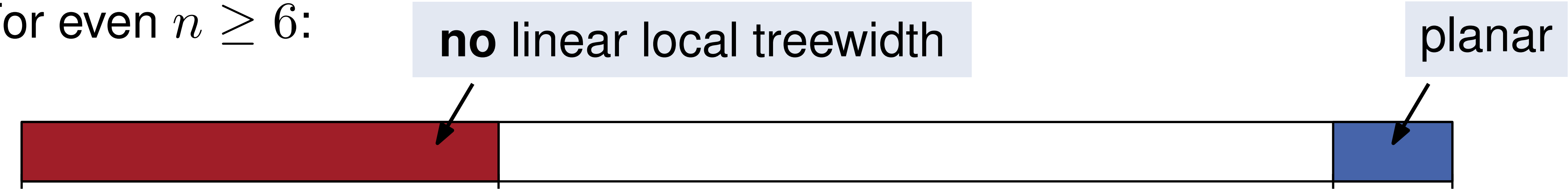
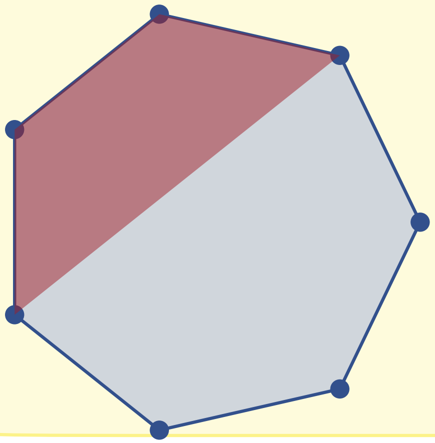
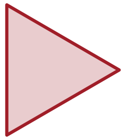
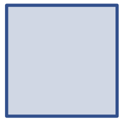
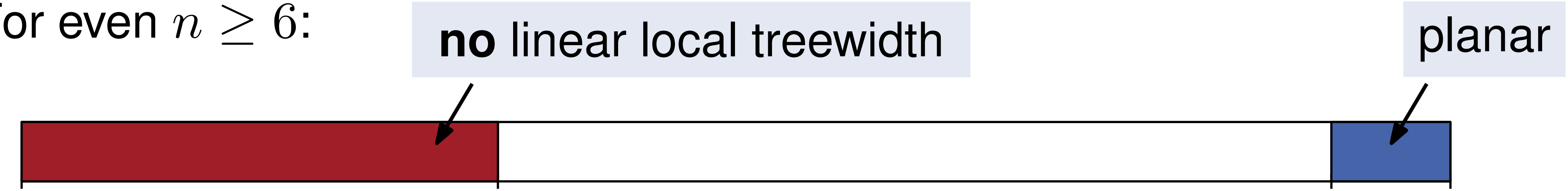


α : 0 $\quad g(n\text{-gon}) \quad \approx 0.885 \quad 1$

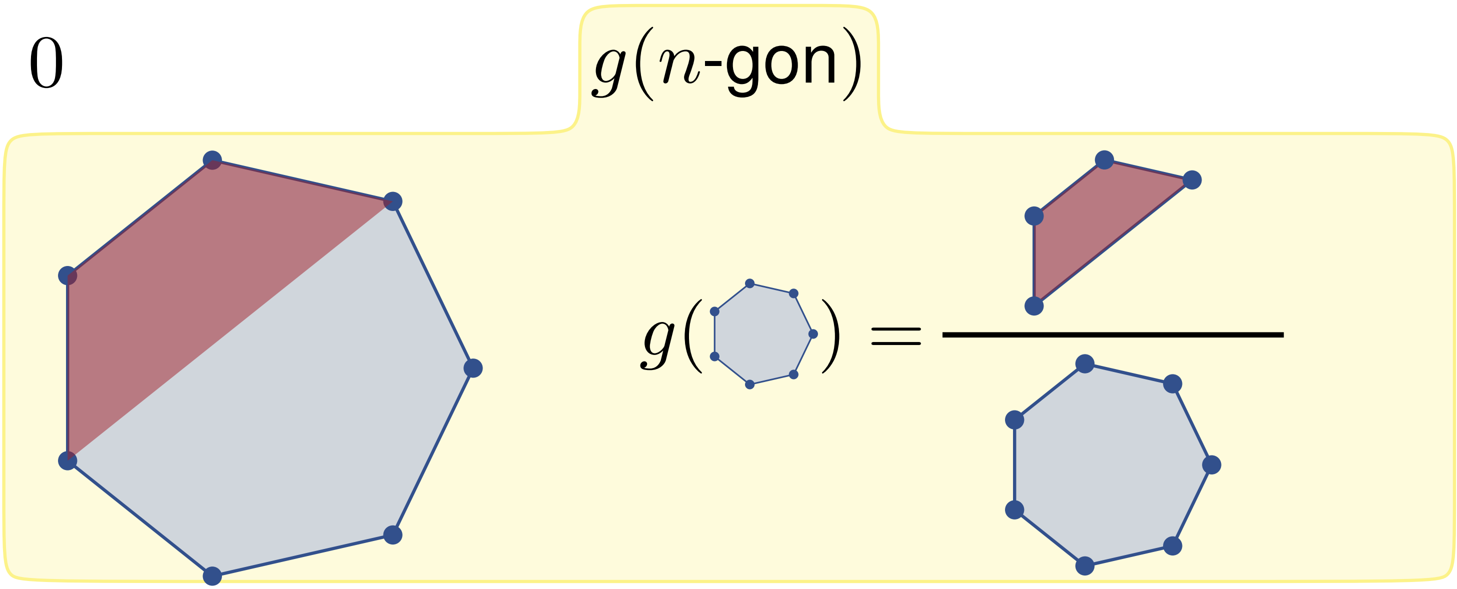


Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.
- For even $n \geq 6$:



$\alpha :$ 0 ≈ 0.885 1



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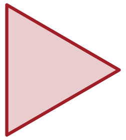
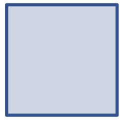
- For  and  : **no** product structure for $\alpha < 1$.
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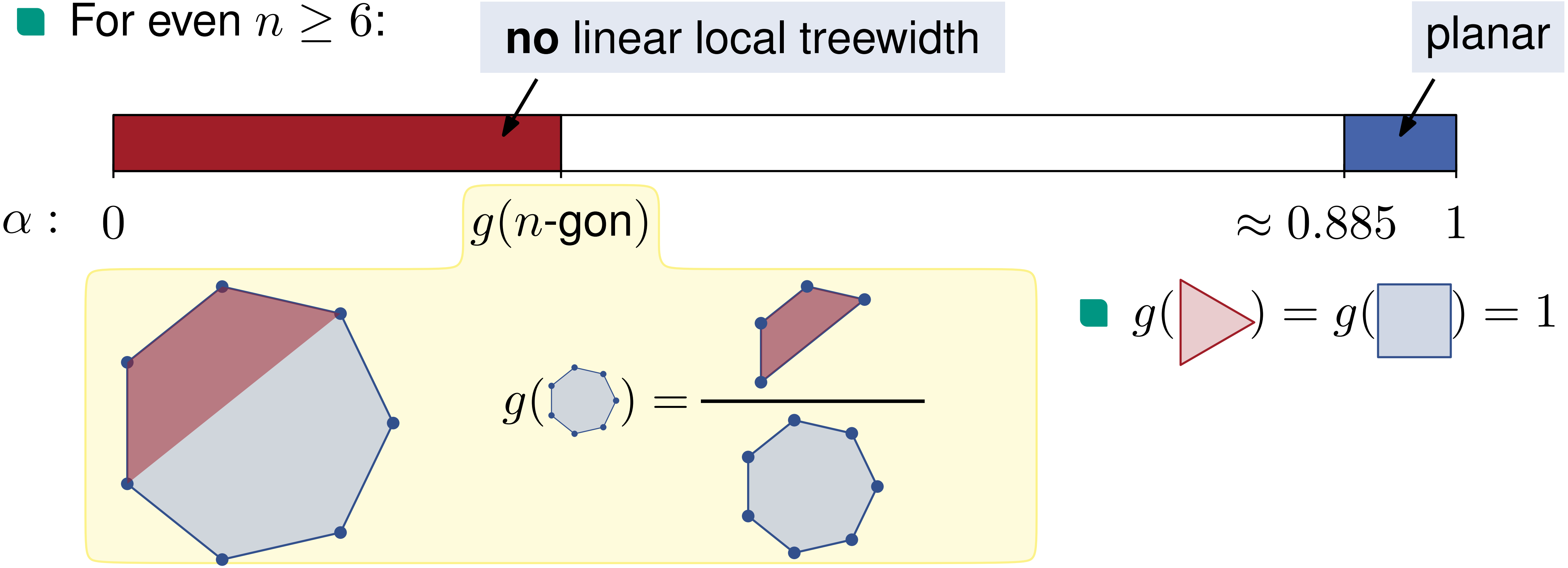

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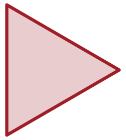
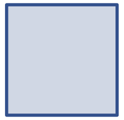
- For  and  : **no** product structure for $\alpha < 1$.
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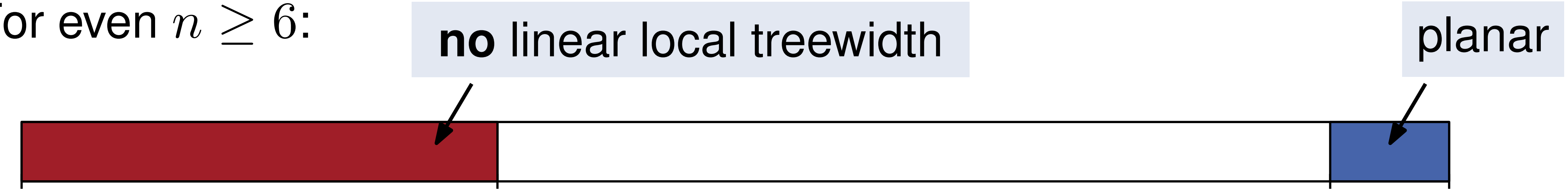

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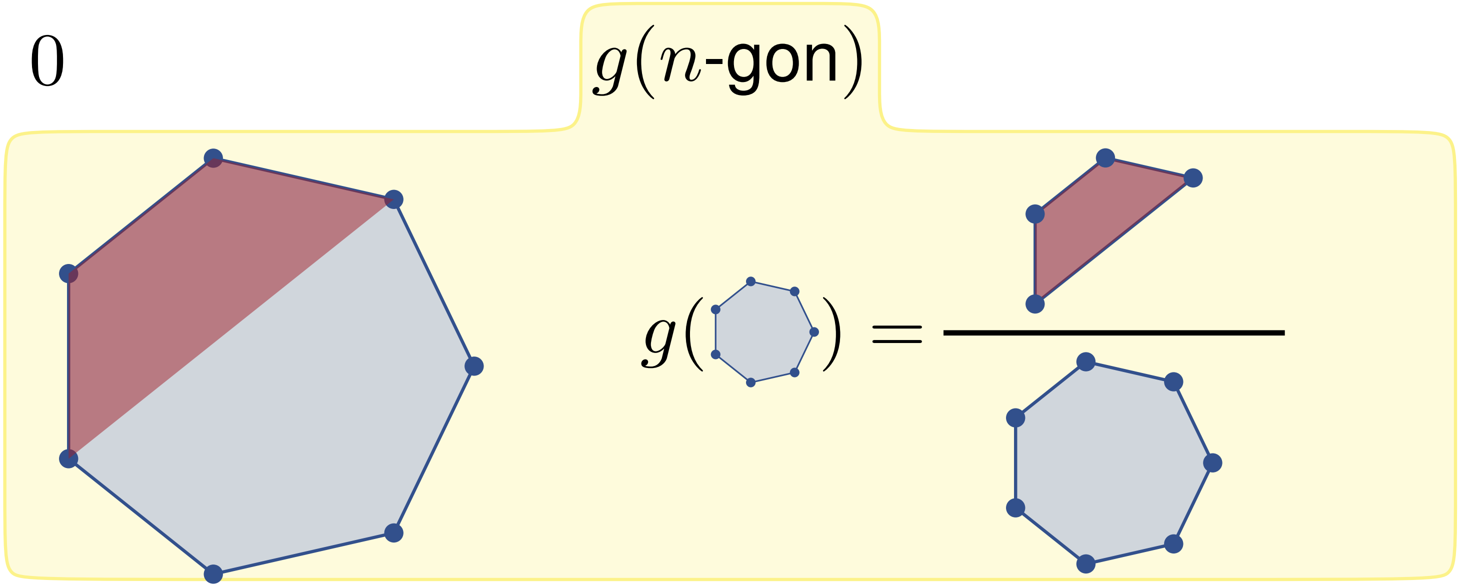
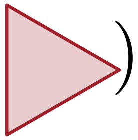
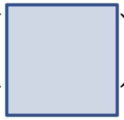
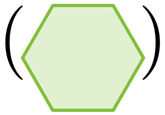
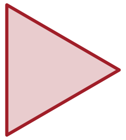
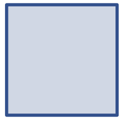


- $g($$) = g($$) = 1$
- $g($$) = \frac{1}{2}$

Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.
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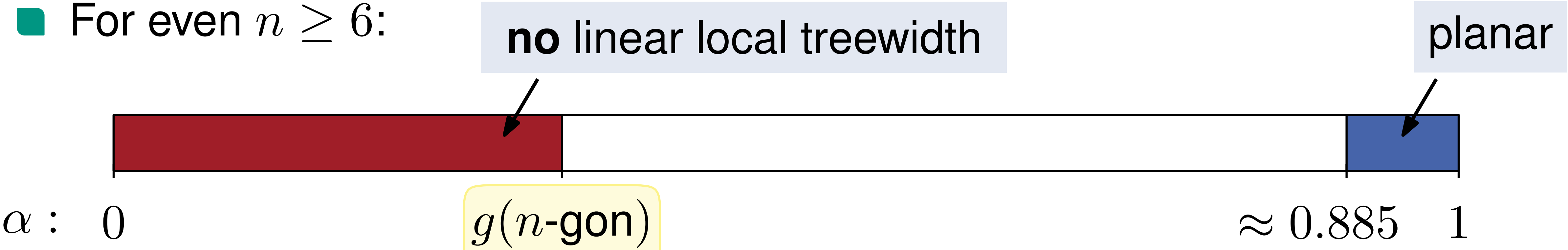
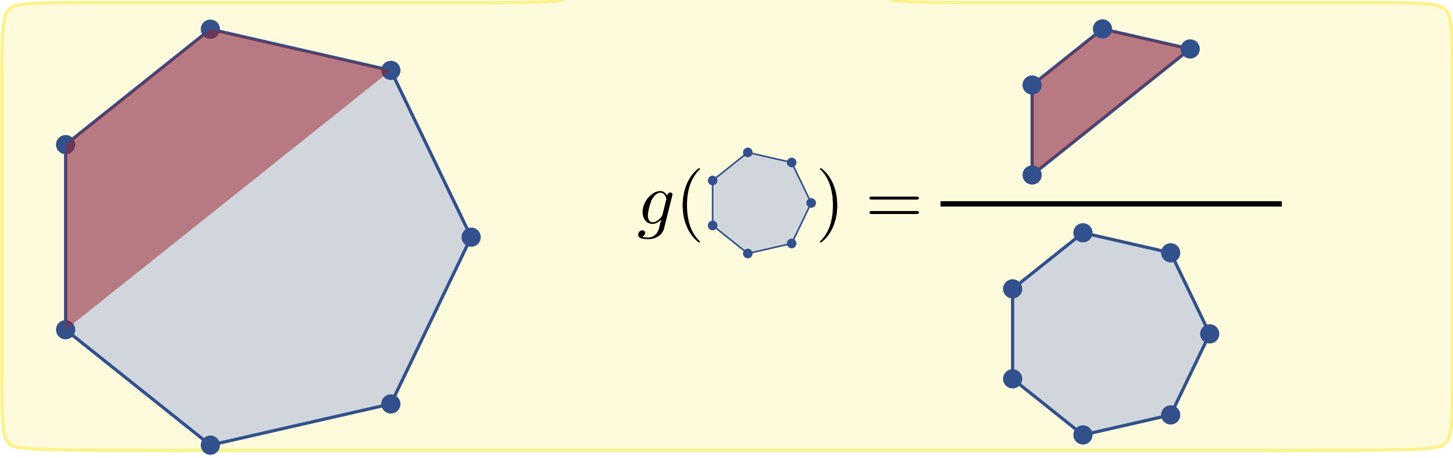
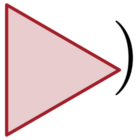
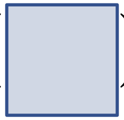
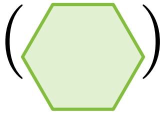




- $g($$) = g($$) = 1$
- $g($$) = \frac{1}{2}$
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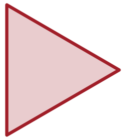
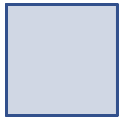
Our Results for Regular n-gons

- For  and  : **no** product structure for $\alpha < 1$.
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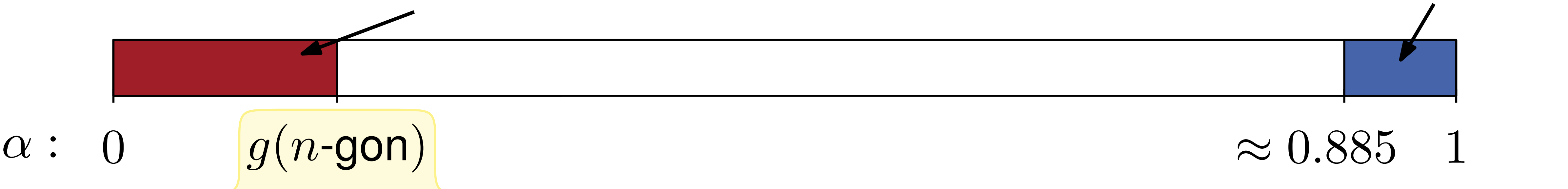
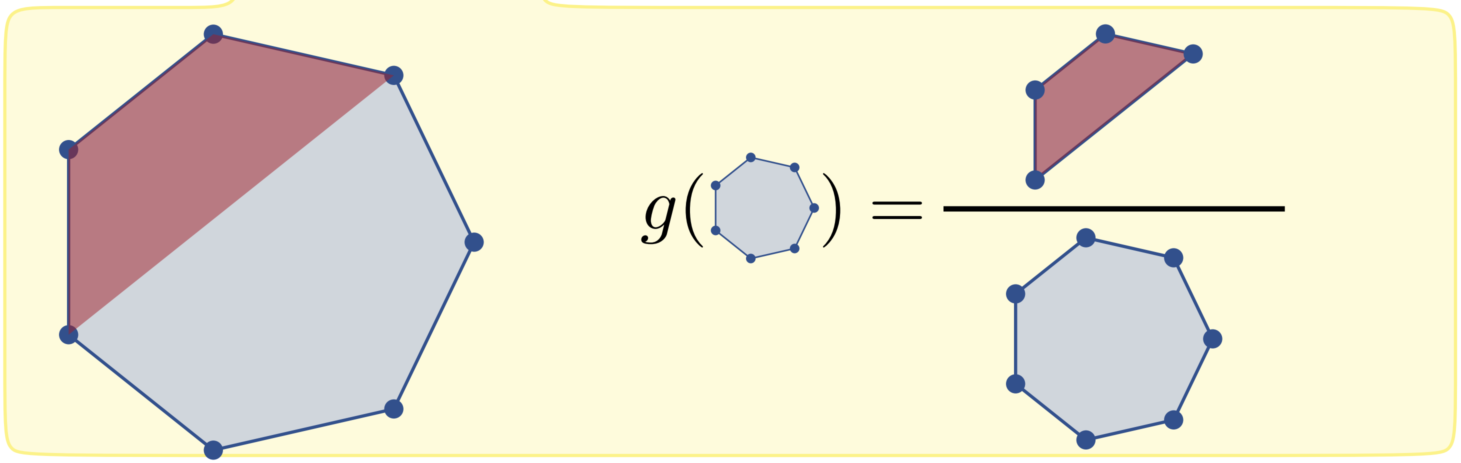
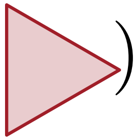
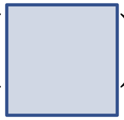
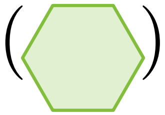




- $g($  $) = g($  $) = 1$
- $g($  $) = \frac{1}{2}$
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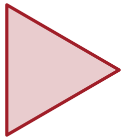
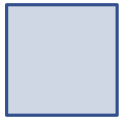
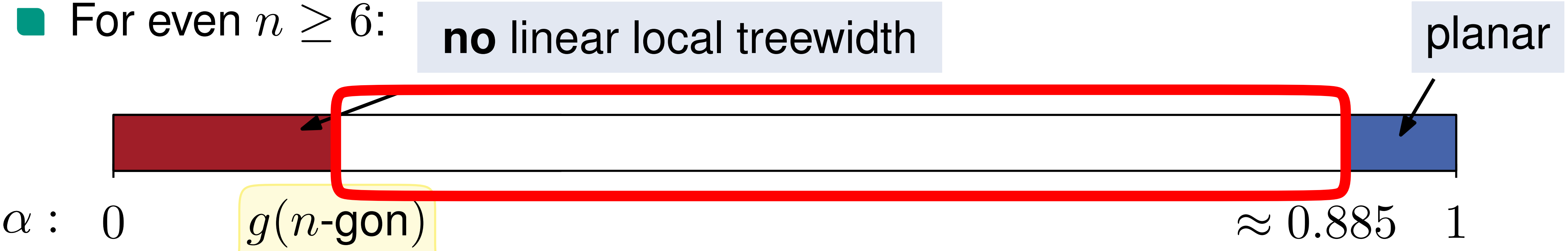
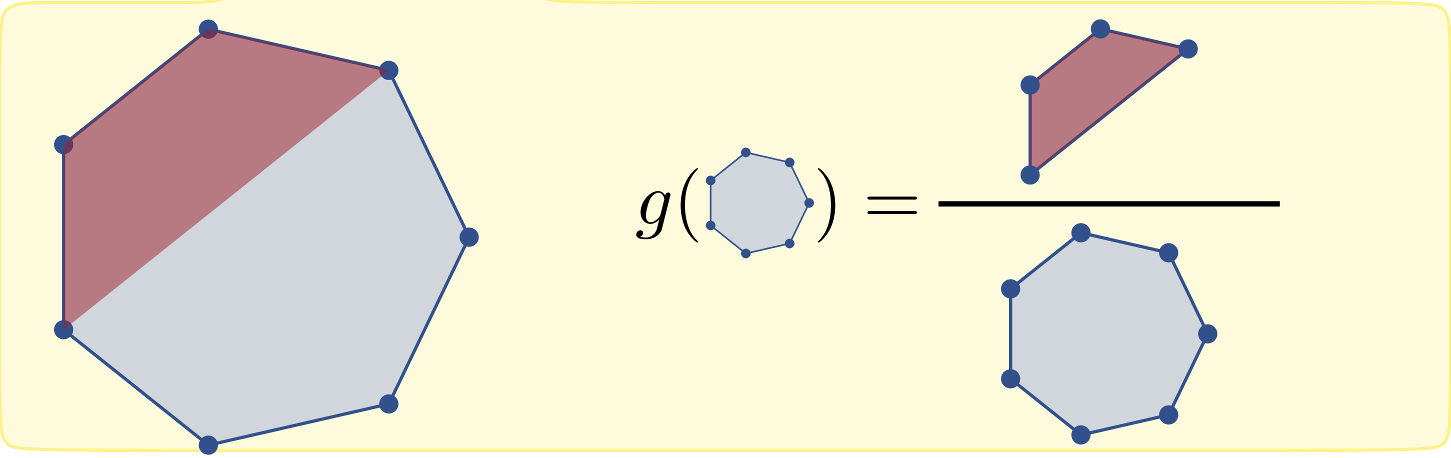
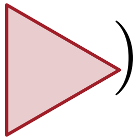
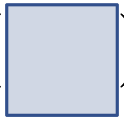
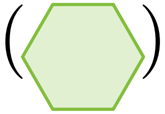
- For  and  : **no** product structure for $\alpha < 1$.
- For even $n \geq 6$: **no** linear local treewidth





- $g($$) = g($$) = 1$
- $g($$) = \frac{1}{2}$
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k-Independent Crossing Drawings

k-independent crossing: no edge is crossed by more than k independent edges.

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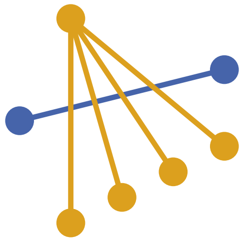

1-independent crossing

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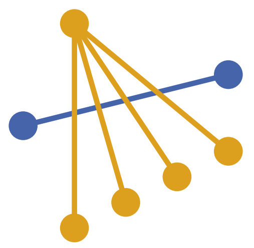

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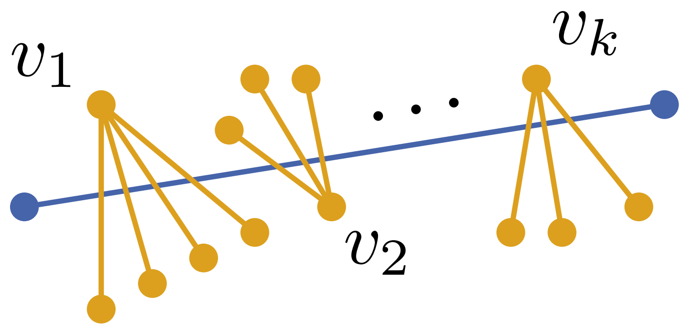

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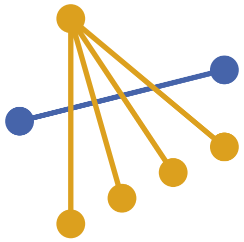

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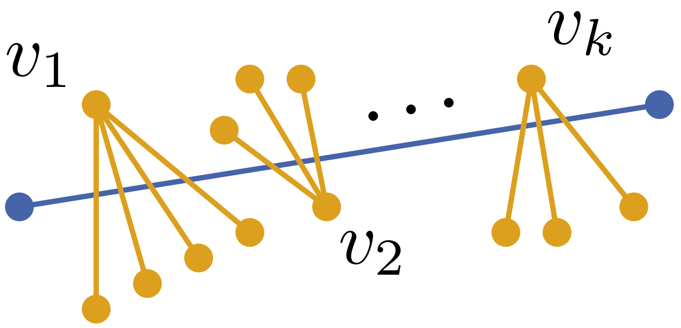
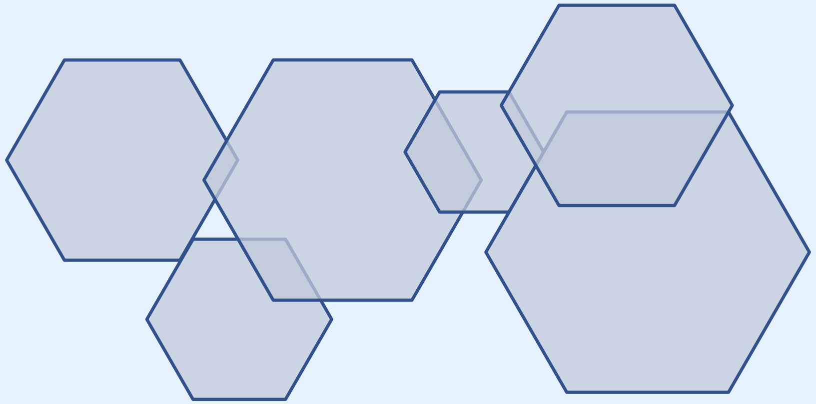


k-independent crossing

canonical drawings



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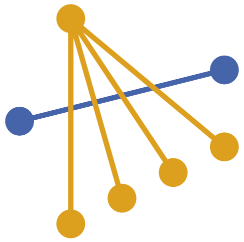

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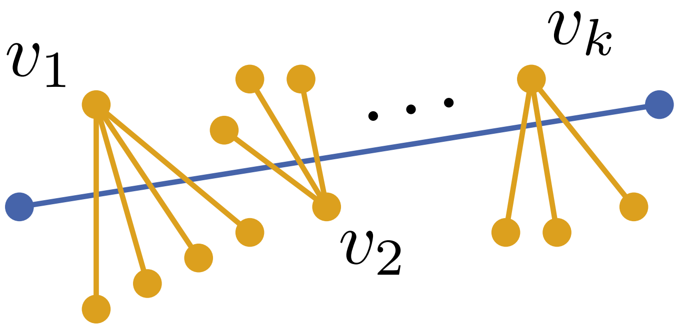

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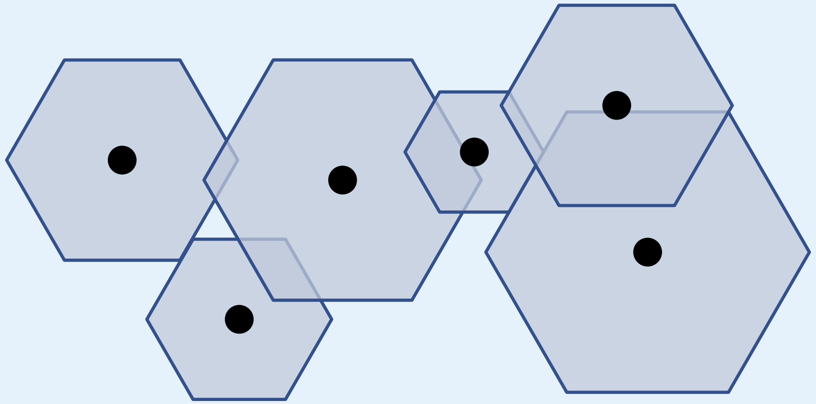

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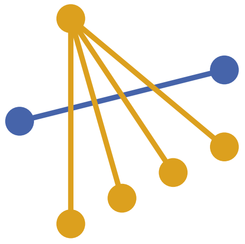

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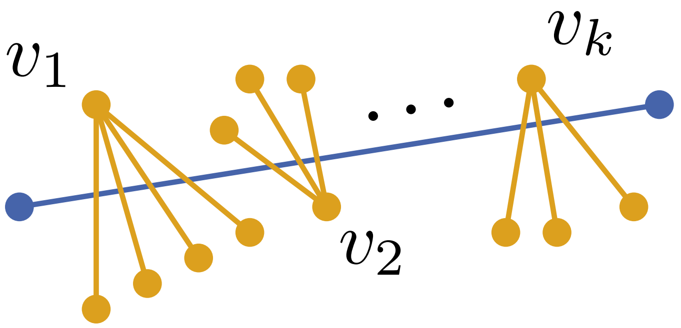

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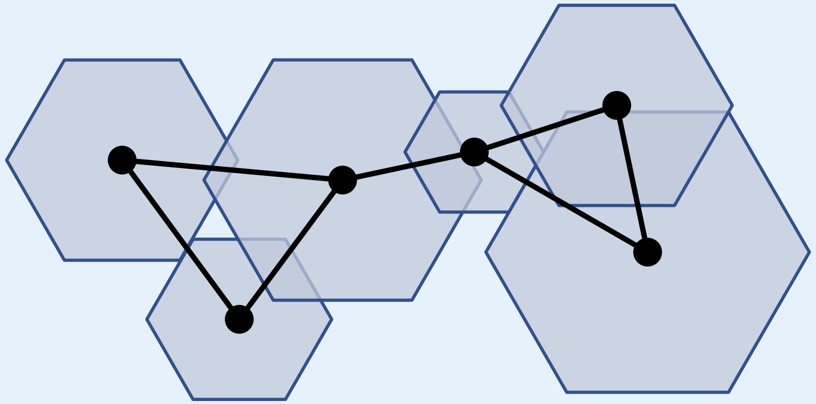

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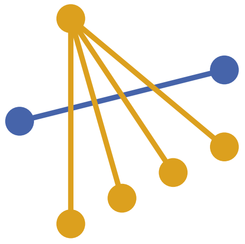

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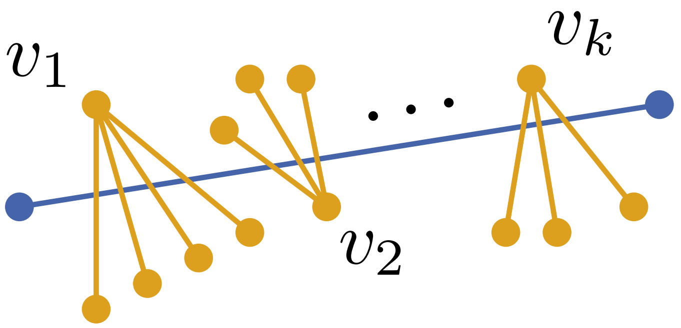

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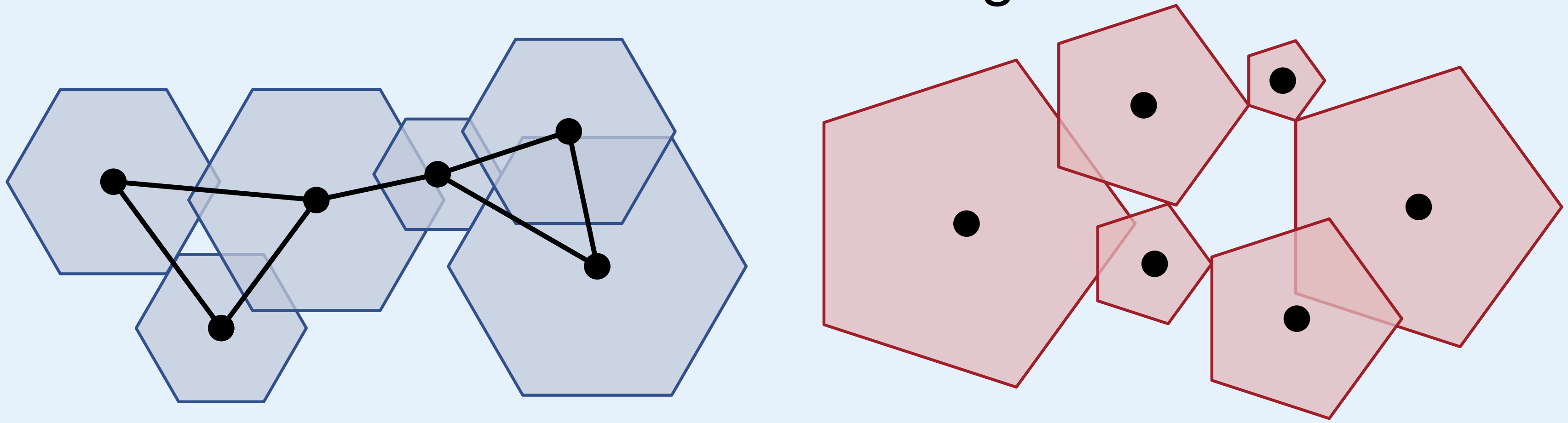

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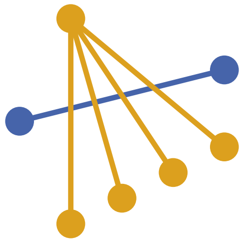

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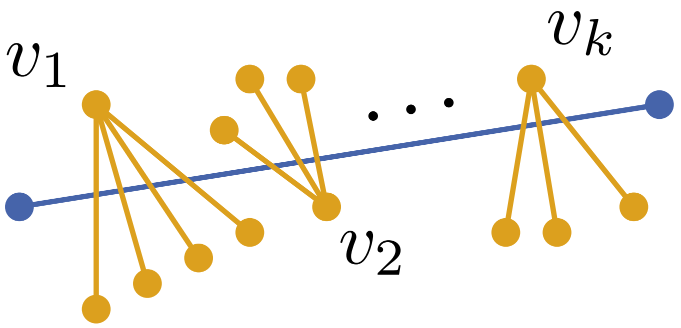

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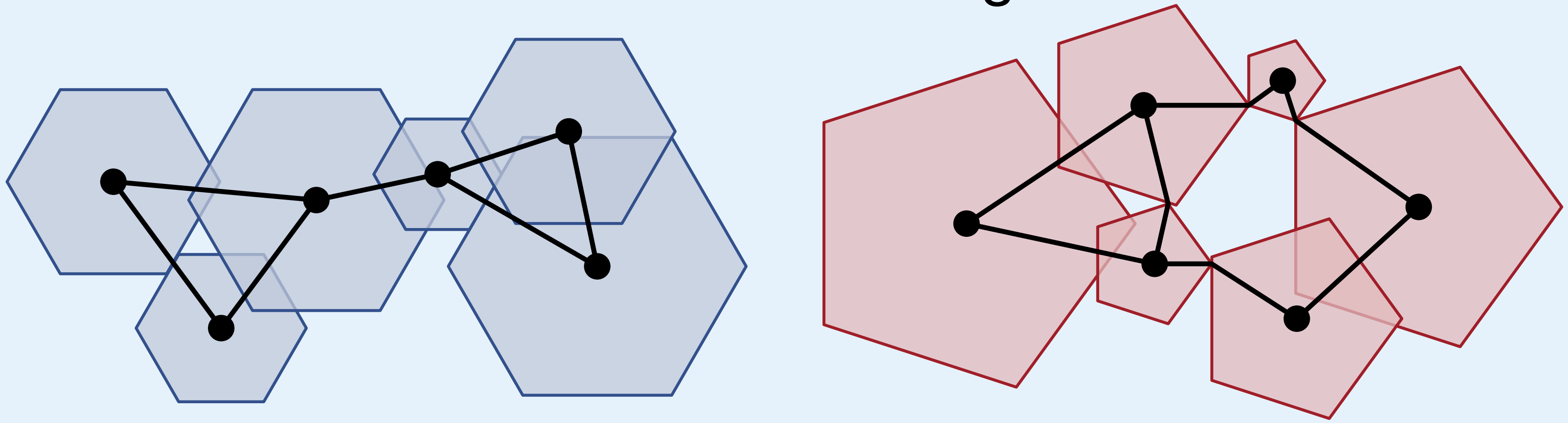
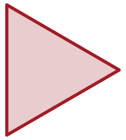
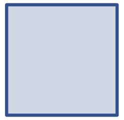


Conclusion

- For  and  : **no** product structure for $\alpha < 1$.
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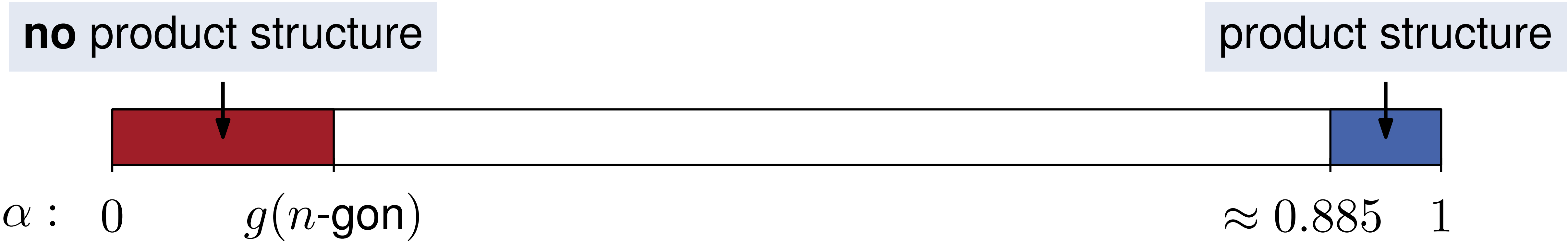

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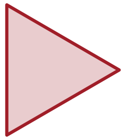
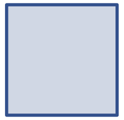
- For  and  : **no** product structure for $\alpha < 1$.
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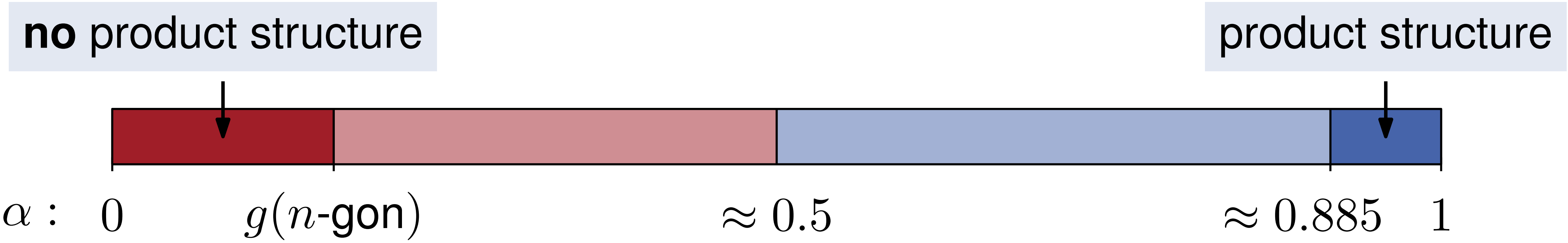

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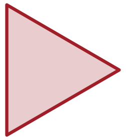
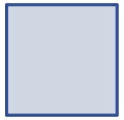
- For  and  : **no** product structure for $\alpha < 1$.
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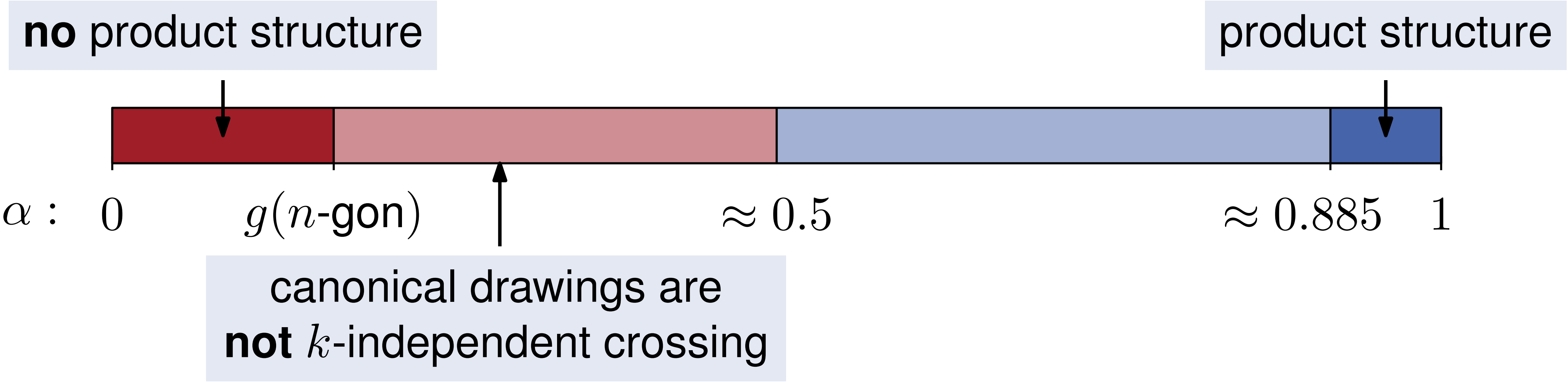

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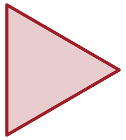
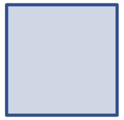
- For  and  : **no** product structure for $\alpha < 1$.
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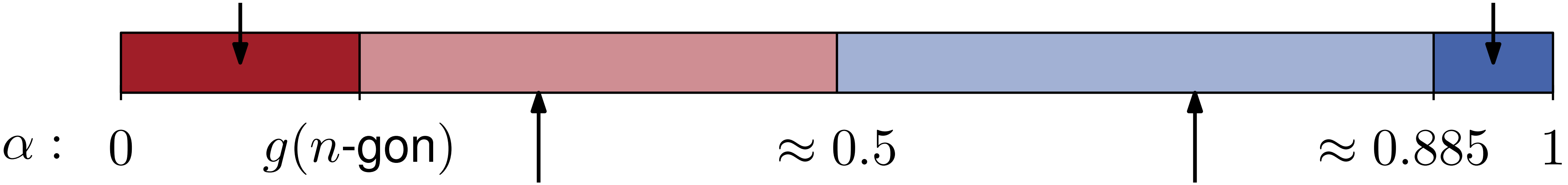

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not k-independent crossing

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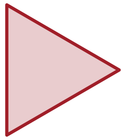
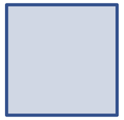
Conclusion

- For  and  : **no** product structure for $\alpha < 1$.
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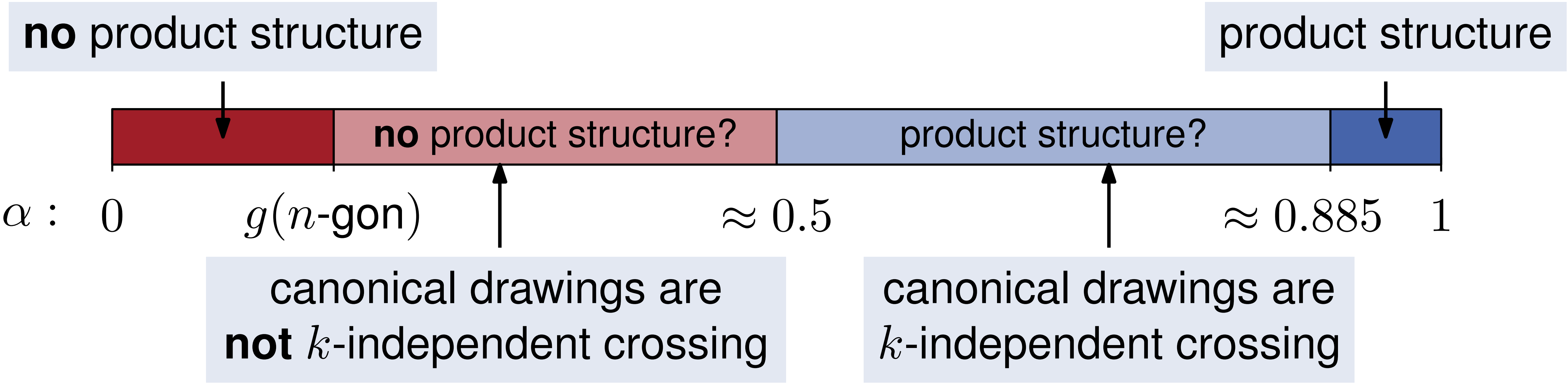
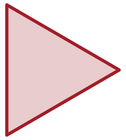
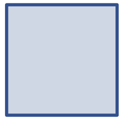
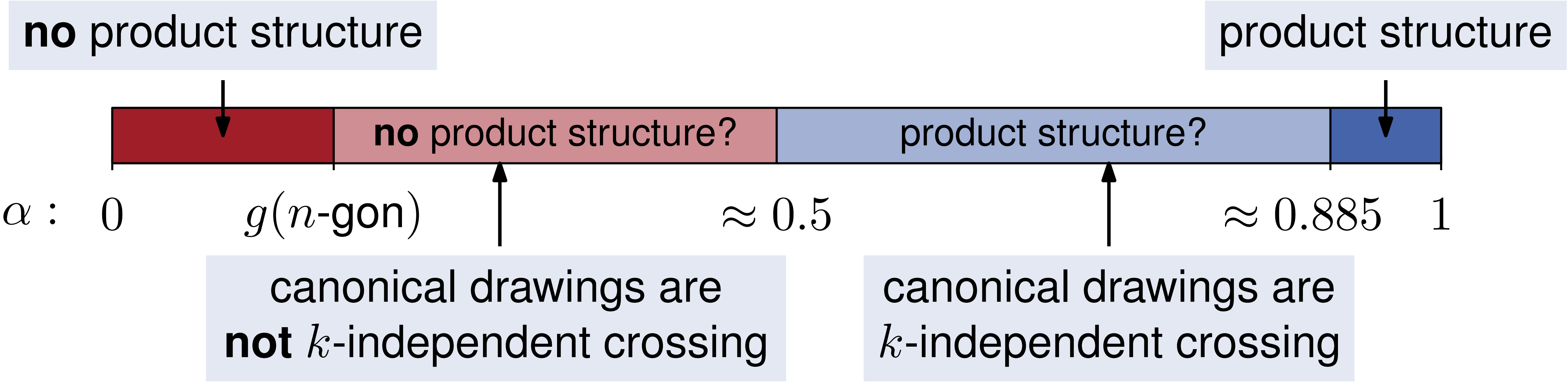


Conclusion

- For  and  : **no** product structure for $\alpha < 1$.
- For even $n \geq 6$:



Question: Do k-independent crossing graphs have product structure?