Outside-Obstacle Representations with All Vertices on the Outer Face

Oksana Firman Philipp Kindermann Jonathan Klawitter
Boris Klemz **Felix Klesen** Alexander Wolff

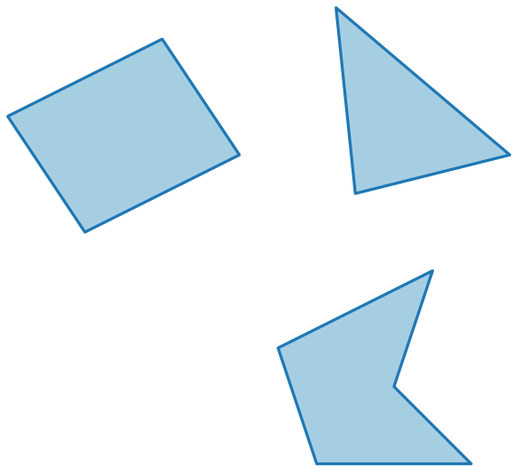
THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Universität Trier

Visibility Graph

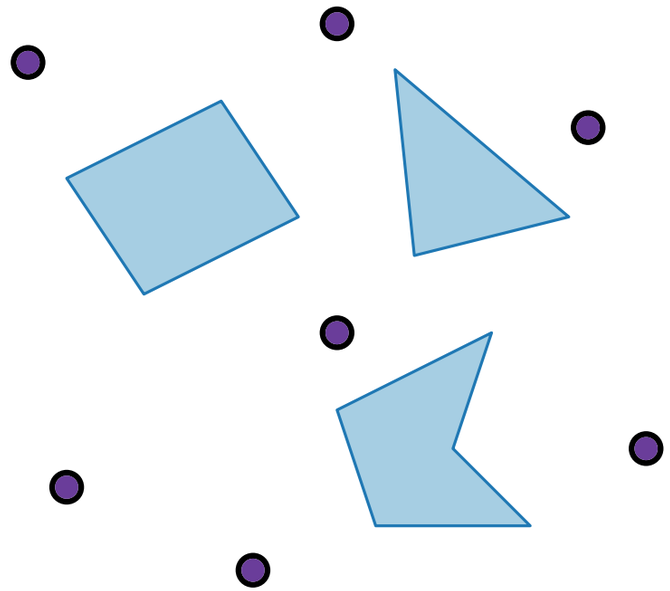
Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)



Visibility Graph

Given:

- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

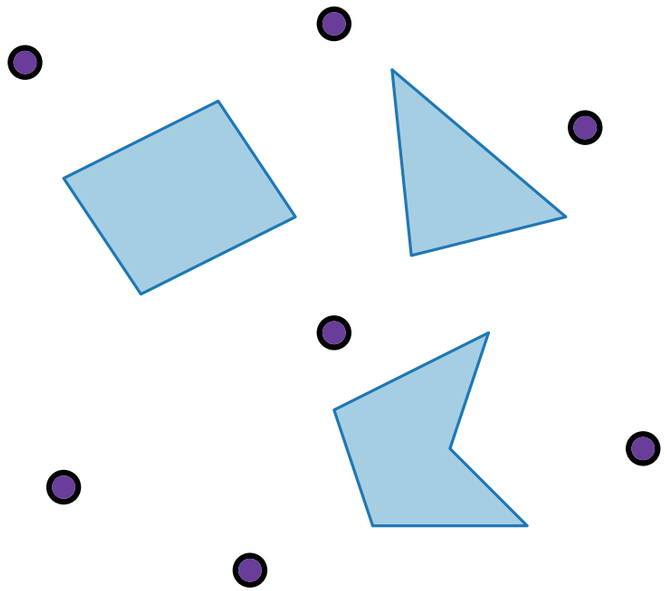


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$

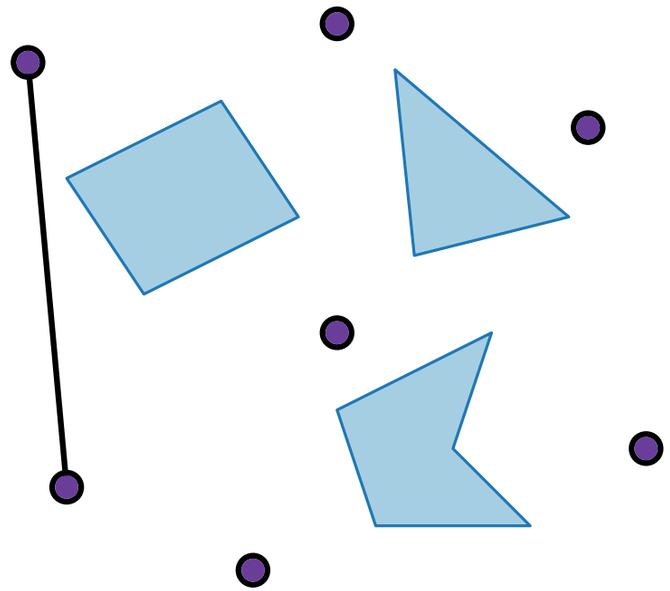


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$

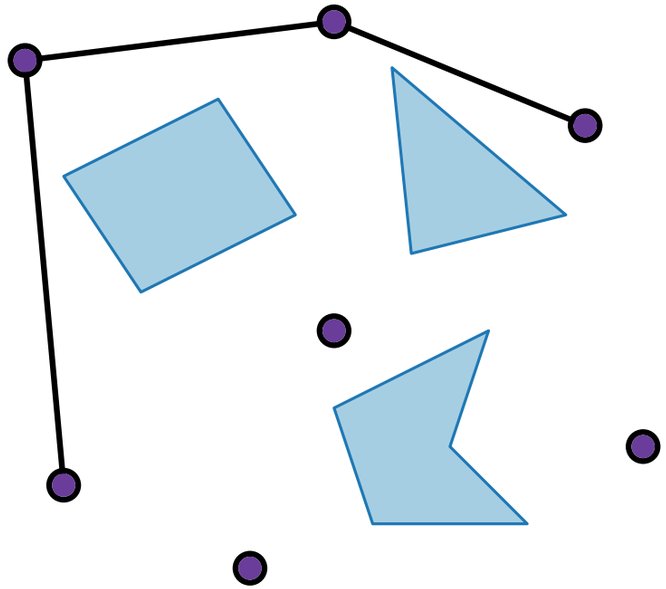


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$

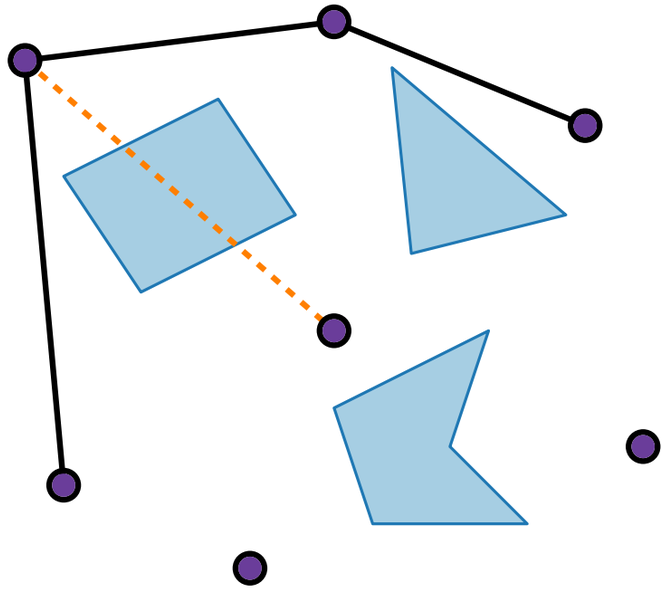


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$

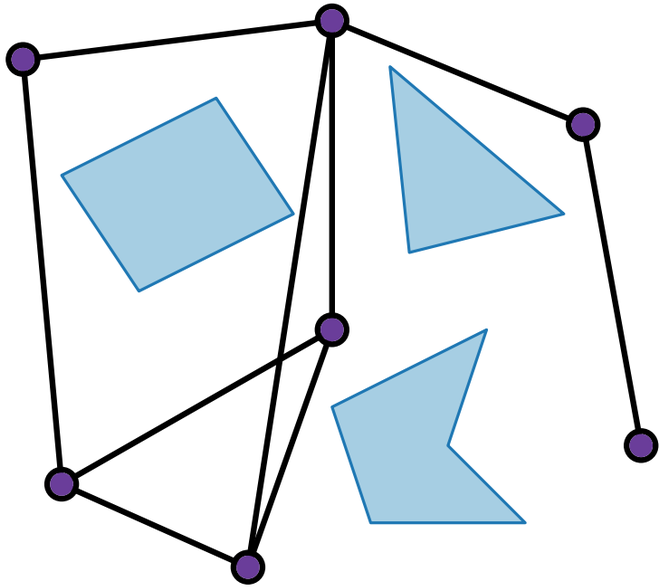


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$

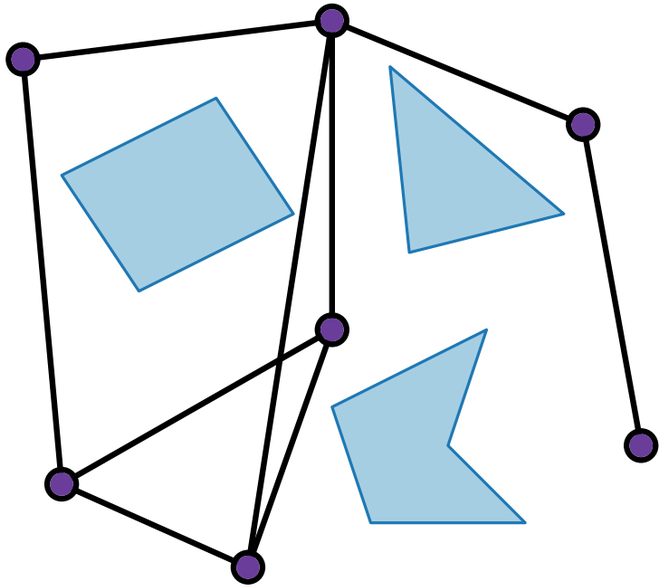


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

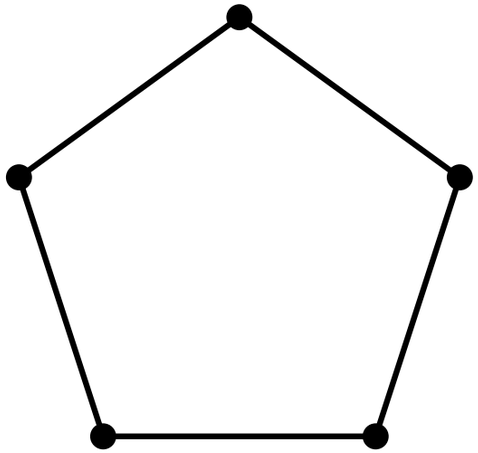
induces ...

visibility graph $G_{\mathcal{C}}(P)$



Obstacle Representation

Given:
- a graph G

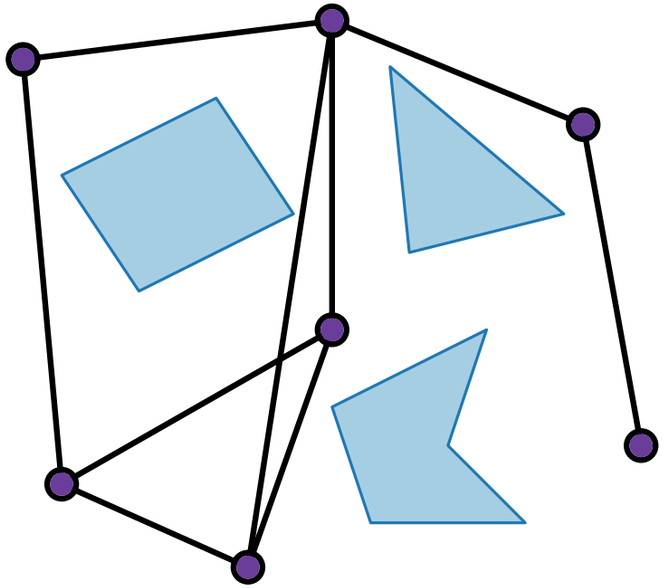


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

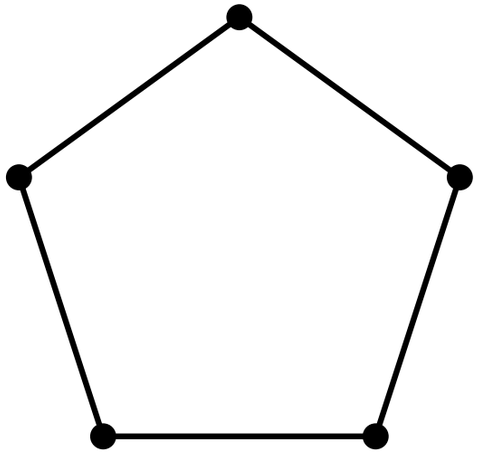
visibility graph $G_{\mathcal{C}}(P)$



Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

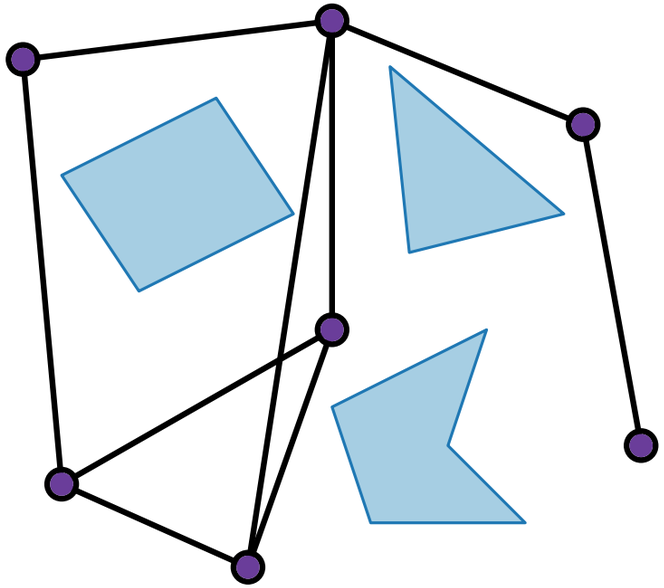


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$

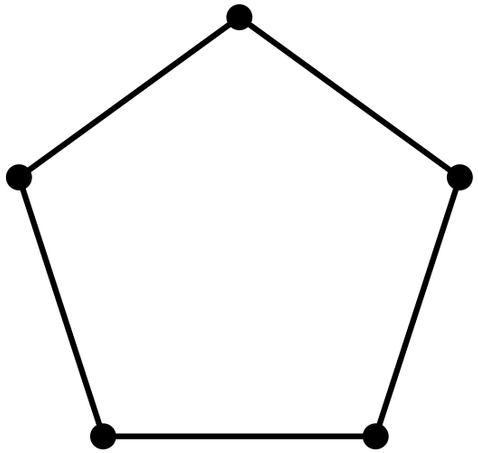


Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles

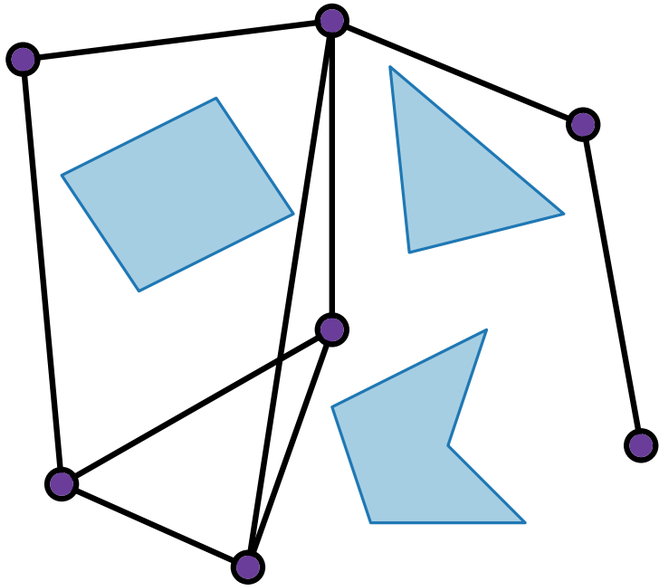


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$

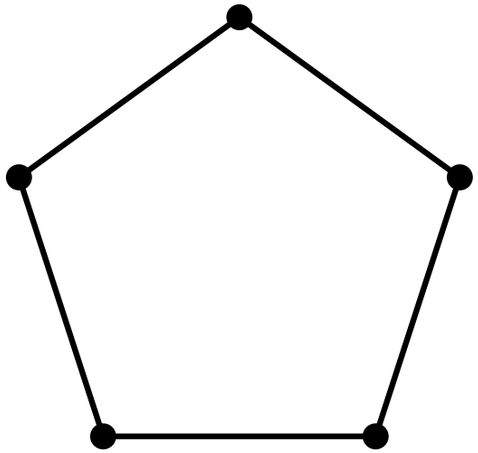


Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

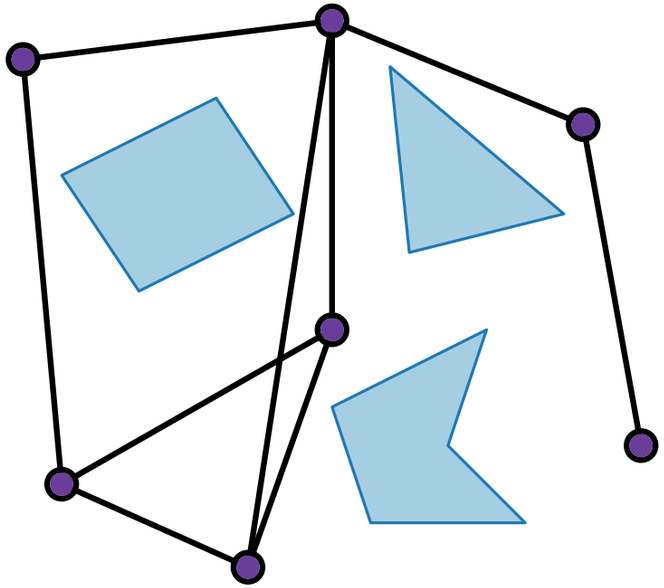


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



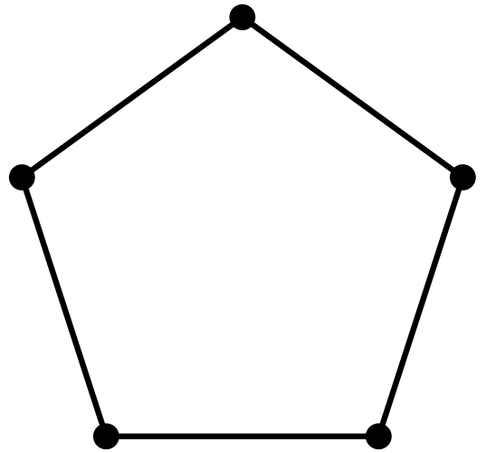
Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

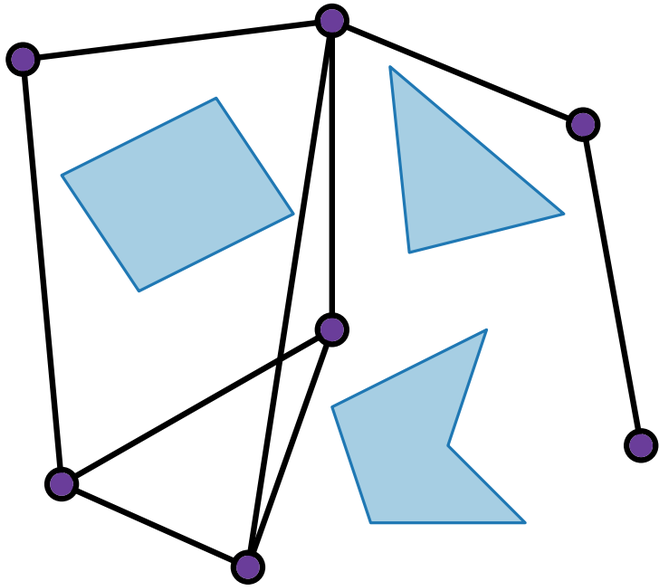


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



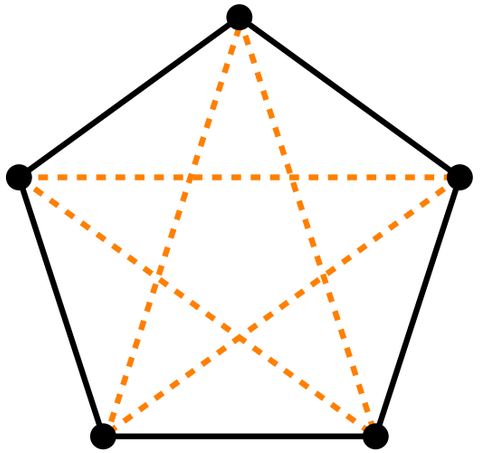
Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

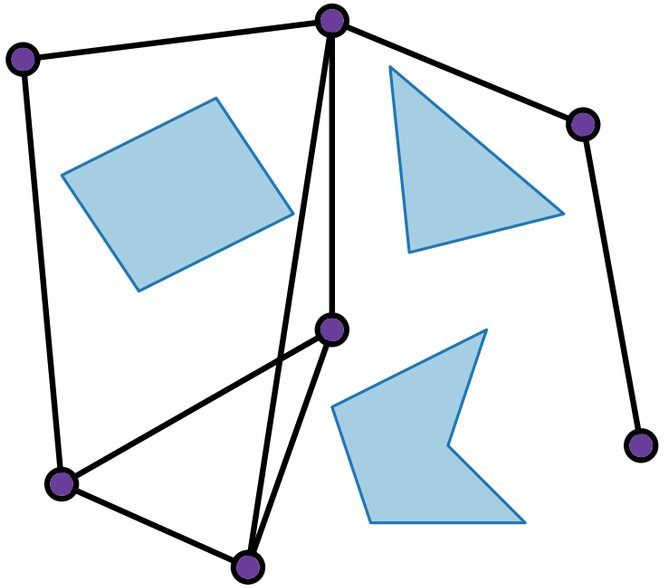


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



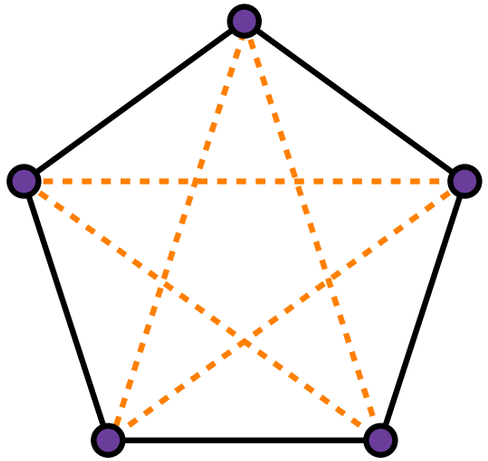
Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

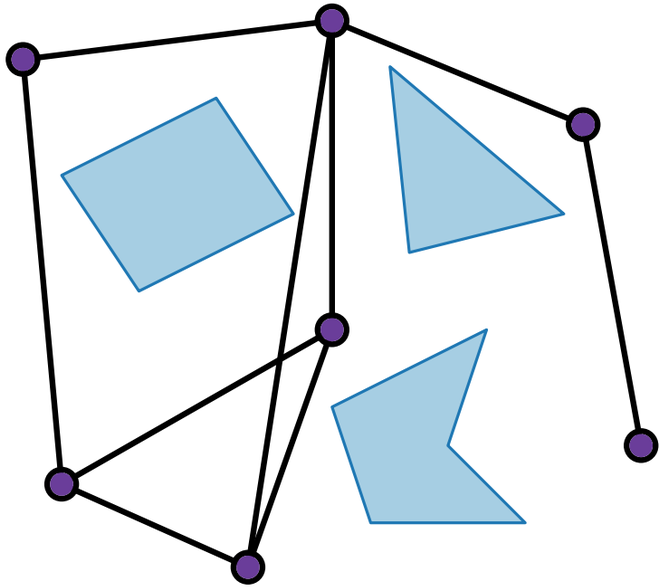


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



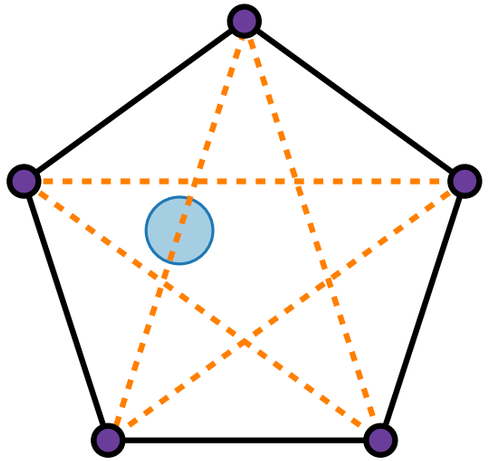
Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

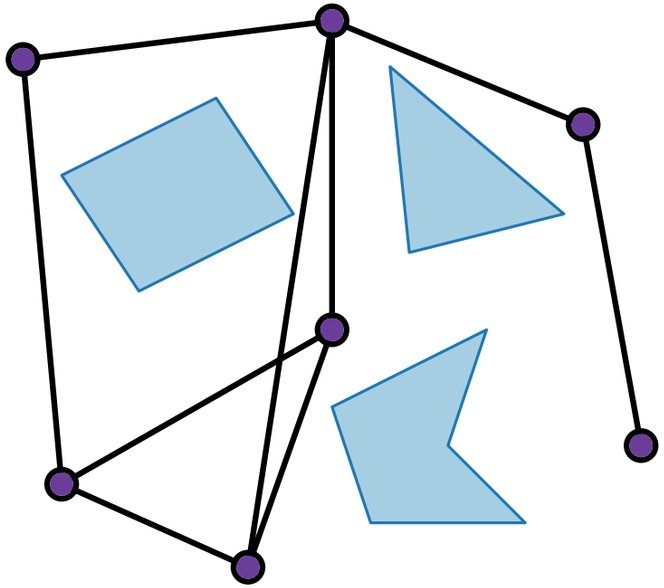


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



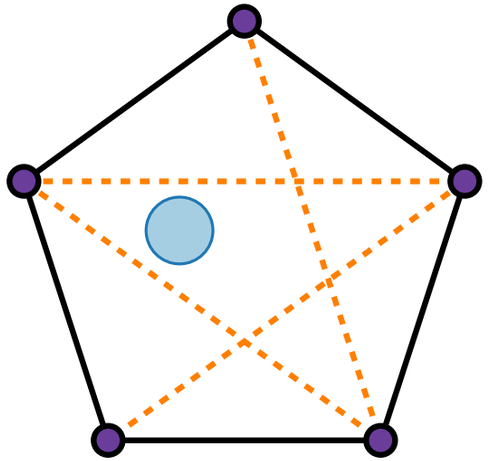
Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

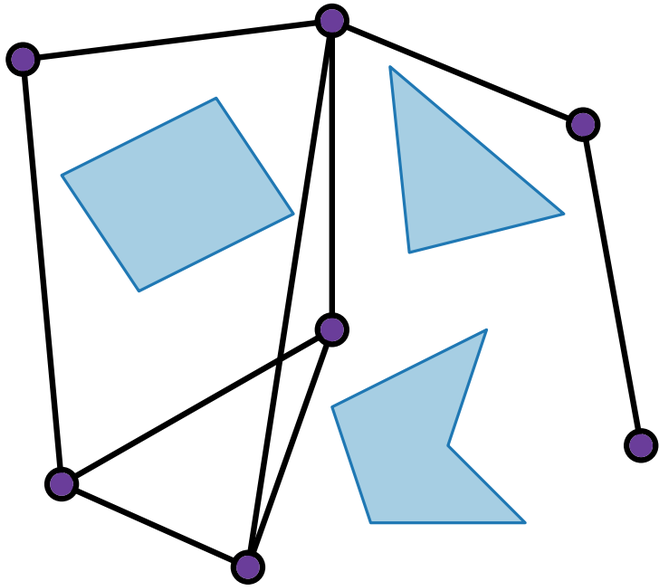


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



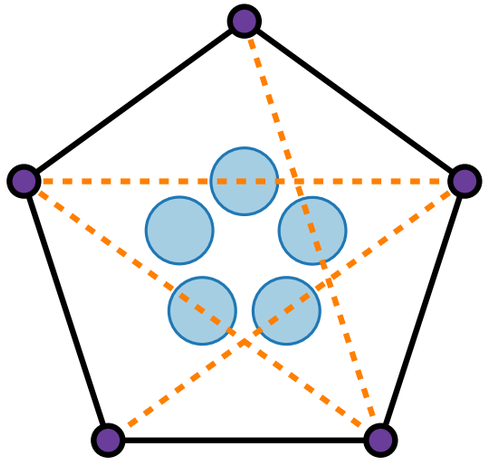
Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

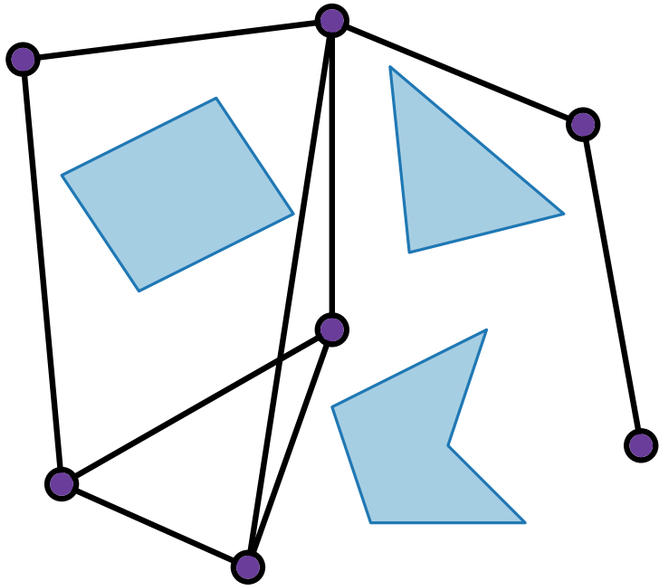


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



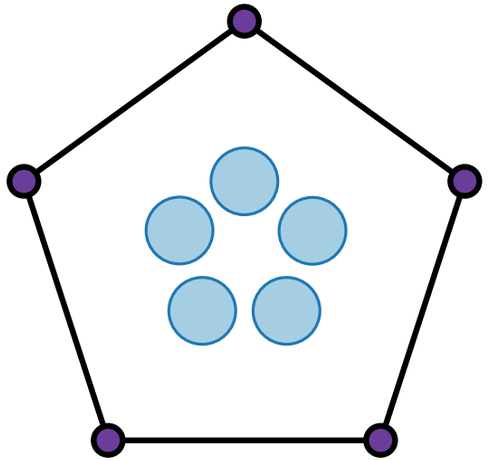
Obstacle Representation

Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

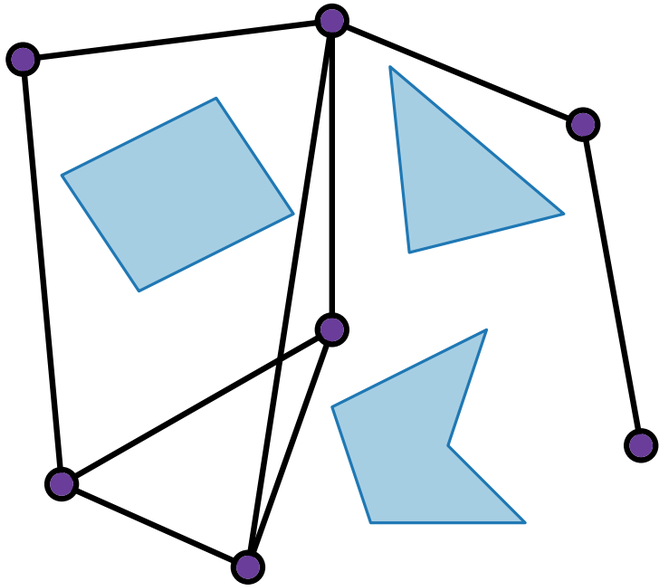


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



Obstacle Representation

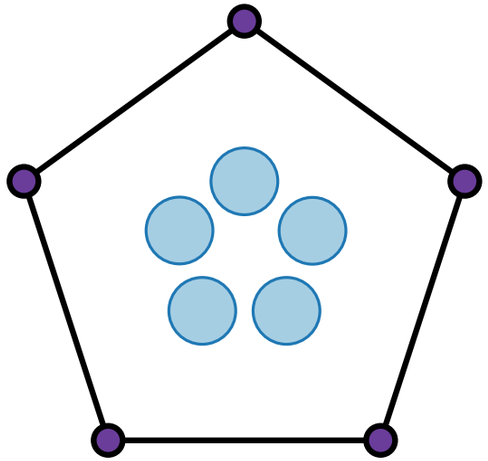
Given:
- a graph G

Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

Every graph has an obstacle representation!

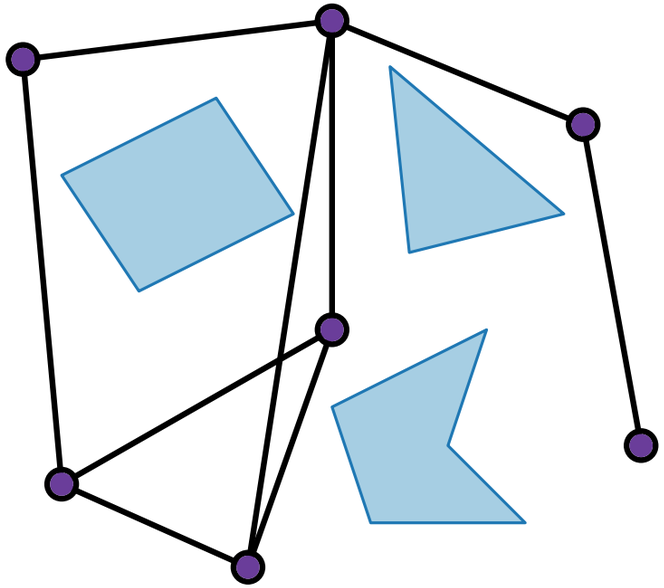


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



Obstacle Representation

Given:
- a graph G

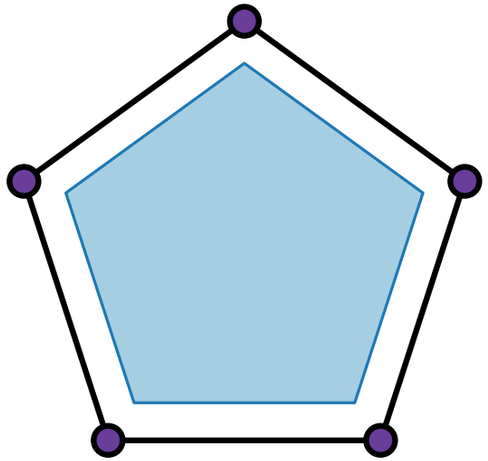
Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

Every graph has an obstacle representation!

$\Rightarrow$ minimization problem

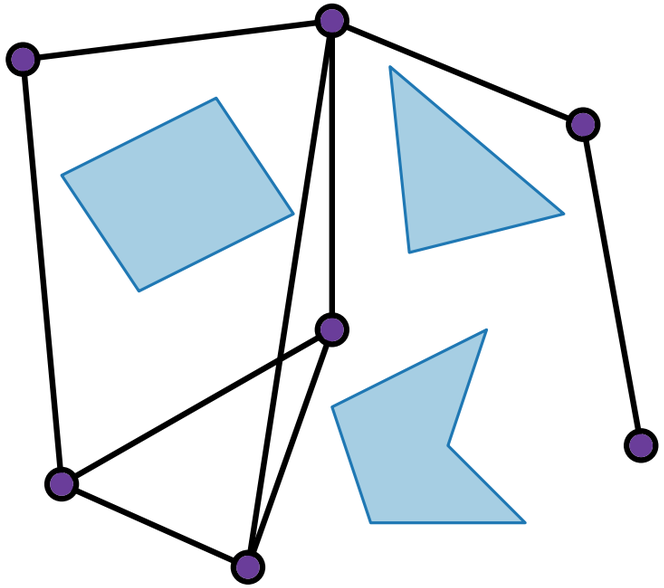


Visibility Graph

Given:
- a set of polygons $\mathcal{C}$ (*obstacles*)
- a set of points P

induces ...

visibility graph $G_{\mathcal{C}}(P)$



Obstacle Representation

Given:
- a graph G

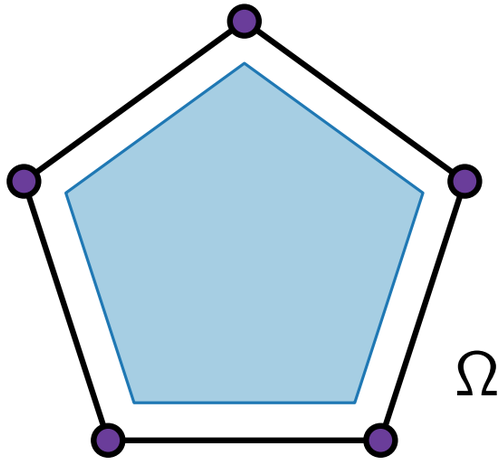
Q.: Does G admit an **obstacle representation**?

Find:
- a set of obstacles
- mapping of $V(G)$ to points P

s.t. $G = G_{\mathcal{C}}(P)$

Every graph has an obstacle representation!

$\Rightarrow$ minimization problem



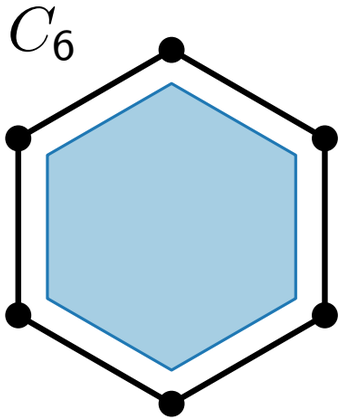
$O(n \log n)$

[Balko et al., *GD* 2015]

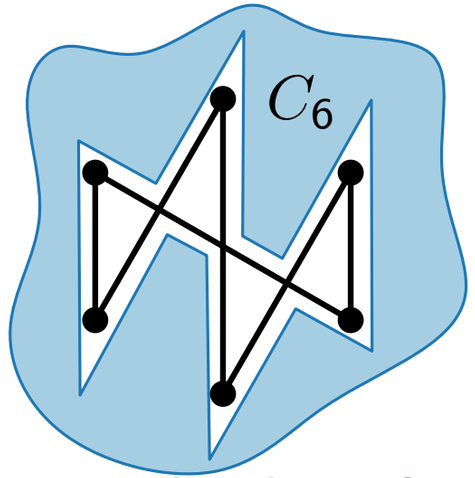
$\Omega(n/\log\log n)$

[Balko et al., *ESA* 2022]

Previous Work

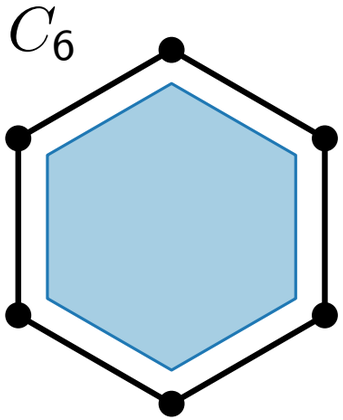


inside obstacle

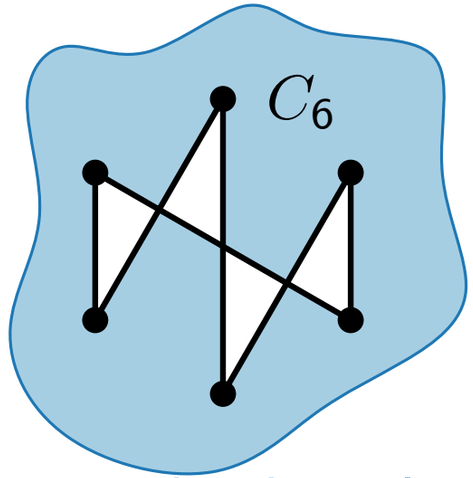


outside obstacle

Previous Work

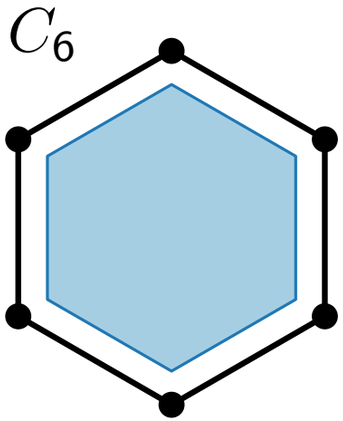


inside obstacle

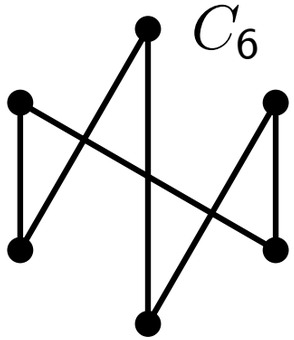


outside obstacle

Previous Work

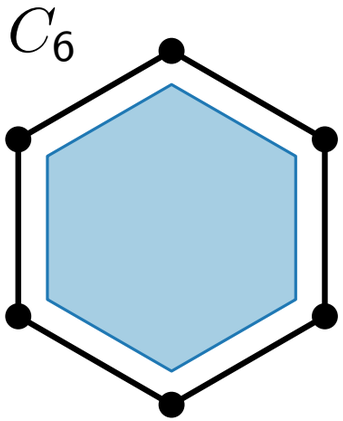


inside obstacle



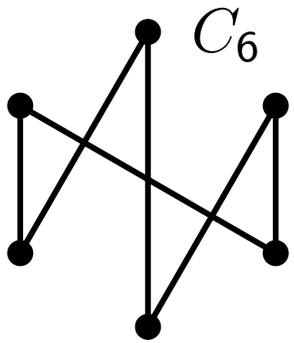
outside obstacle

Previous Work



inside obstacle

- single convex obstacle

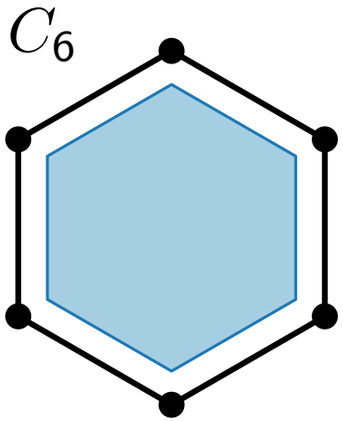


outside obstacle

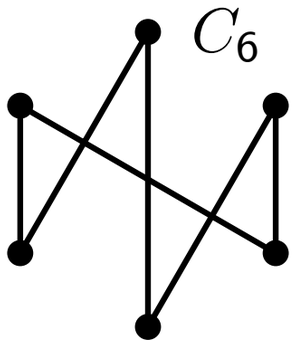
- every outerplanar graph

[Alpert et al., *DCG* 2010]

Previous Work



inside obstacle



outside obstacle

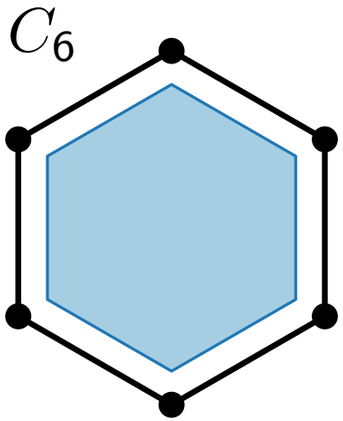
[Alpert et al., *DCG* 2010]

- single convex obstacle
- every outerplanar graph

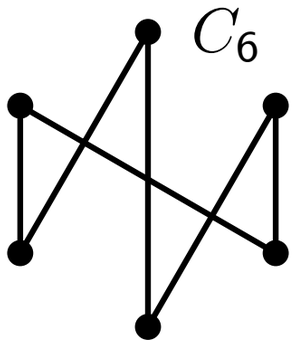
[Berman et al., *JGAA* 2017]

- necessary conditions to have a single obstacle
- planar graphs (icosahedron needs 2 obstacles)

Previous Work



inside obstacle



outside obstacle

[Alpert et al., *DCG* 2010]

- single convex obstacle
- every outerplanar graph

[Berman et al., *JGAA* 2017]

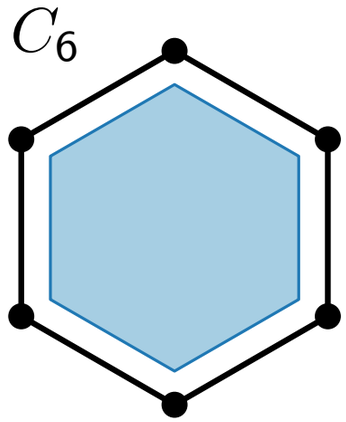
- necessary conditions to have a single obstacle
- planar graphs (icosahedron needs 2 obstacles)

[Chaplick et al., *GD* 2016]

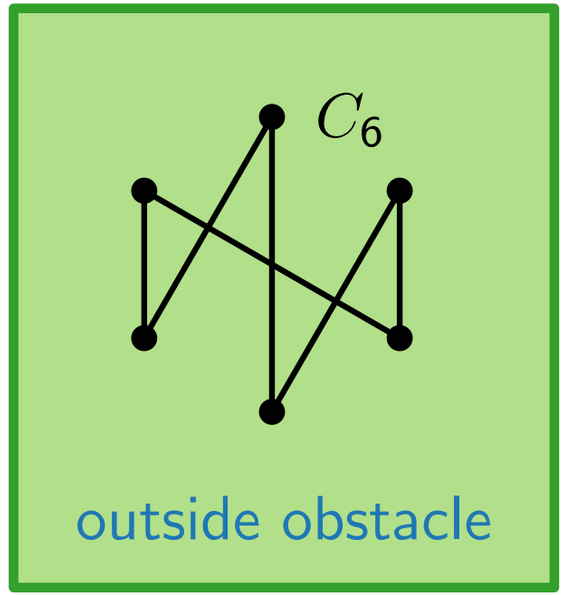
- every graph with ≤ 7 vertices

- incomparable (with a single obstacle)

Previous Work



inside obstacle



outside obstacle

[Alpert et al., *DCG* 2010]

- single convex obstacle

- every outerplanar graph

[Berman et al., *JGAA* 2017]

- necessary conditions to have a single obstacle
- planar graphs (icosahedron needs 2 obstacles)

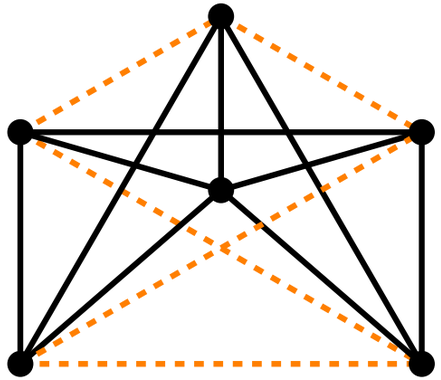
[Chaplick et al., *GD* 2016]

- every graph with ≤ 7 vertices

- incomparable (with a single obstacle)

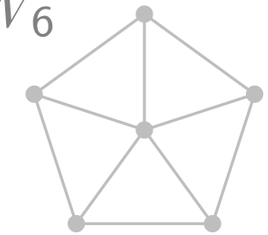
Types of Outside-Obstacle Representation

General



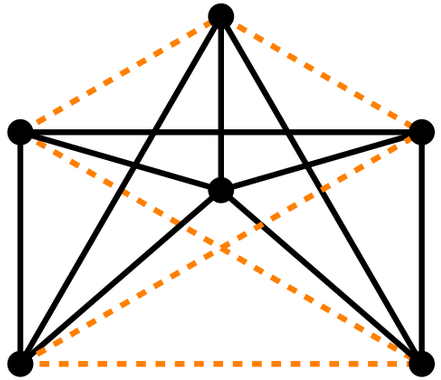
all vertices on
the outer face

W_6



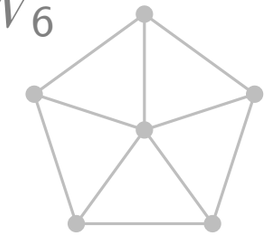
Types of Outside-Obstacle Representation

General

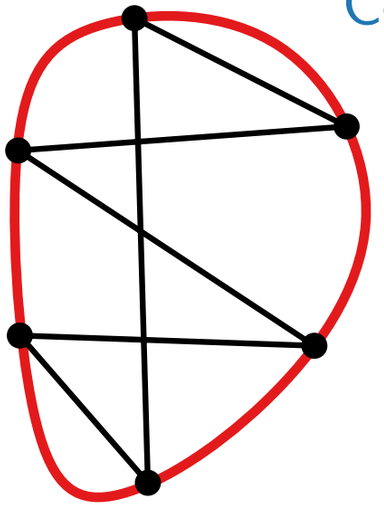


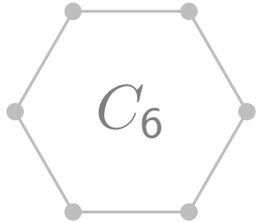
all vertices on
the outer face

W_6



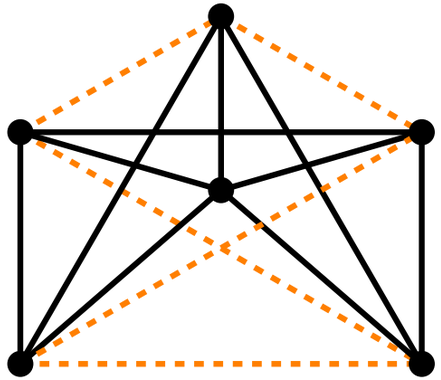
Convex





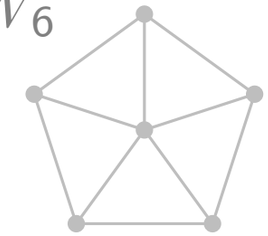
Types of Outside-Obstacle Representation

General

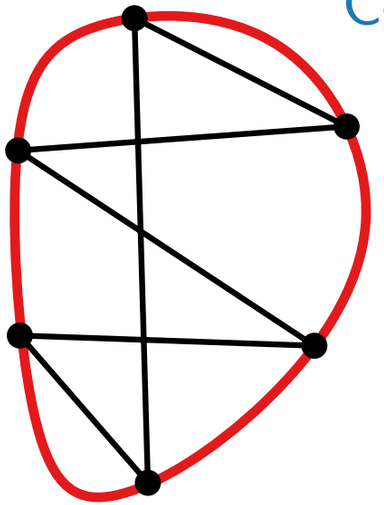


all vertices on
the outer face

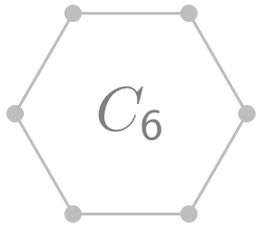
W_6



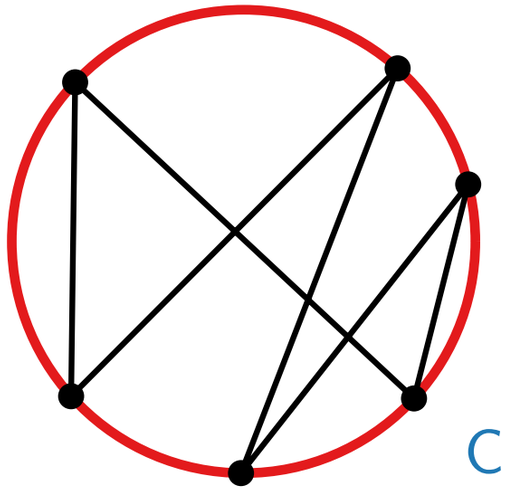
Convex



C_6

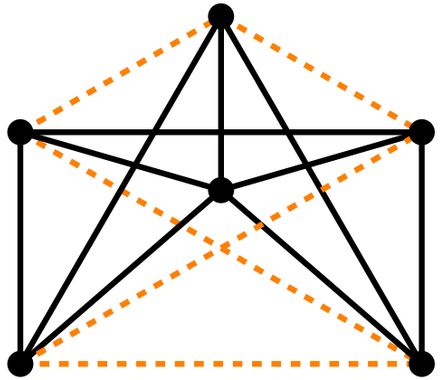


Circular



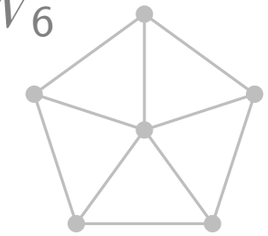
Types of Outside-Obstacle Representation

General

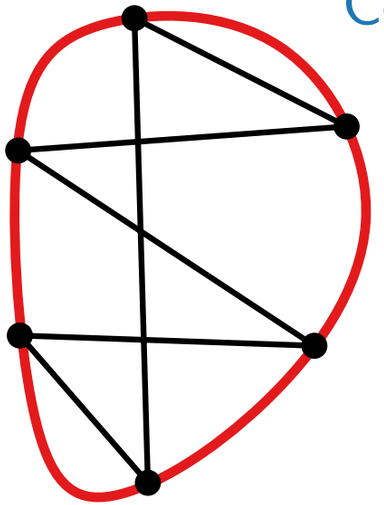


all vertices on
the outer face

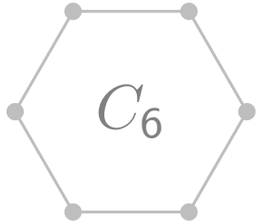
W_6



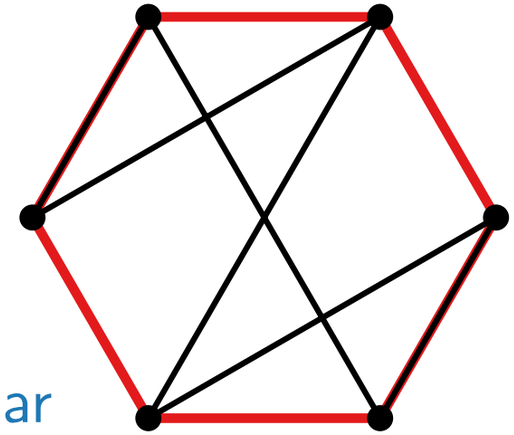
Convex



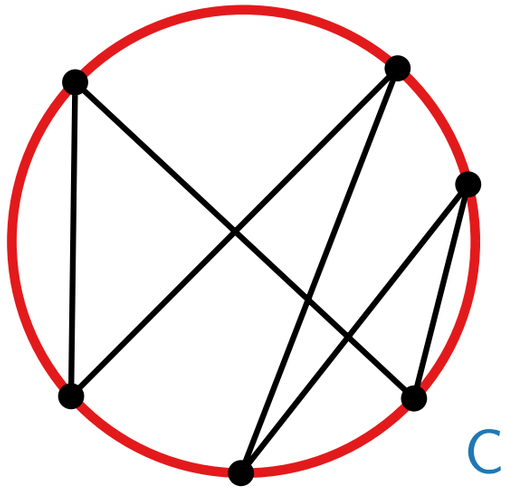
C_6



Regular

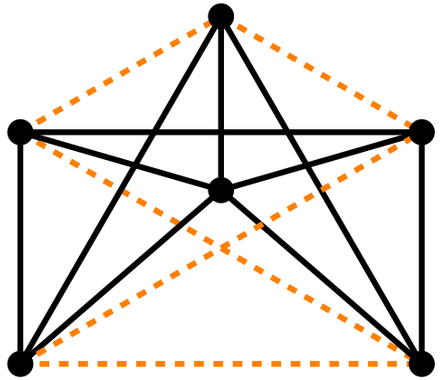


Circular



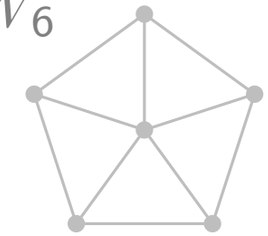
Types of Outside-Obstacle Representation

General

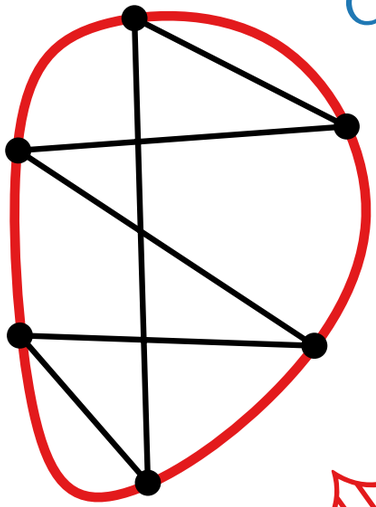


all vertices on
the outer face

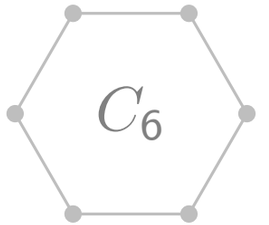
W_6



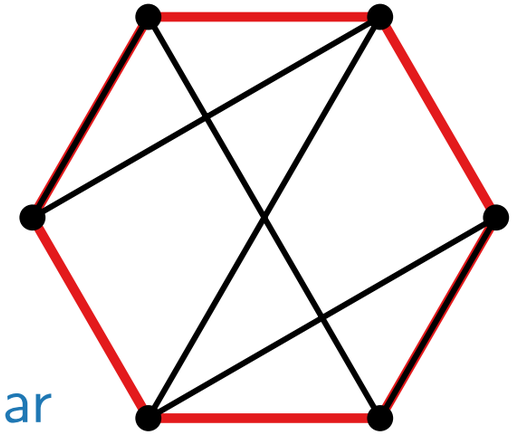
Convex

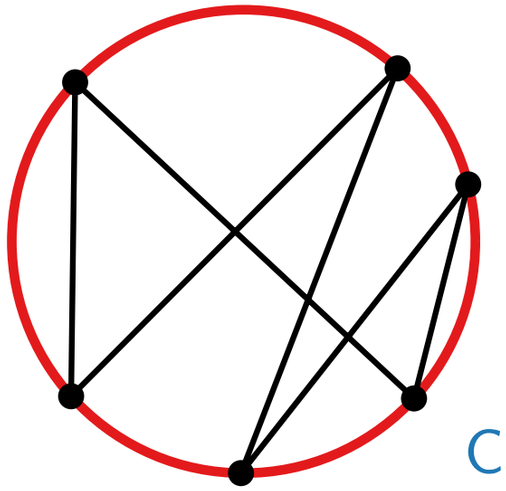


C_6



Regular

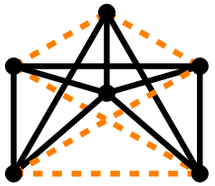




Circular

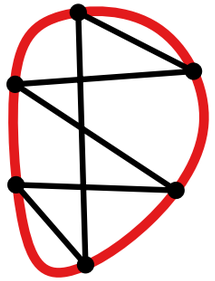
Our Contribution

General

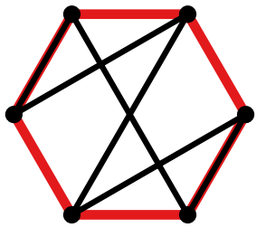


all vertices on
the outer face

Convex

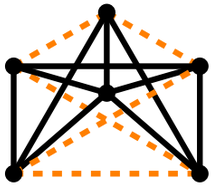


Regular



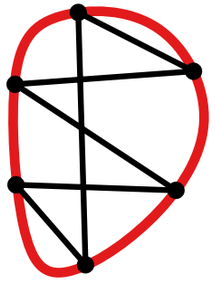
Our Contribution

General

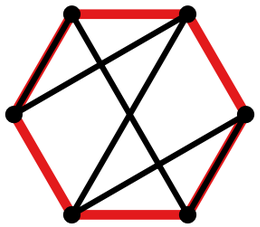


all vertices on
the outer face

Convex



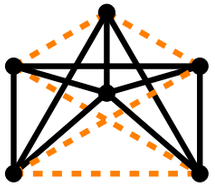
Regular



- cactus

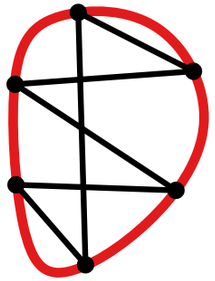
Our Contribution

General

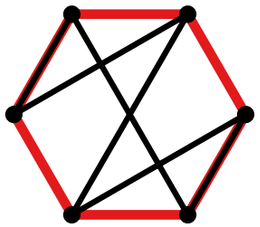


all vertices on
the outer face

Convex



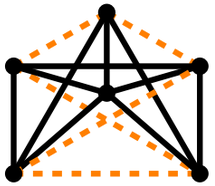
Regular



- cactus
- grid

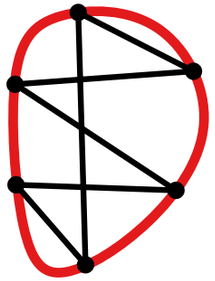
Our Contribution

General

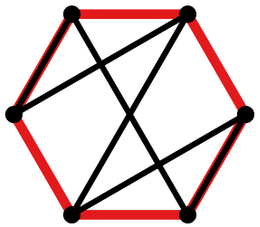


all vertices on
the outer face

Convex



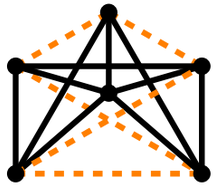
Regular



- cactus
- grid
- outerpath

Our Contribution

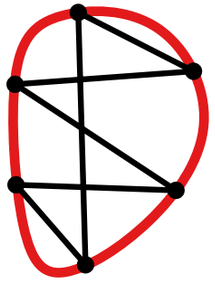
General



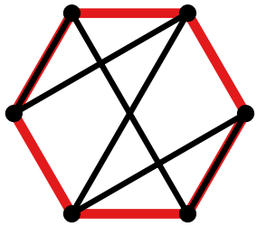
all vertices on
the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]

Convex



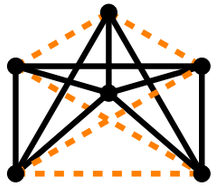
Regular



- cactus
- grid
- outerpath

Our Contribution

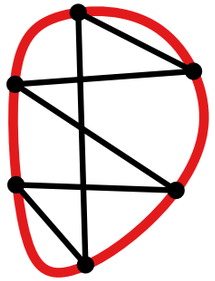
General



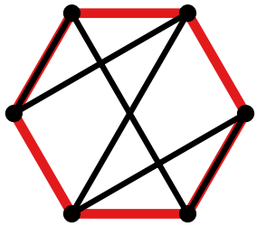
all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree

Convex



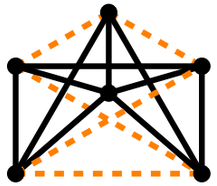
Regular



- cactus
- grid
- outerpath

Our Contribution

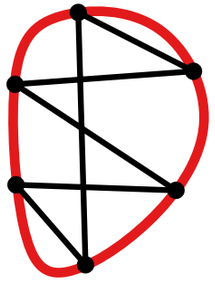
General



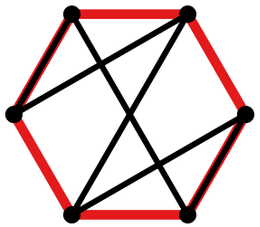
all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs?)

Convex



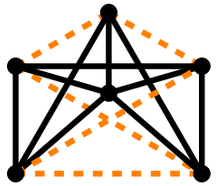
Regular



- cactus (subgraphs?)
- grid (subgraphs?)
- outerpath (subgraphs?)

Our Contribution

General

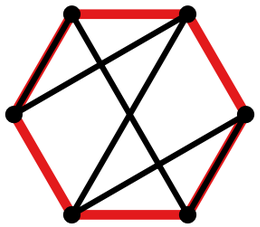


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs?)

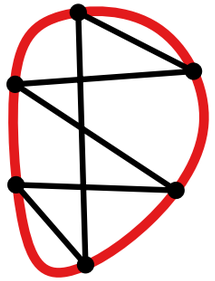
Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

Regular



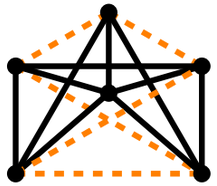
- cactus (subgraphs?)
- grid (subgraphs?)
- outerpath (subgraphs?)

Convex



Our Contribution

General

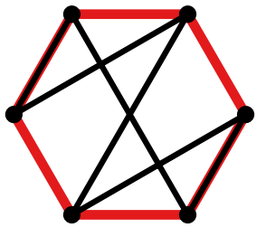


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

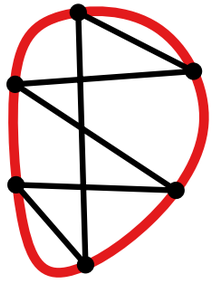
Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

Regular



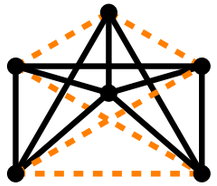
- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

Convex



Our Contribution

General

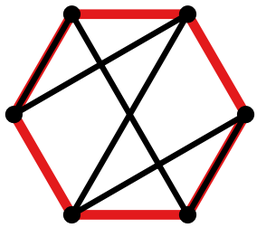


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

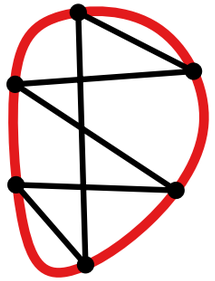
Regular



- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

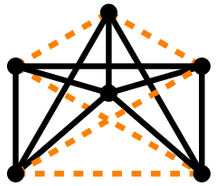
Convex

- tree complement (iff tree is caterpillar)



Our Contribution

General

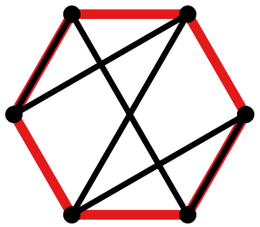


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

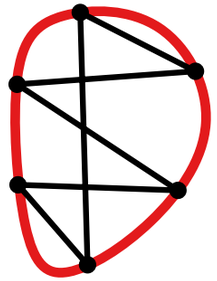
Regular



- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

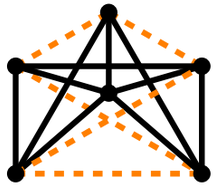
Convex

- tree complement (iff tree is caterpillar)
- $K_n - E(C_k)$ (iff $k \in \{3, 4, n\}$)



Our Contribution

General

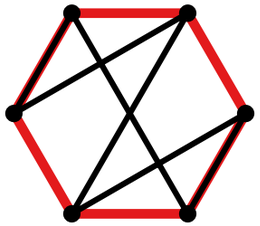


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

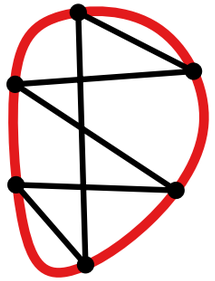
Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

Regular



- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

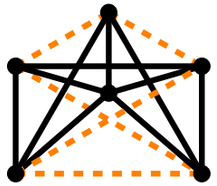
Convex



- tree complement (iff tree is caterpillar)
- $K_n - E(C_k)$ (iff $k \in \{3, 4, n\}$)
- consecutive neighbors property *sufficient*

Our Contribution

General

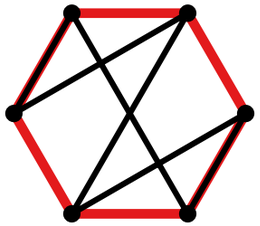


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

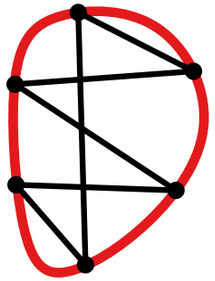
Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

Regular



- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

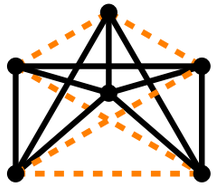
Convex



- tree complement (iff tree is caterpillar)
- $K_n - E(C_k)$ (iff $k \in \{3, 4, n\}$)
- consecutive neighbors property *sufficient*
- gap condition *necessary*

Our Contribution

General

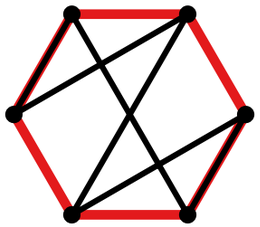


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

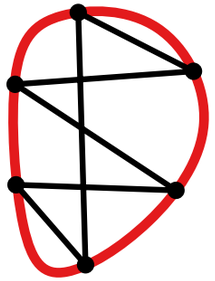
Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

Regular



- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

Convex

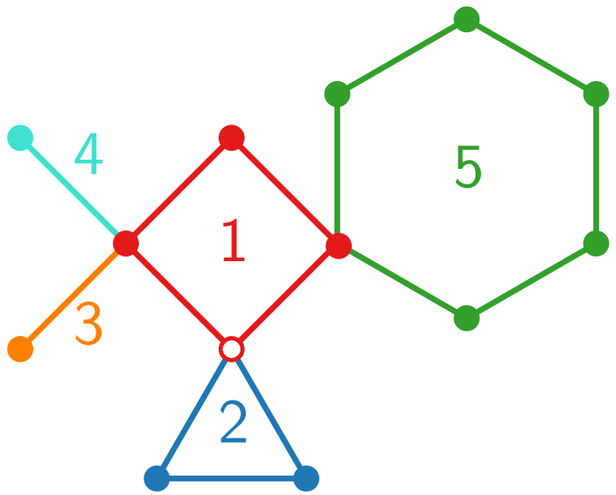


- tree complement (iff tree is caterpillar)
- $K_n - E(C_k)$ (iff $k \in \{3, 4, n\}$)
- consecutive neighbors property *sufficient*
- gap condition *necessary*

Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

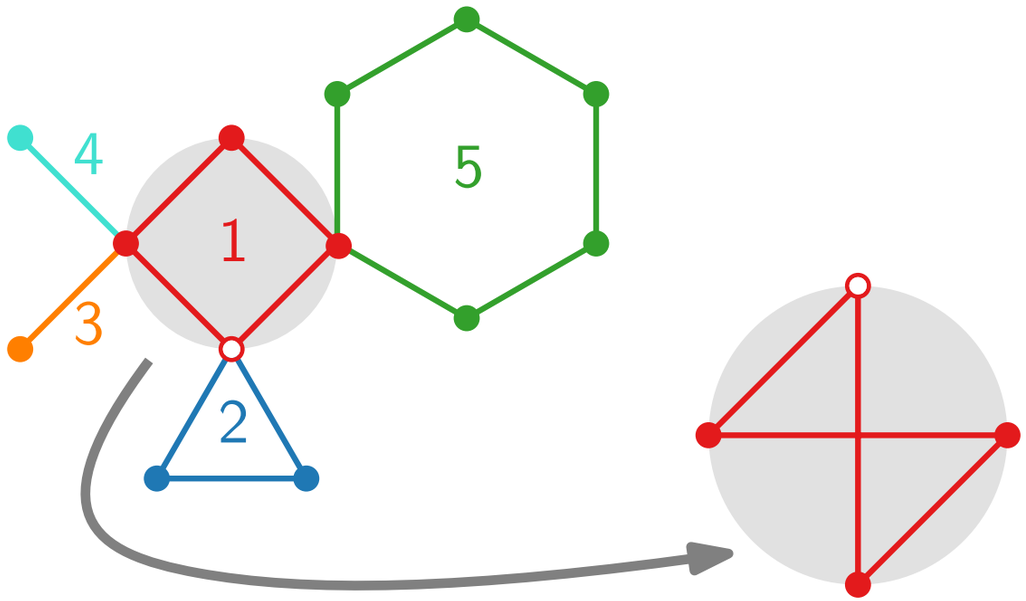
A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.



Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

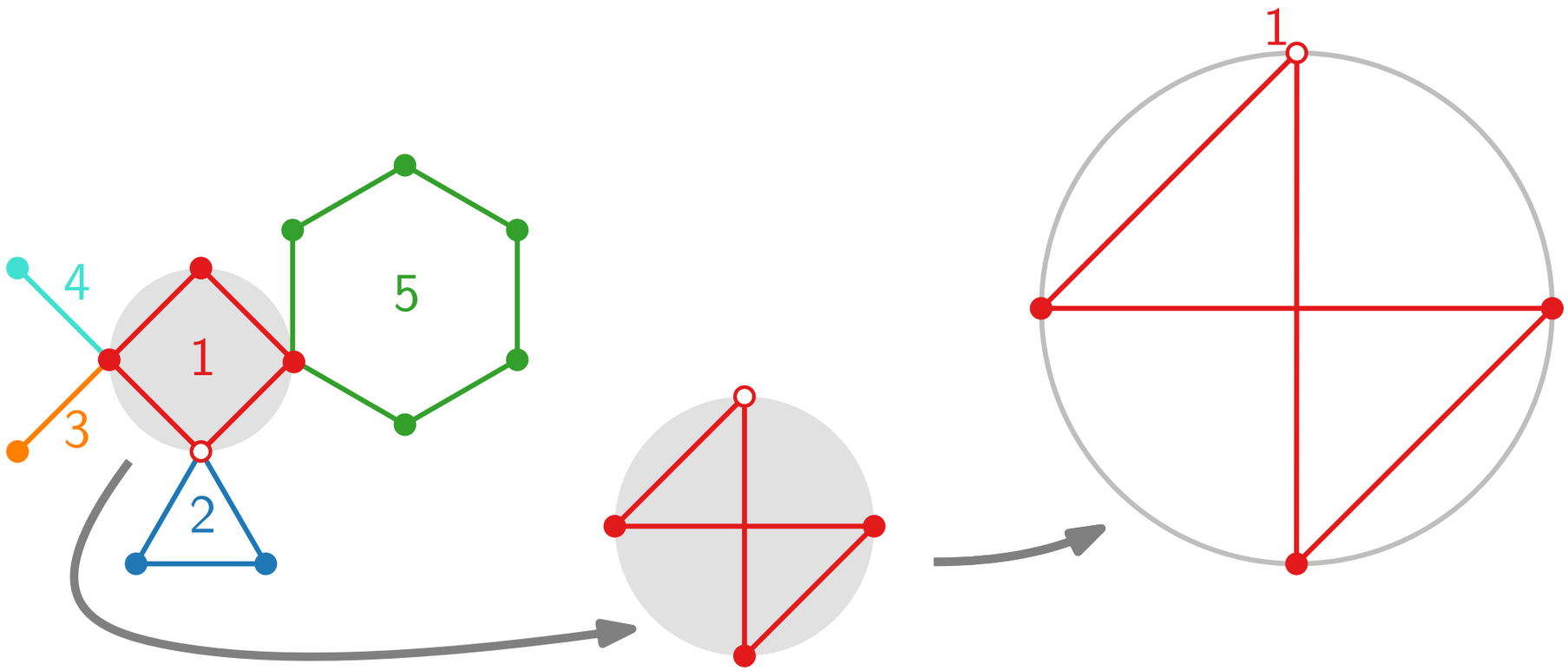
A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.



Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

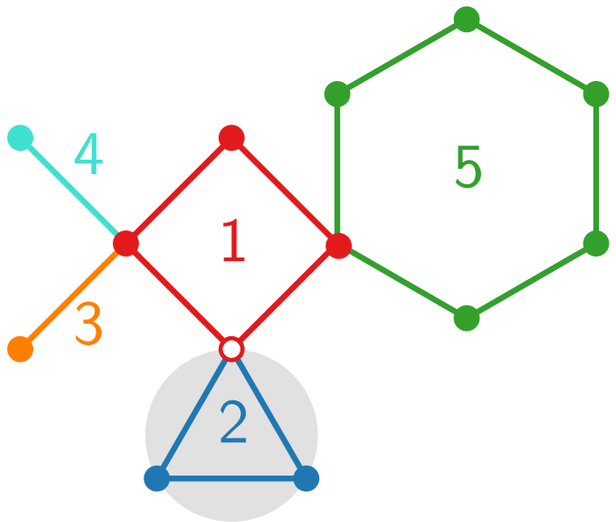
A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

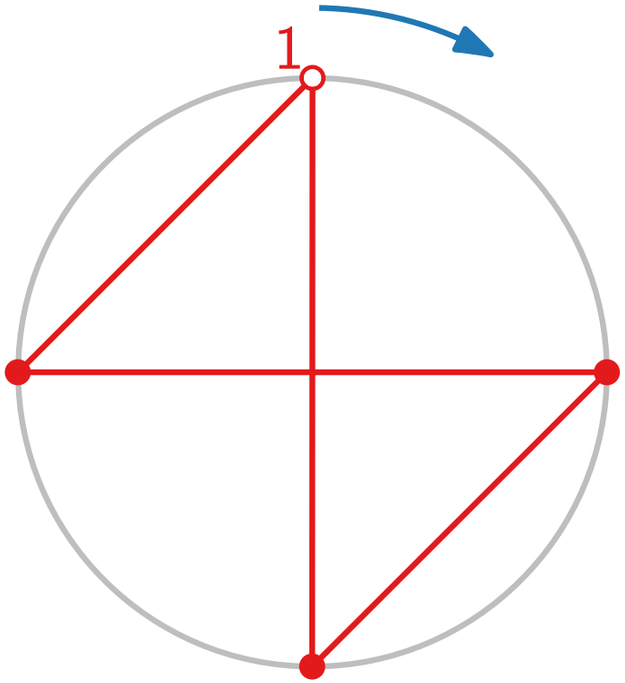


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

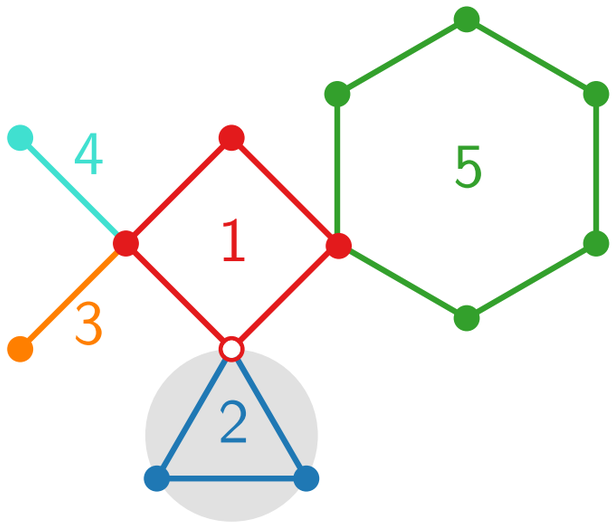


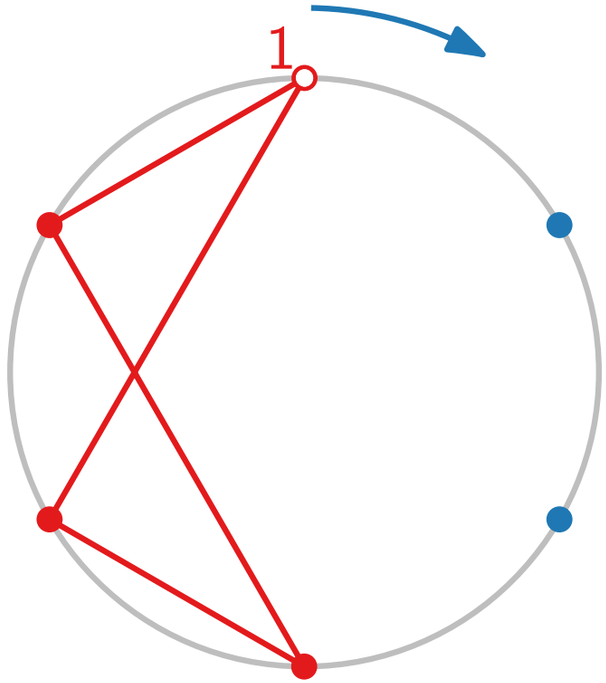


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

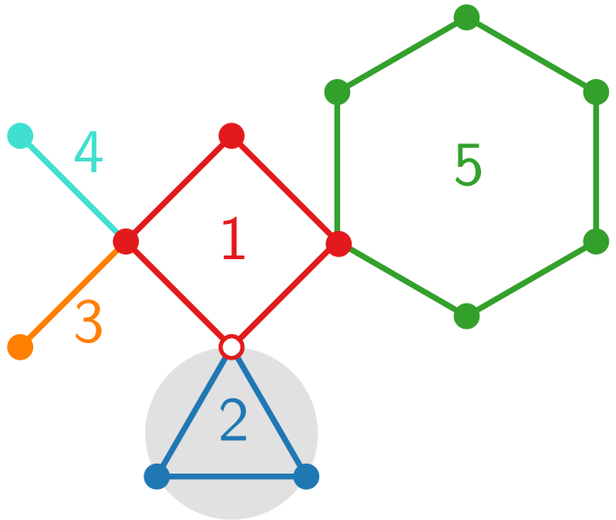


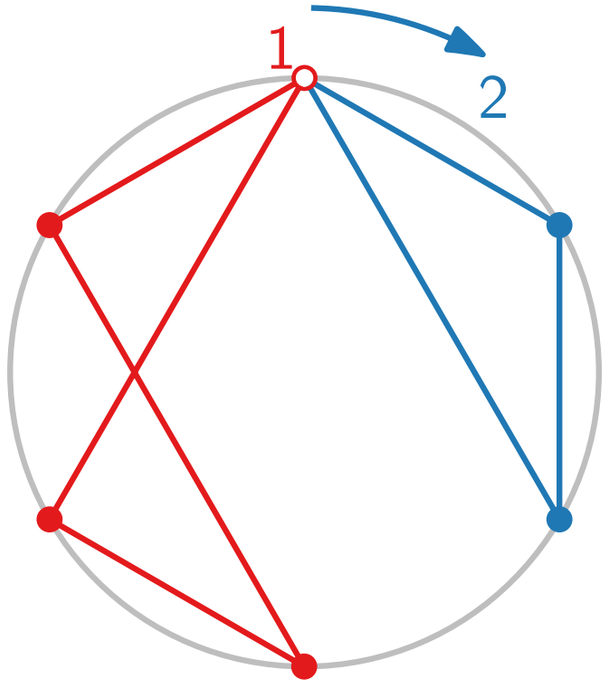


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

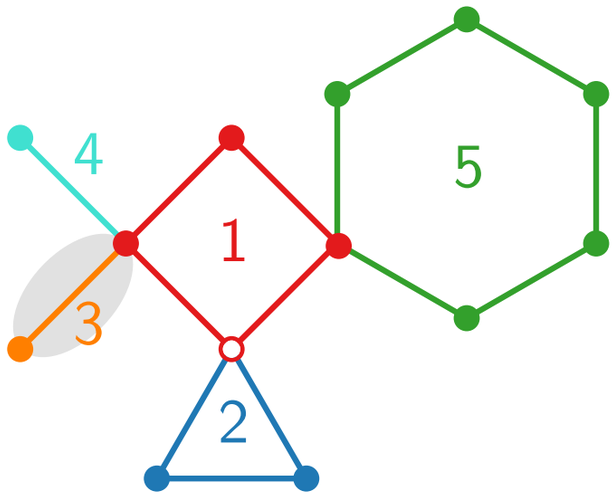


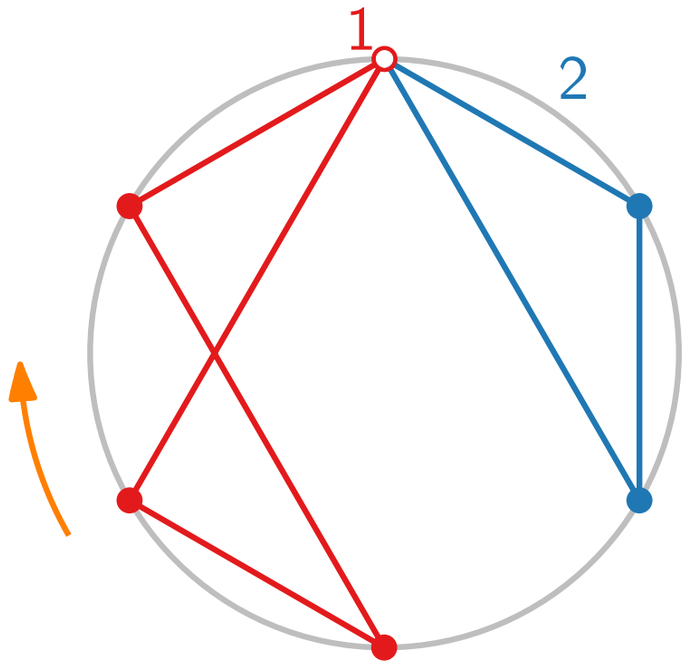


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

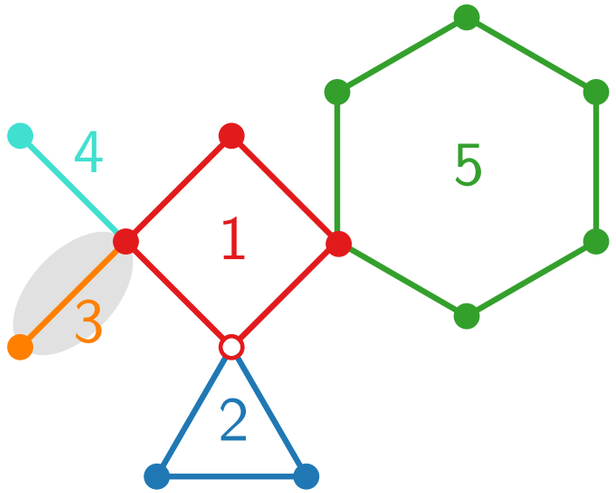


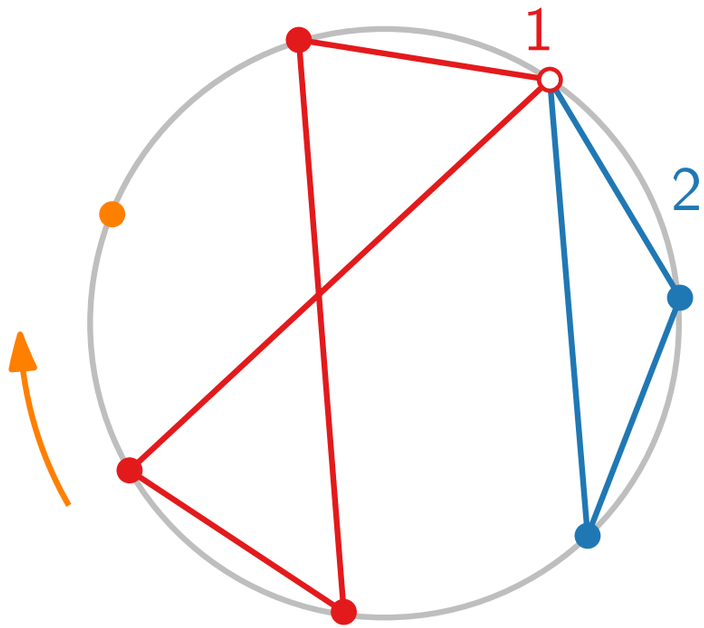


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

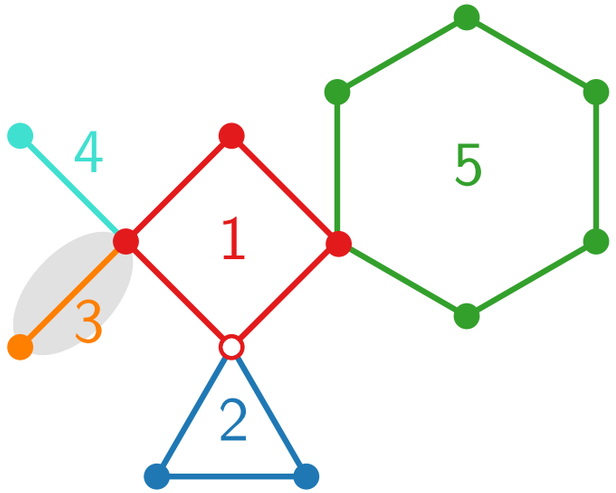


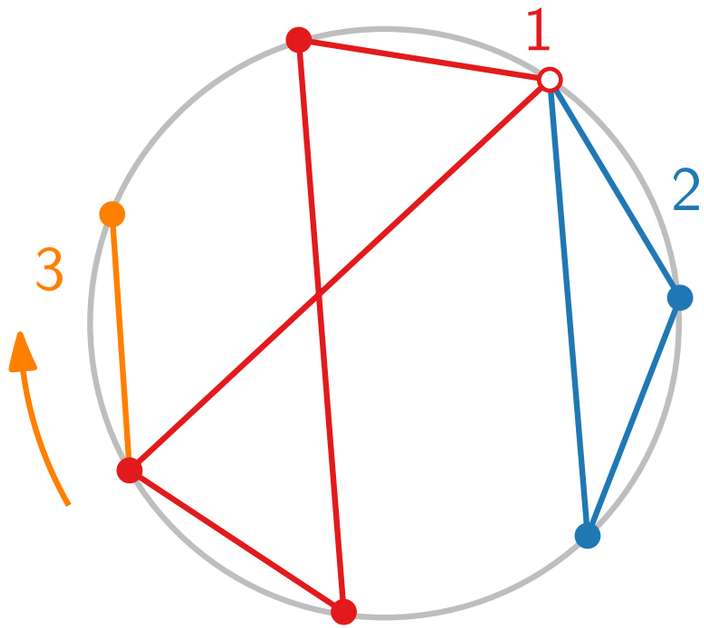


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

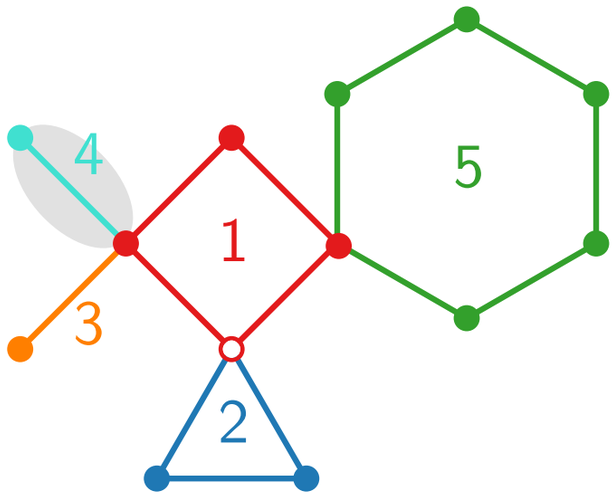


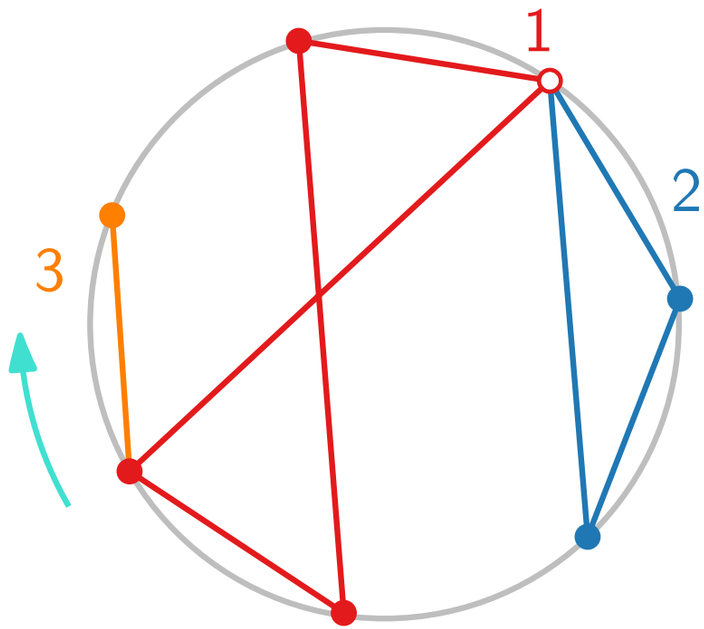


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

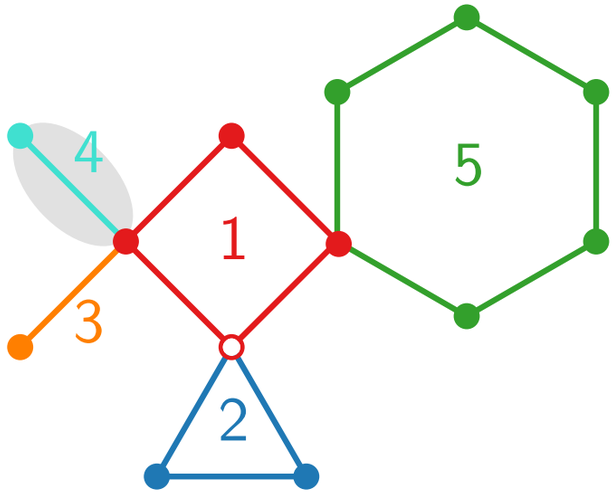


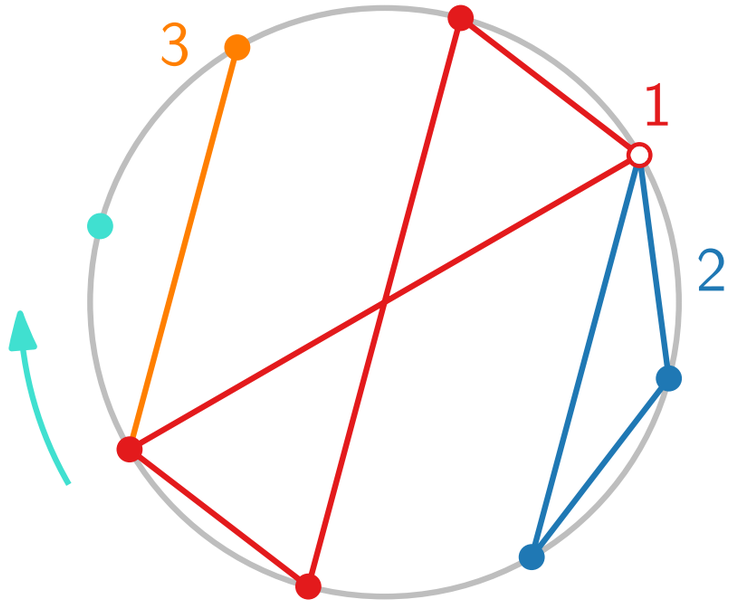


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

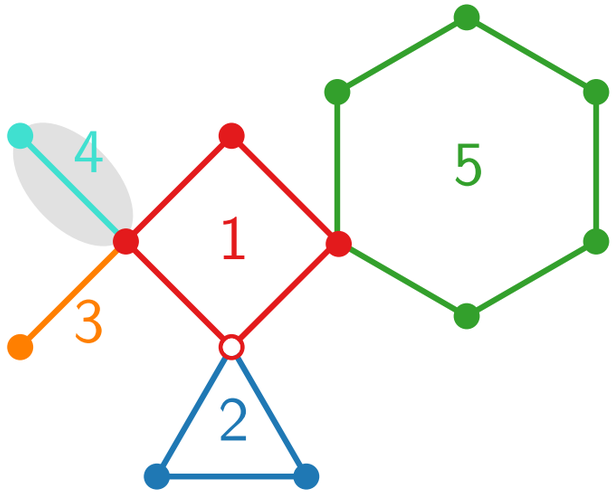


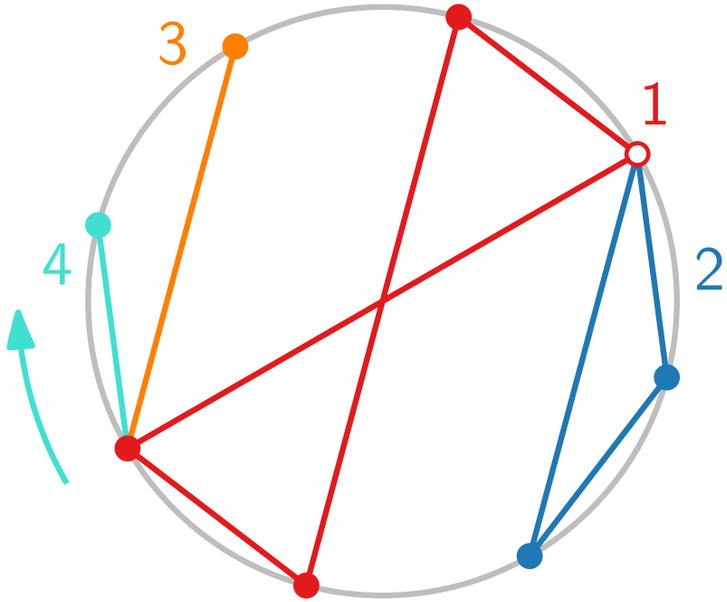


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

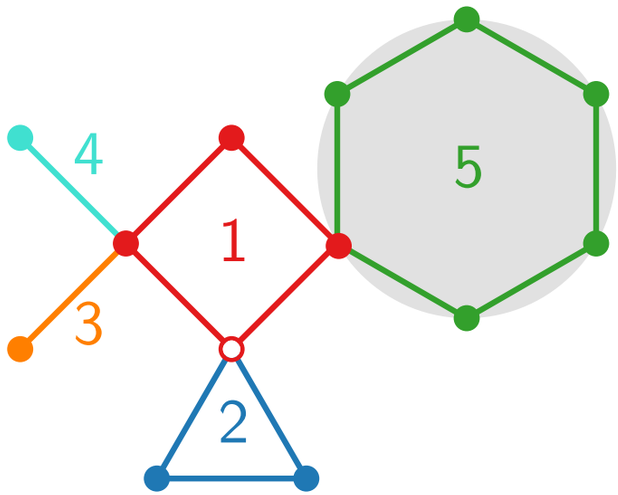


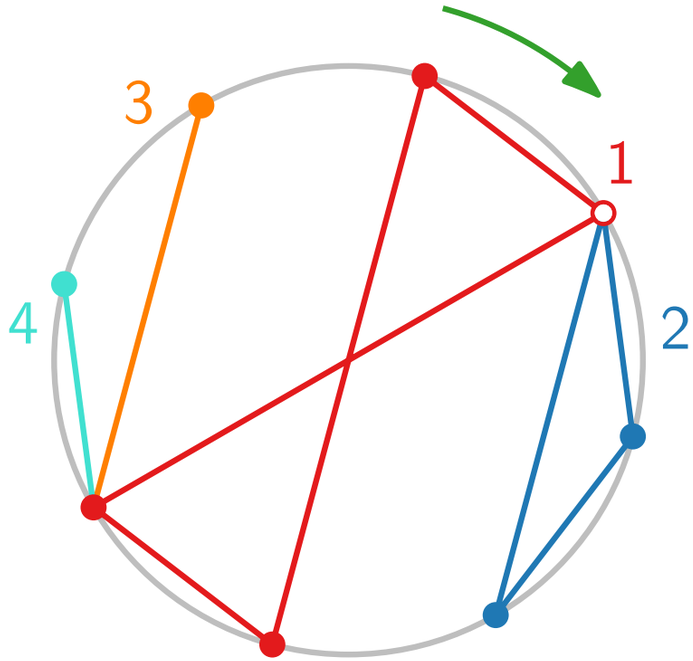


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

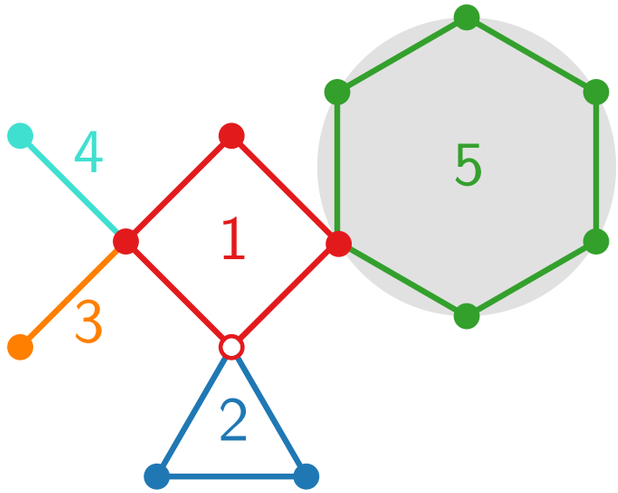


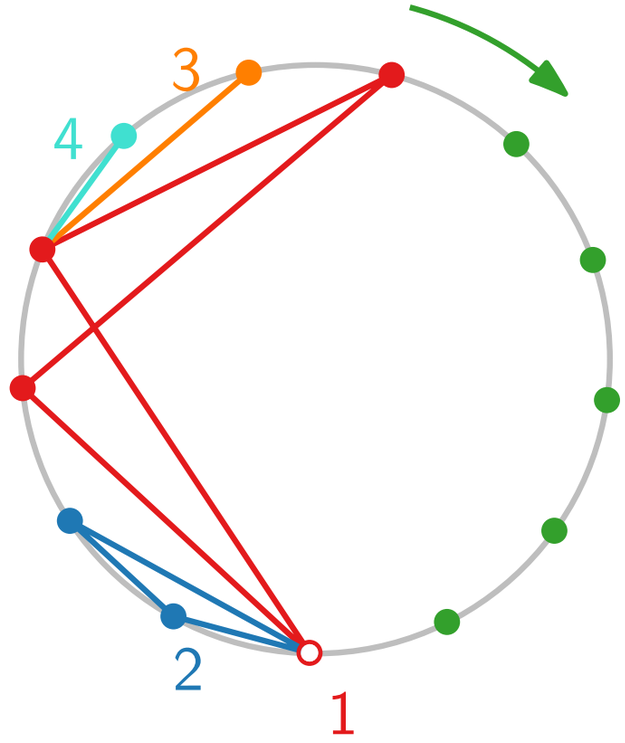


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

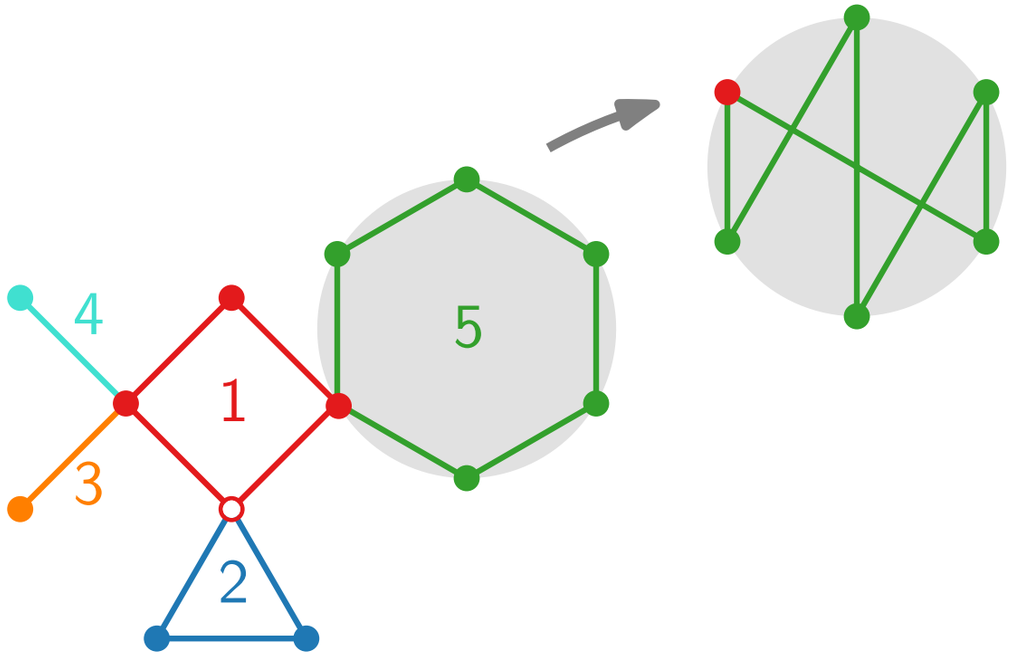


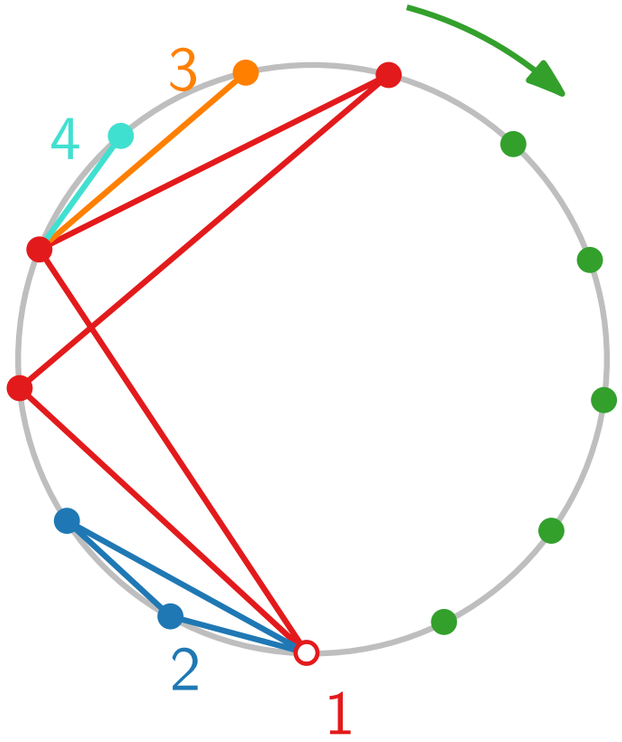


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

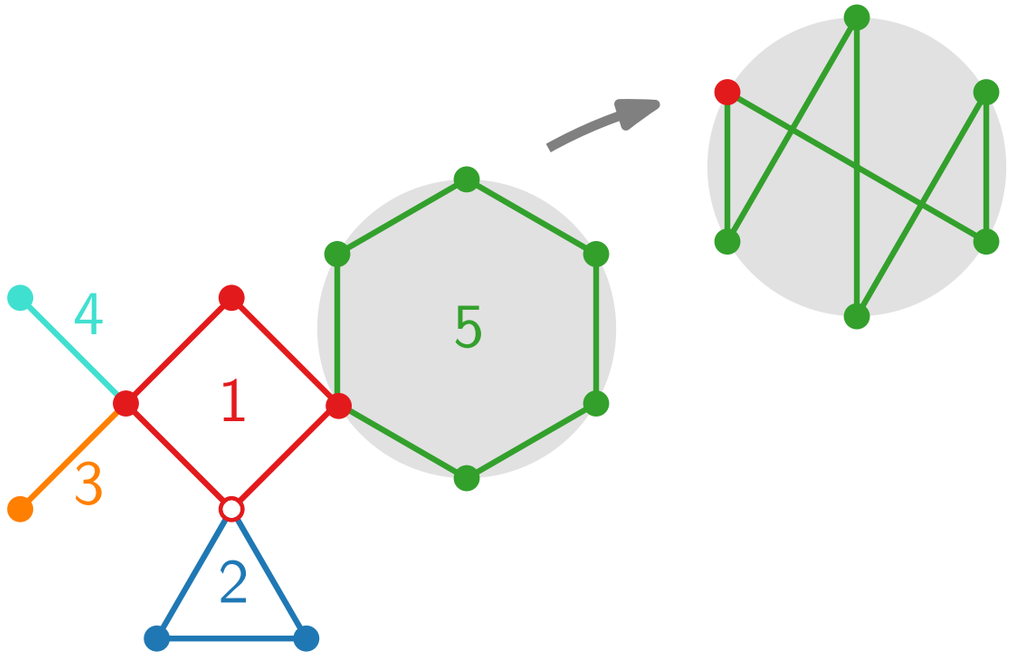


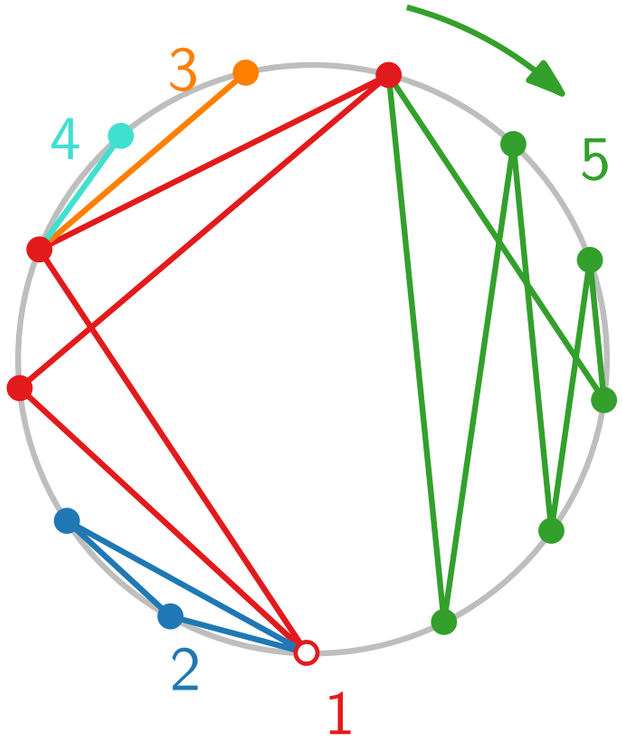


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

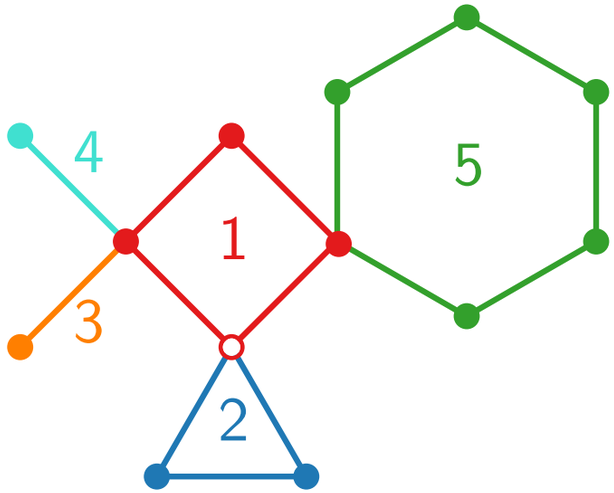


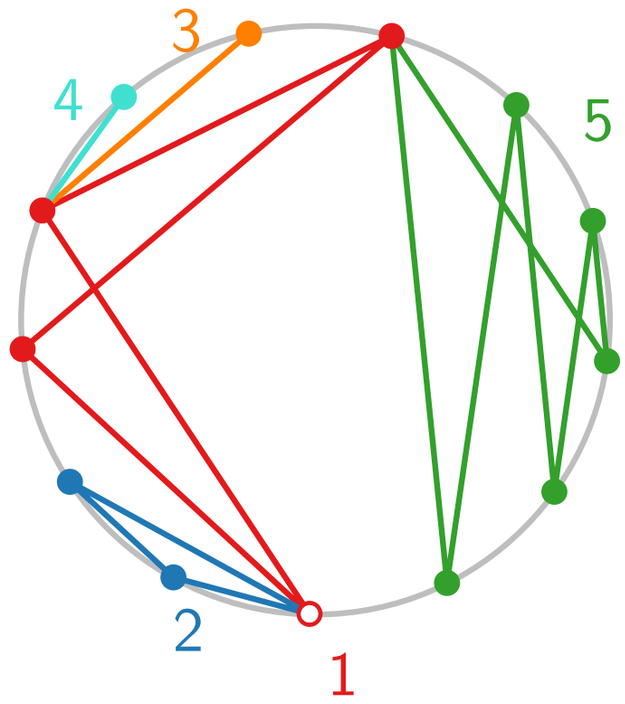


Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

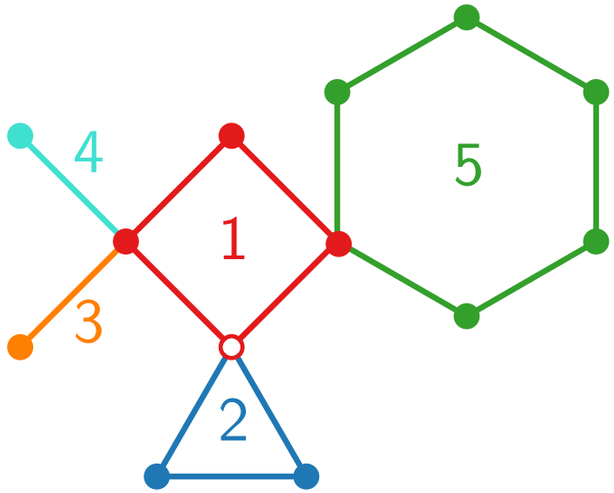




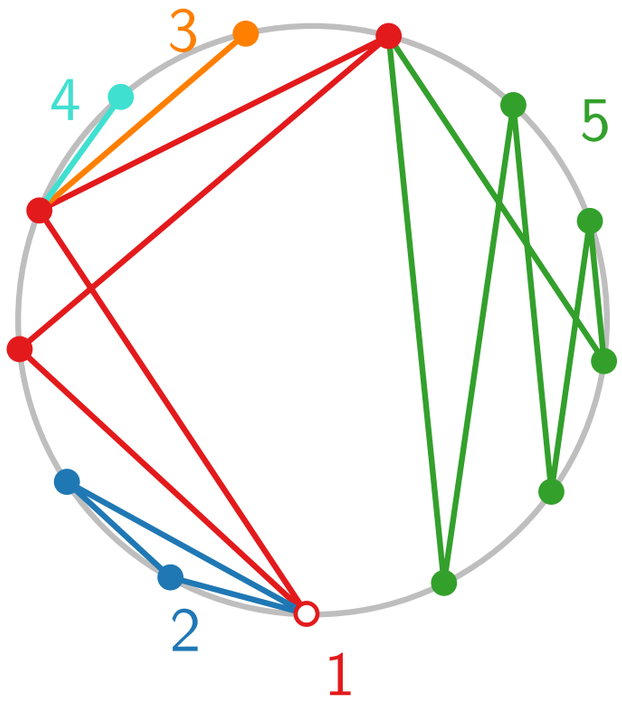
Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.



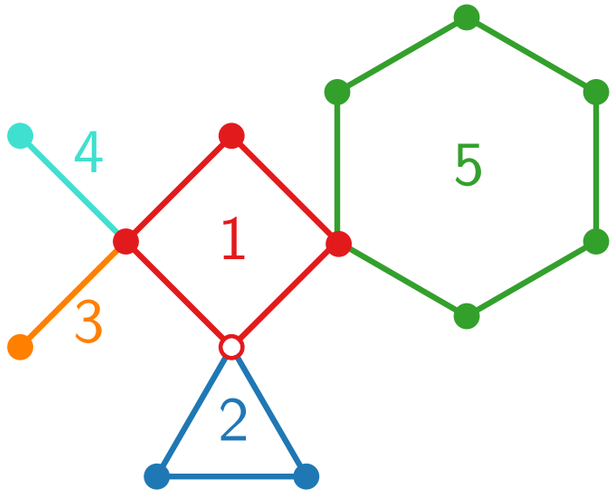
correctness?



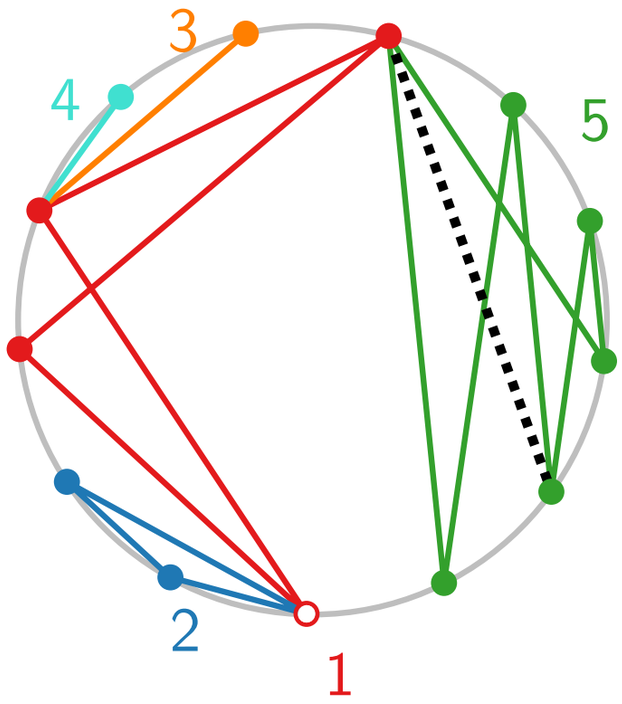
Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.



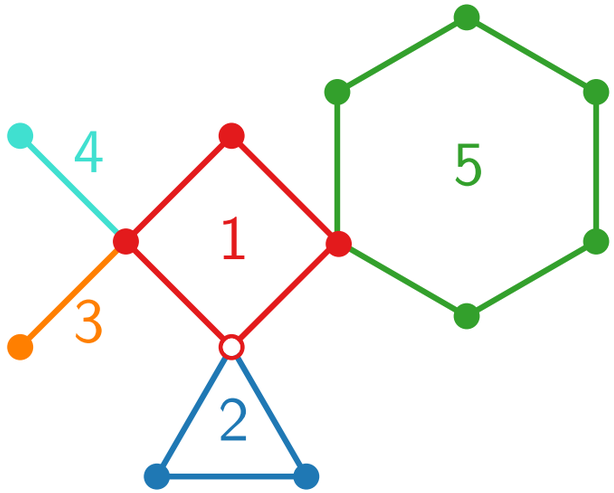
correctness?



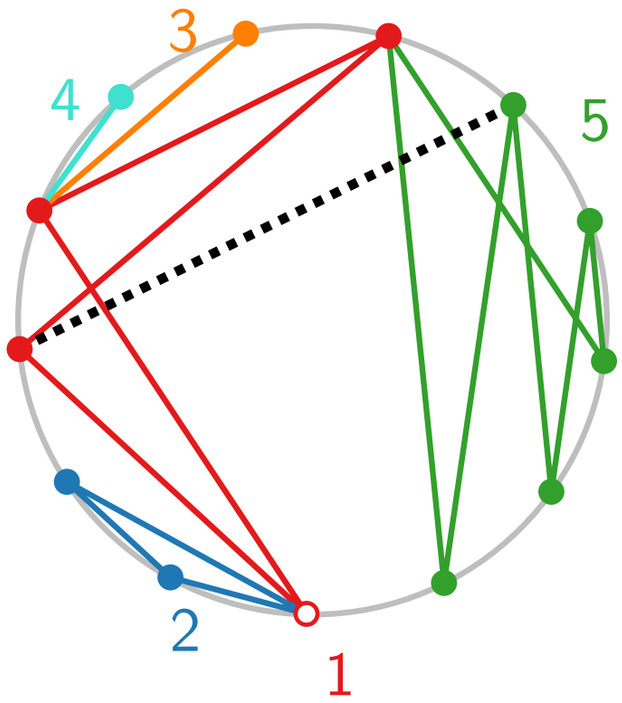
Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.



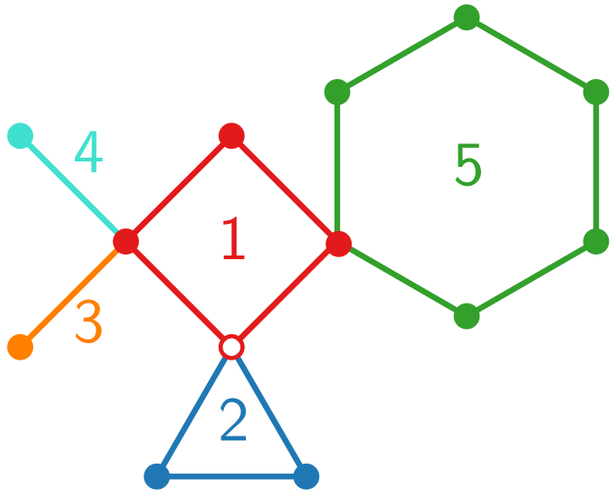
correctness?



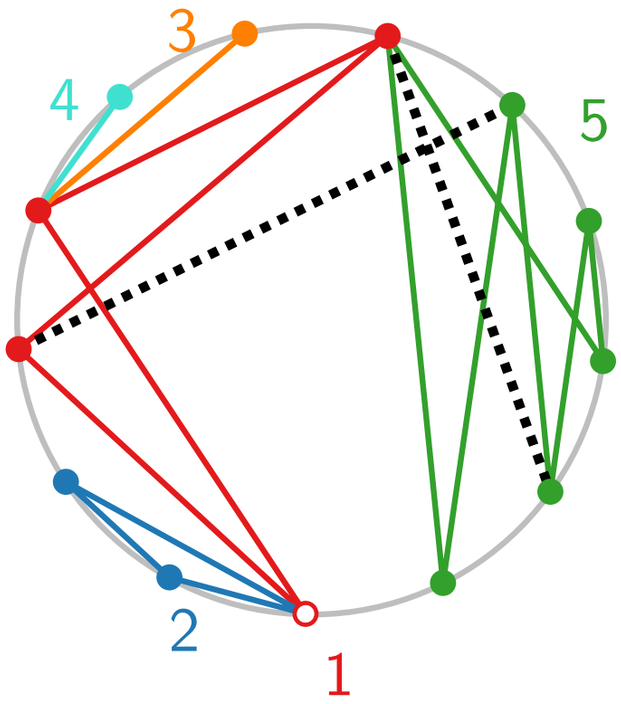
Regular Outside-Obstacle Representation

Theorem.
Every **cactus** admits a reducible regular outside-obstacle representation.

A *cactus* is a connected graph where every edge is contained in at most *one* simple cycle.

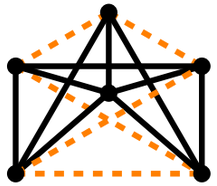


correctness ✓



Our Contribution

General

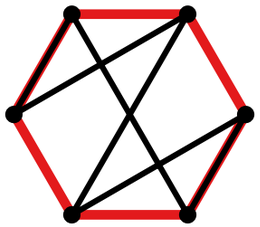


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

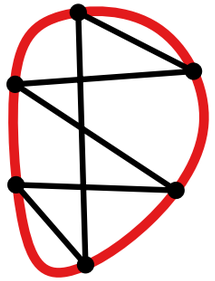
Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

Regular



- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

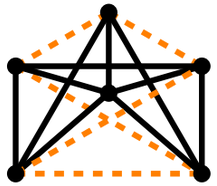
Convex



- tree complement (iff tree is caterpillar)
- $K_n - E(C_k)$ (iff $k \in \{3, 4, n\}$)
- consecutive neighbors property *sufficient*
- gap condition *necessary*

Our Contribution

General

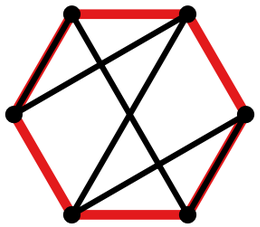


all vertices on the outer face

- outerplanar graph [Alpert et al., *DCG* 2010]
- 2-tree (subgraphs ✓)

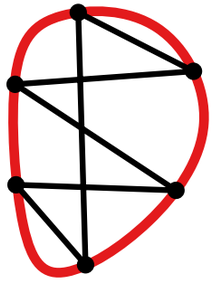
Def. An outside-obstacle representation of a graph is *reducible* if all its edges are incident to the outer face.

Regular



- cactus (subgraphs ✓)
- grid (subgraphs ✓)
- outerpath (subgraphs ✓)

Convex



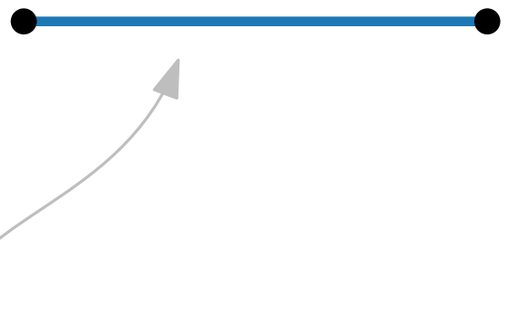
- tree complement (iff tree is caterpillar)
- $K_n - E(C_k)$ (iff $k \in \{3, 4, n\}$)
- consecutive neighbors property *sufficient*
- gap condition *necessary*

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.



base edge

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

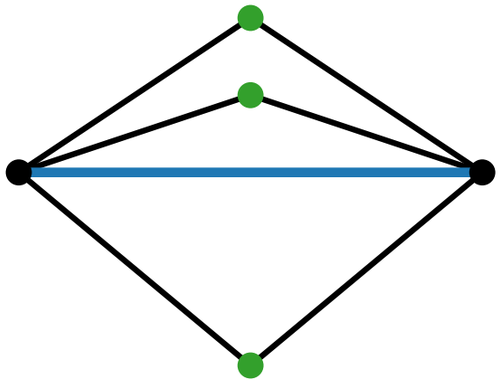
inactive vertices ●

base edge

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ●

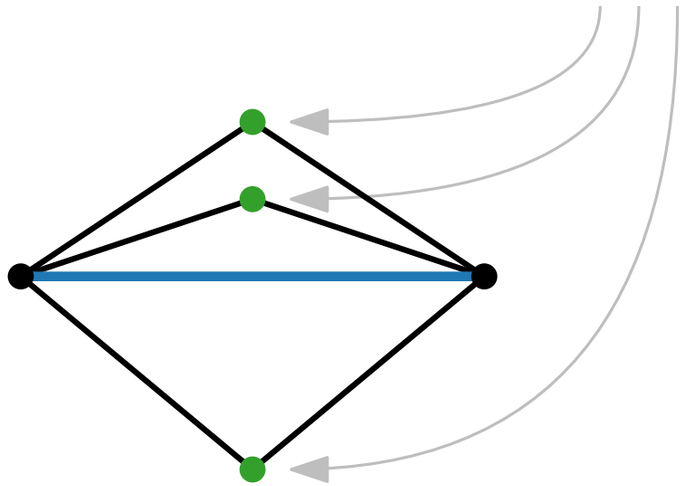


base edge

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*

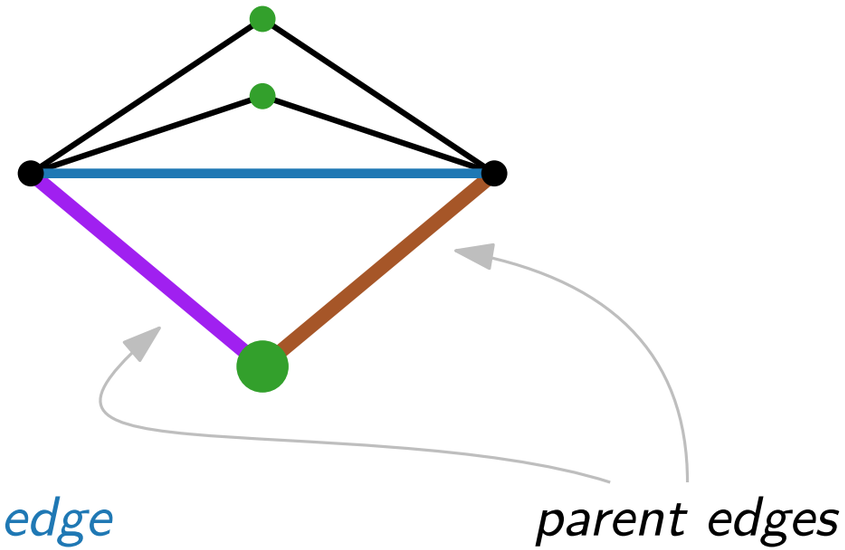


base edge

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*



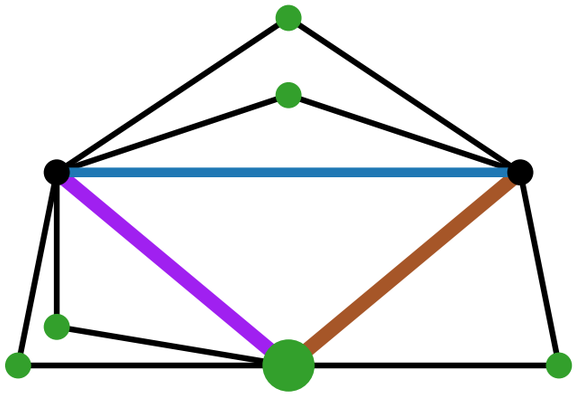
base edge

parent edges

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*

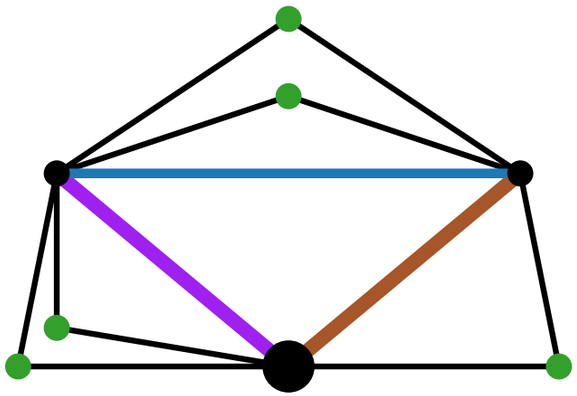


base edge *parent edges*

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*

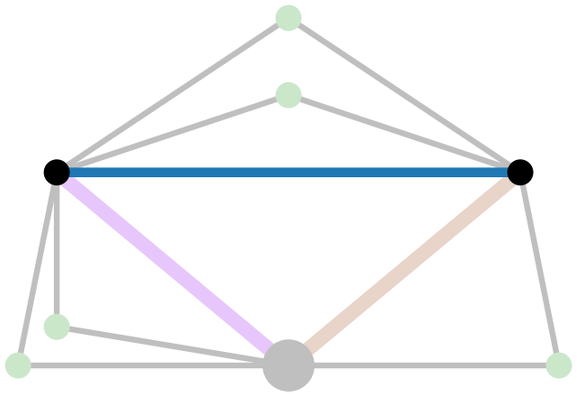


base edge *parent edges*

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*



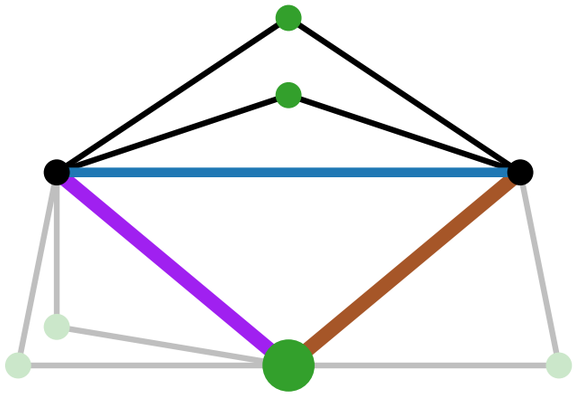
base edge

parent edges

(General) Outside-Obstacle Representation

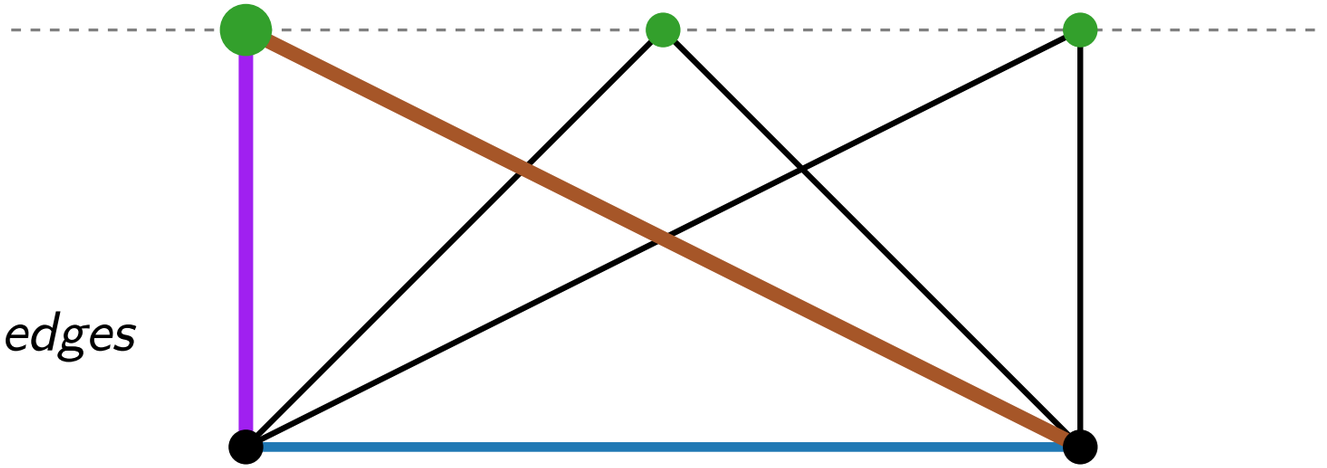
Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*



base edge

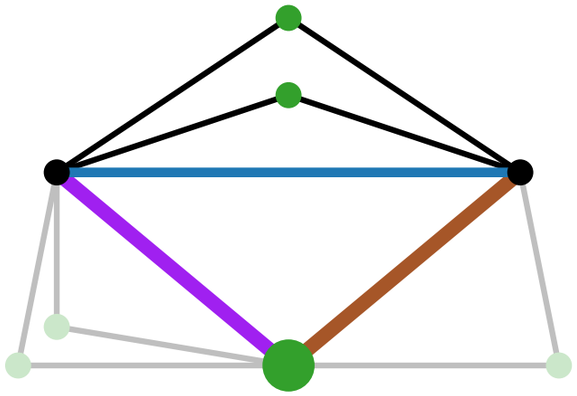
parent edges



(General) Outside-Obstacle Representation

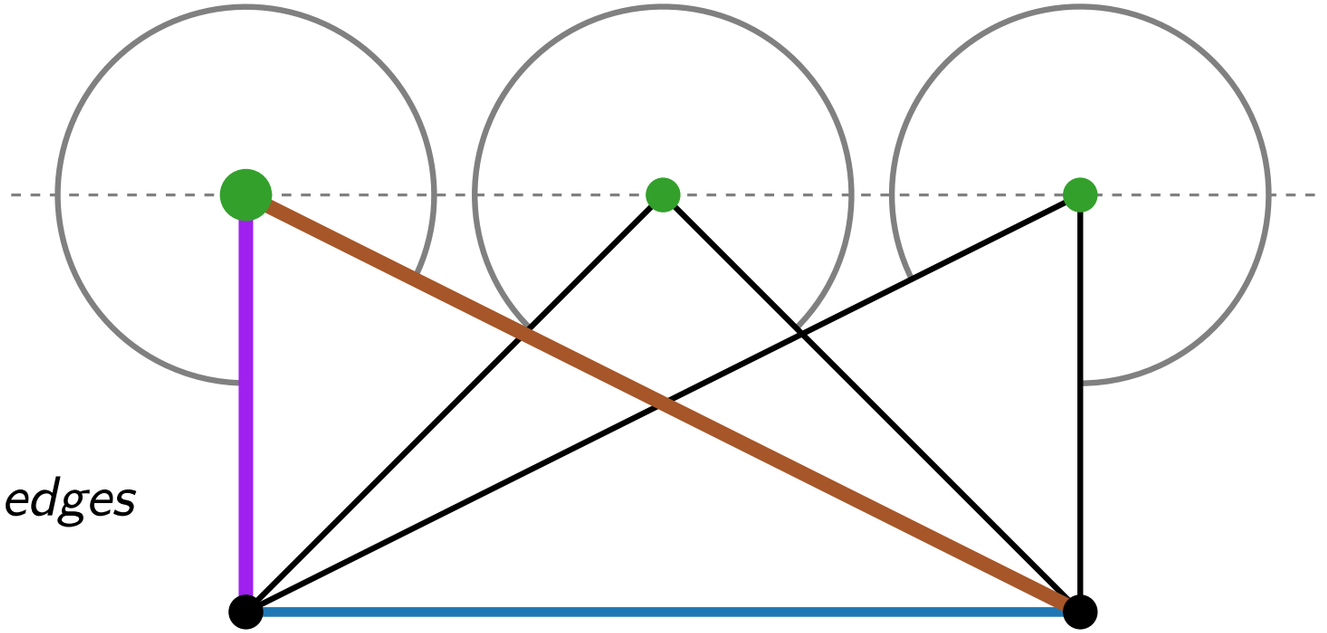
Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*



base edge

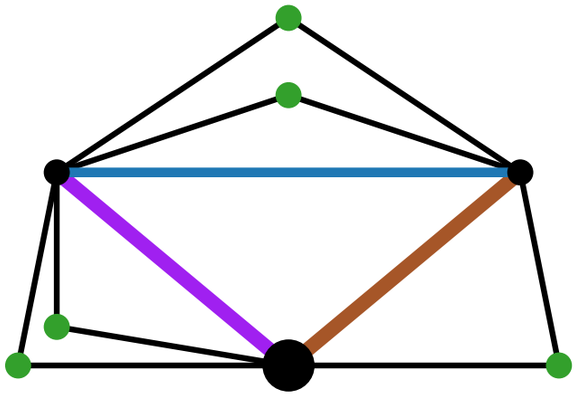
parent edges



(General) Outside-Obstacle Representation

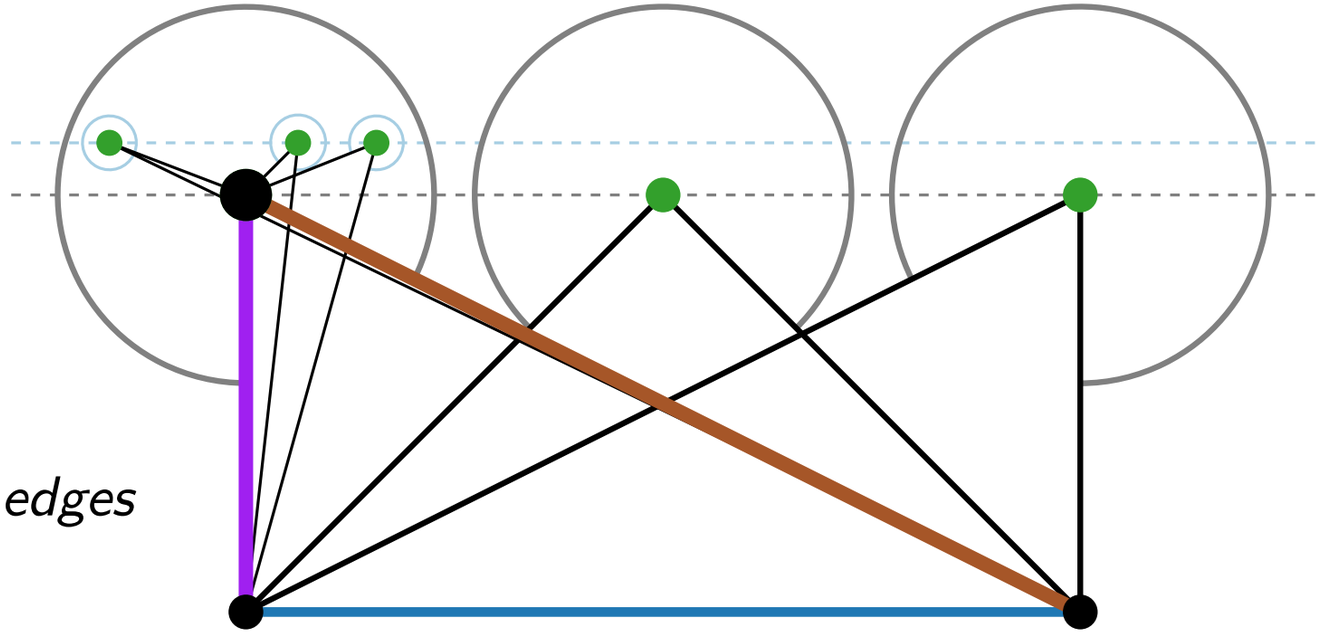
Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

inactive vertices ● ● *active vertices*



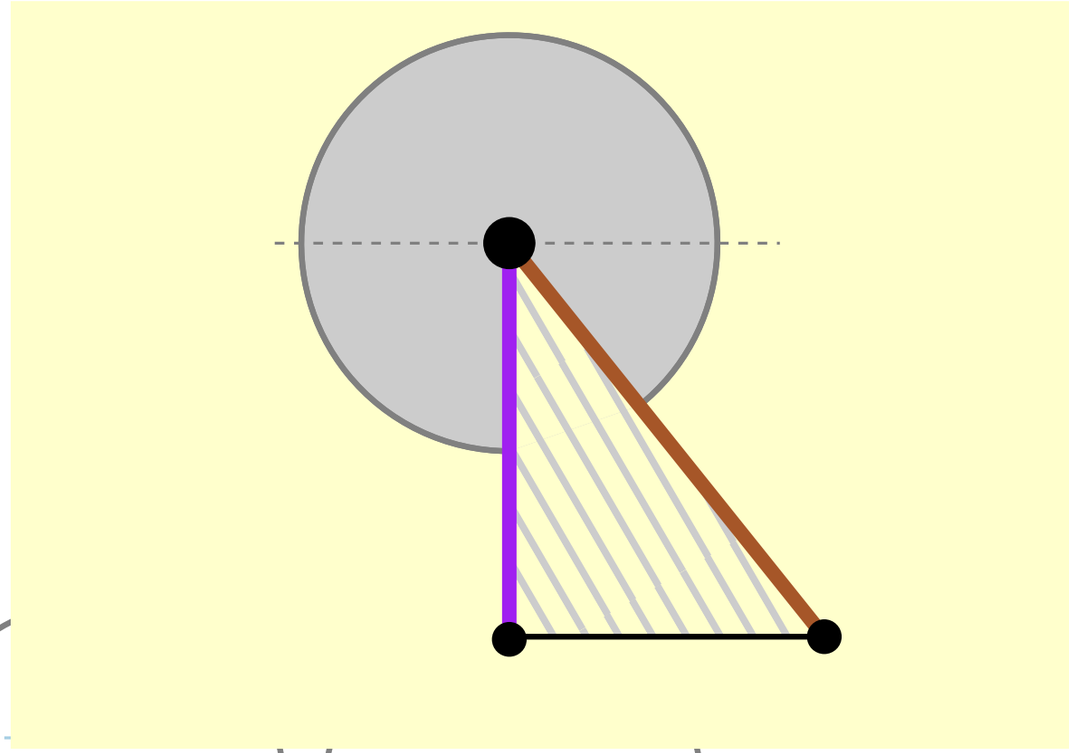
base edge

parent edges

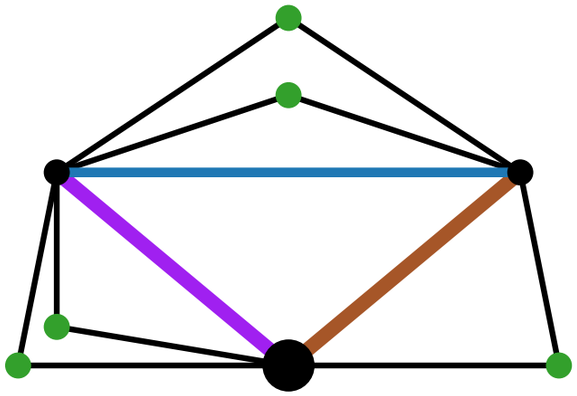


(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

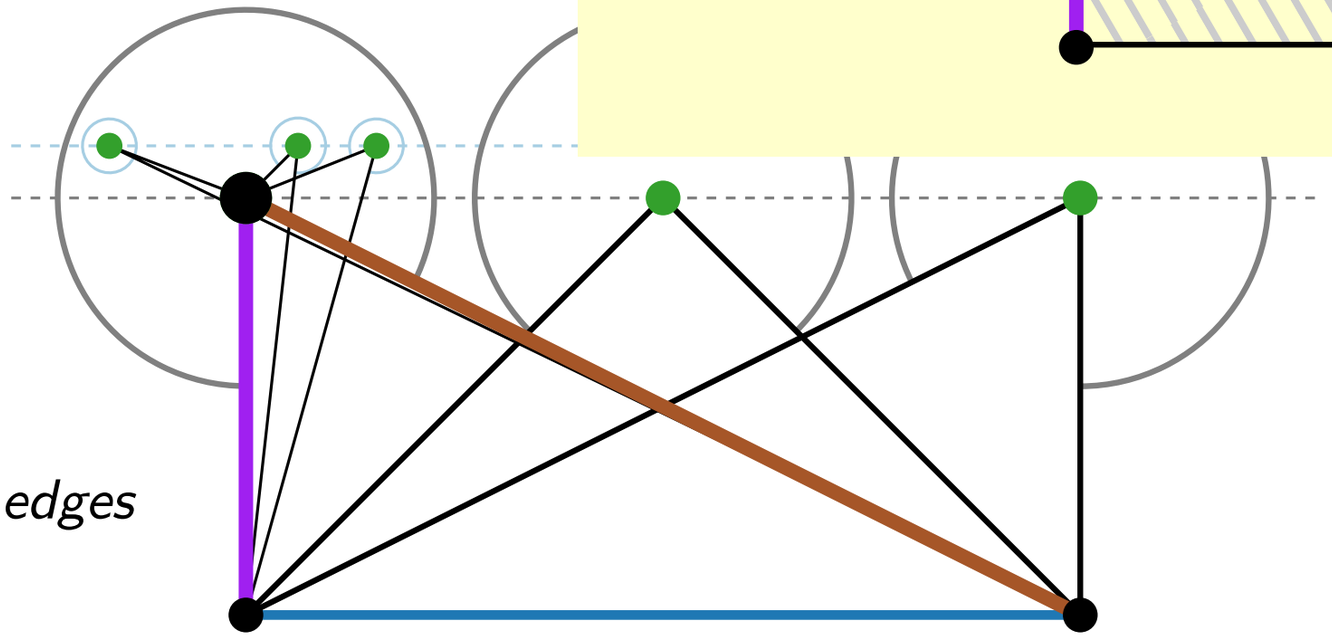


inactive vertices ● ● *active vertices*



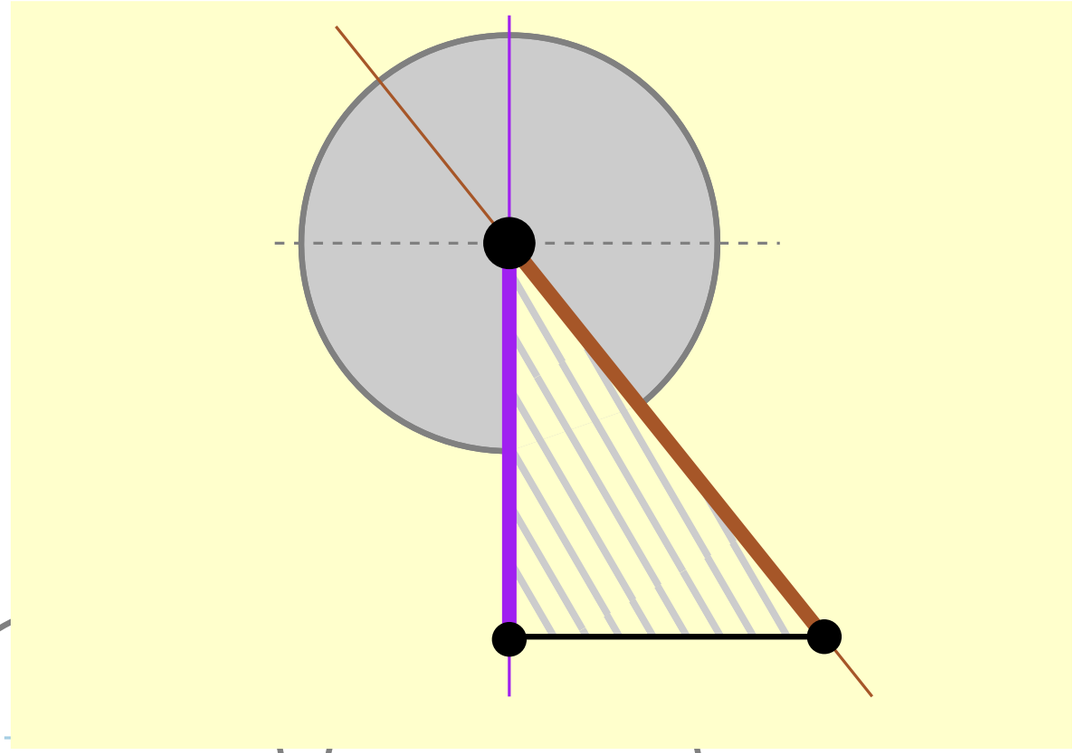
base edge

parent edges

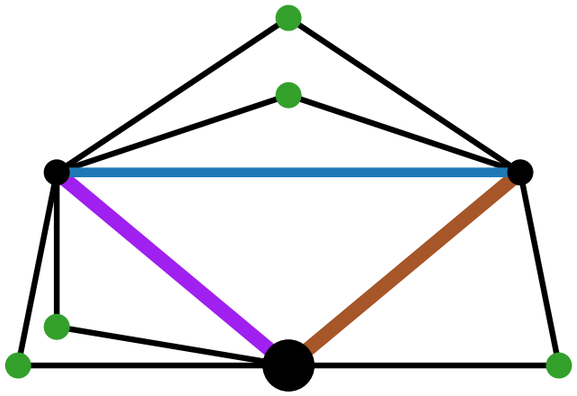


(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

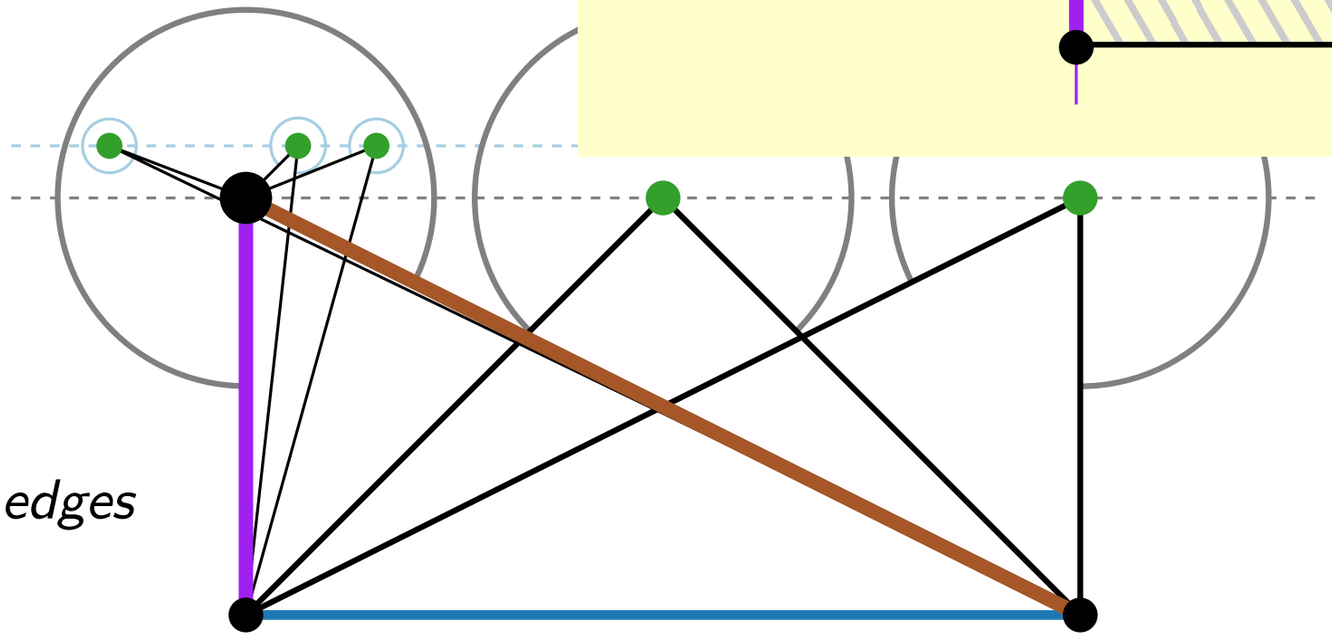


inactive vertices ● ● *active vertices*



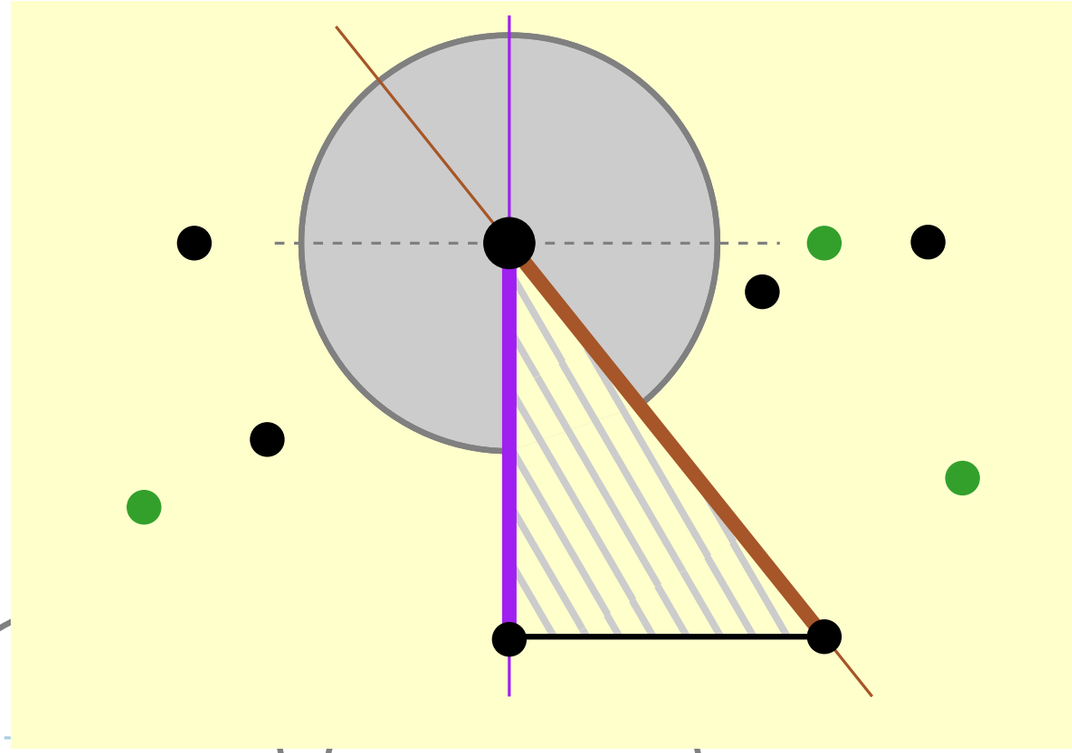
base edge

parent edges

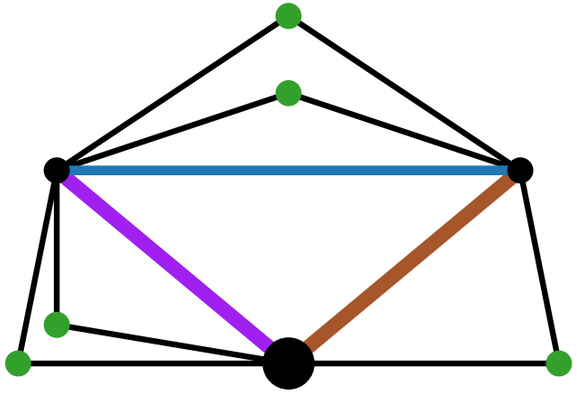


(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

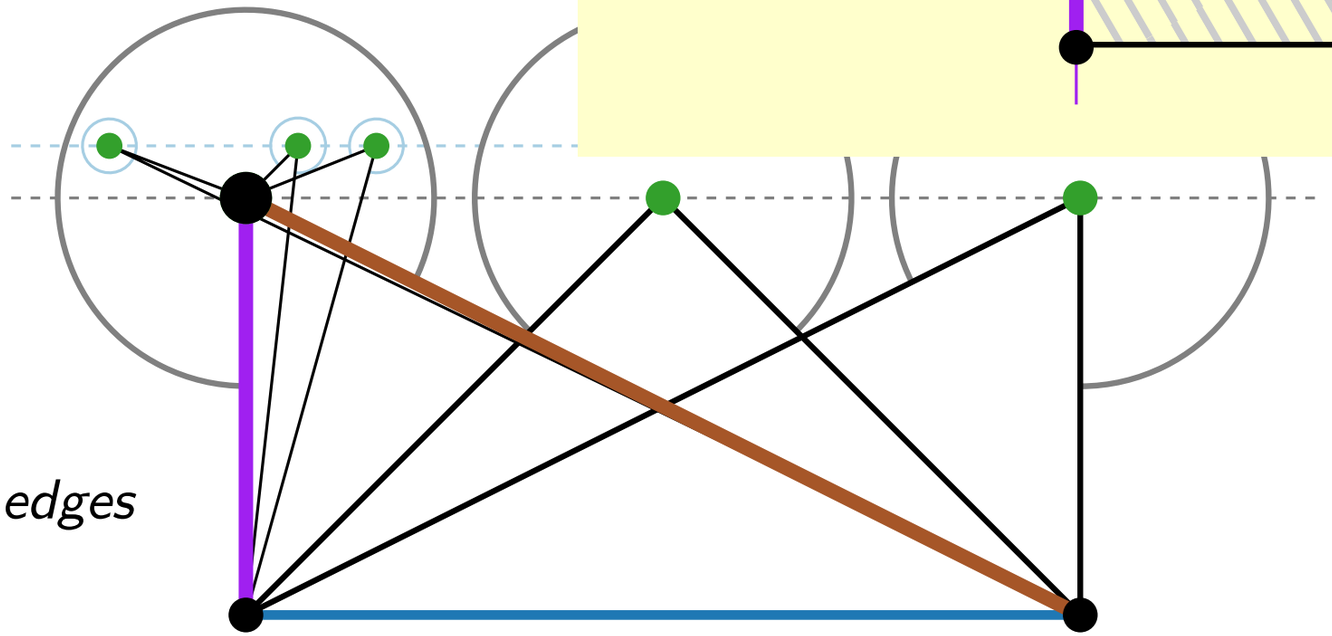


inactive vertices ● ● *active vertices*



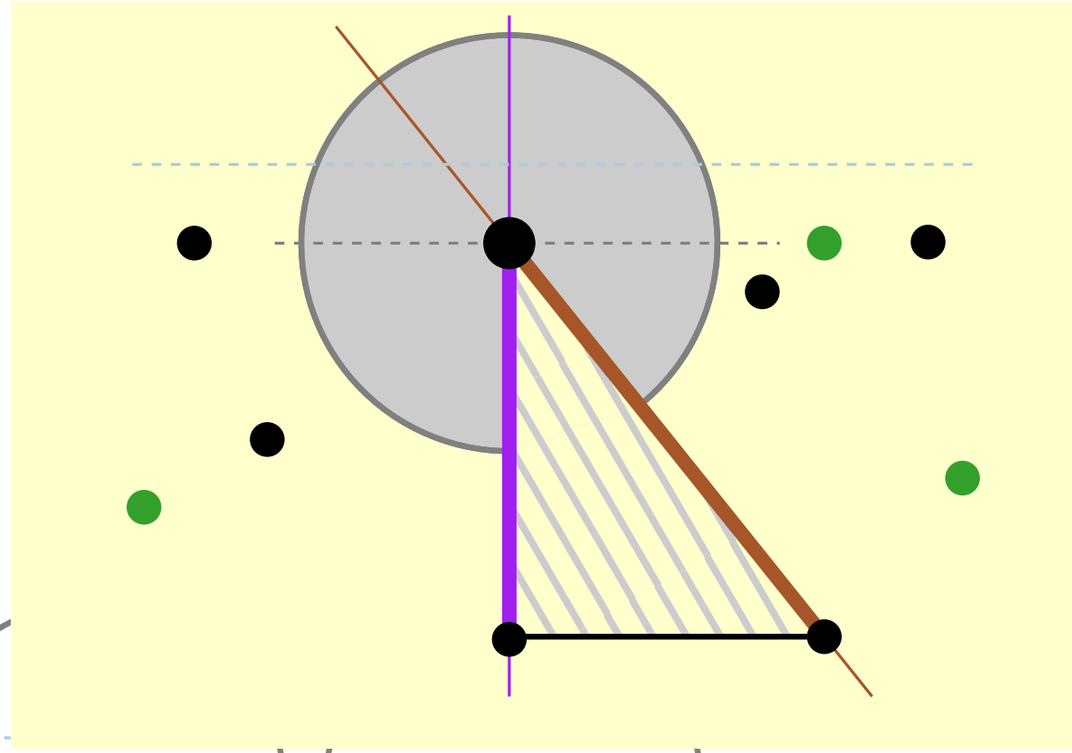
base edge

parent edges

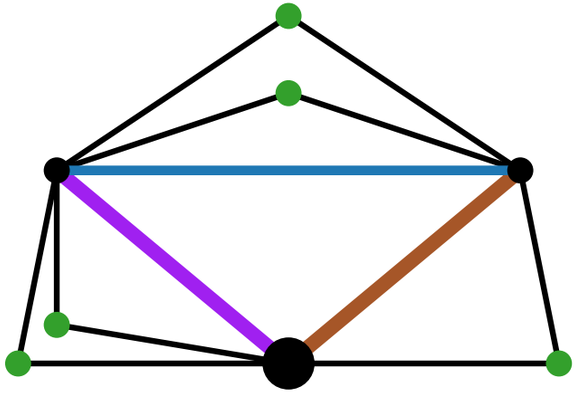


(General) Outside-Obstacle Representation

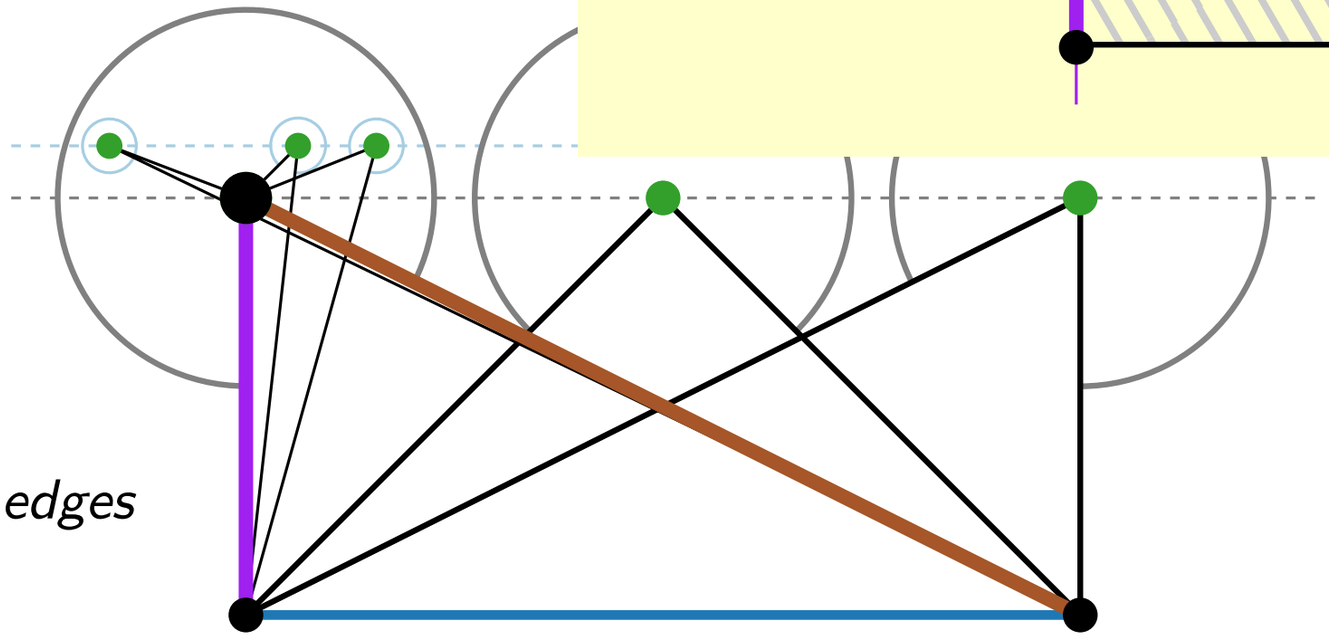
Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.



inactive vertices ● ● *active vertices*



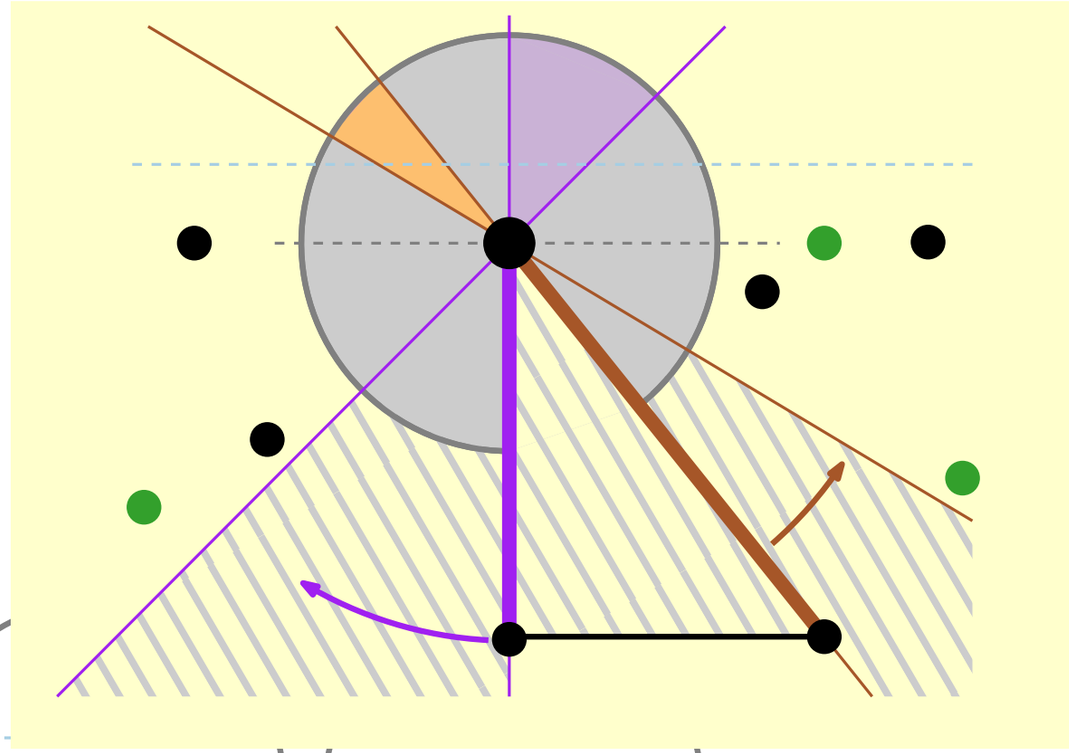
base edge



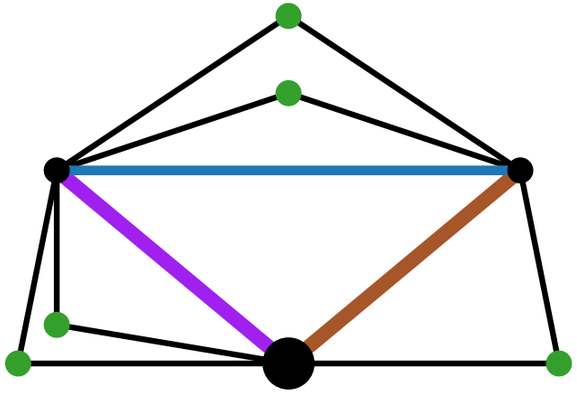
parent edges

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

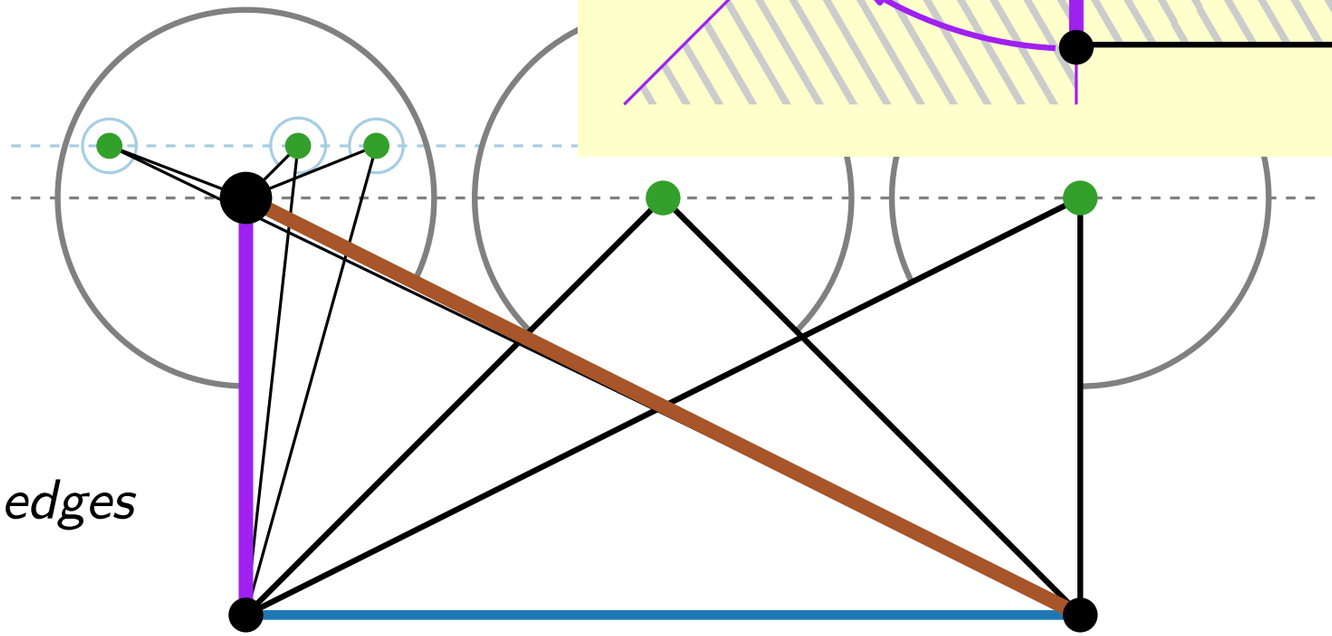


inactive vertices ● ● *active vertices*



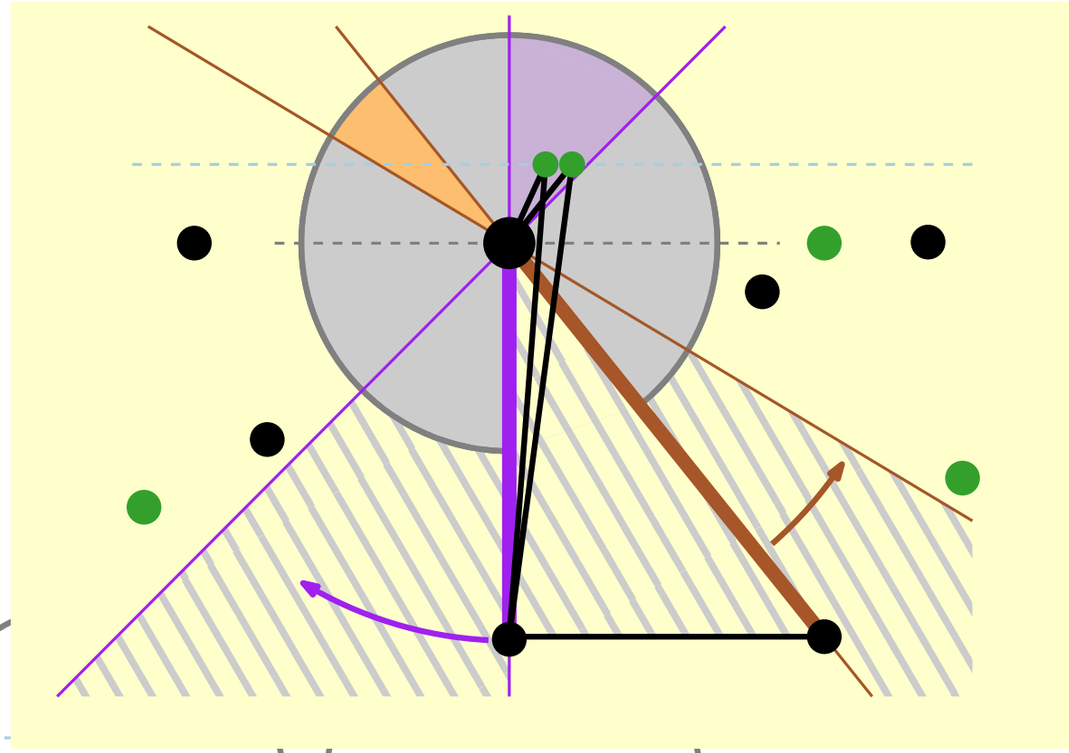
base edge

parent edges

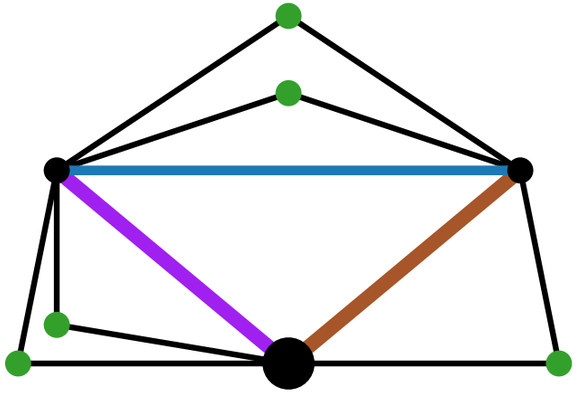


(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

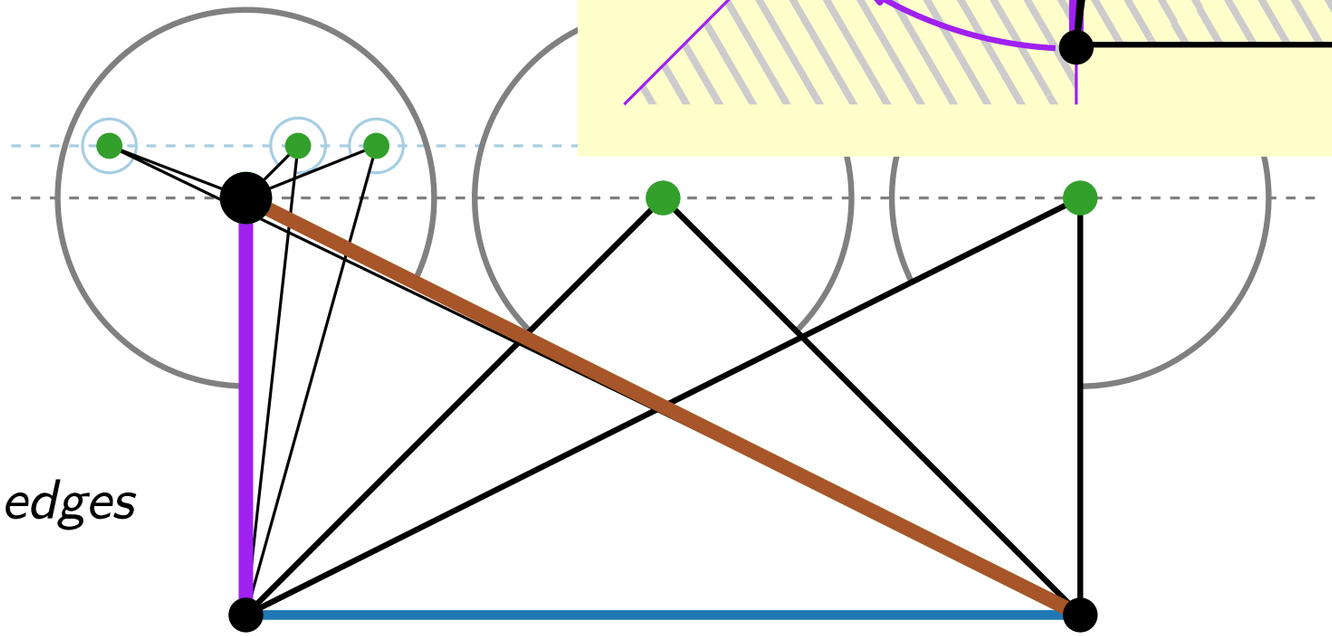


inactive vertices ● ● *active vertices*



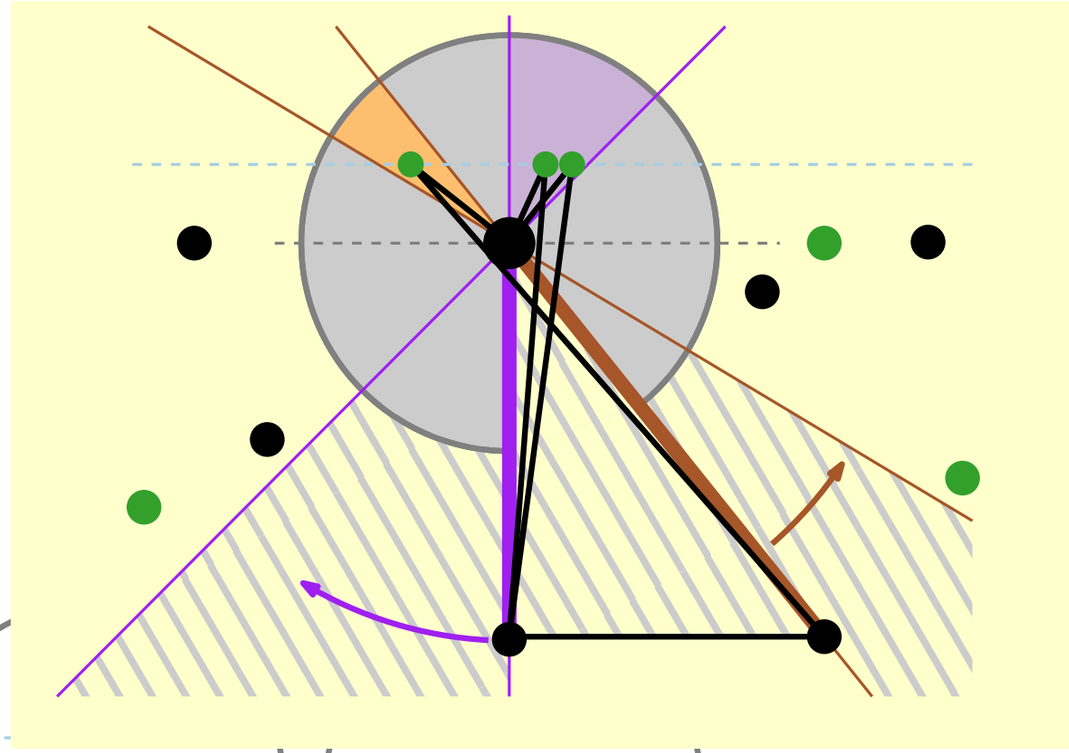
base edge

parent edges

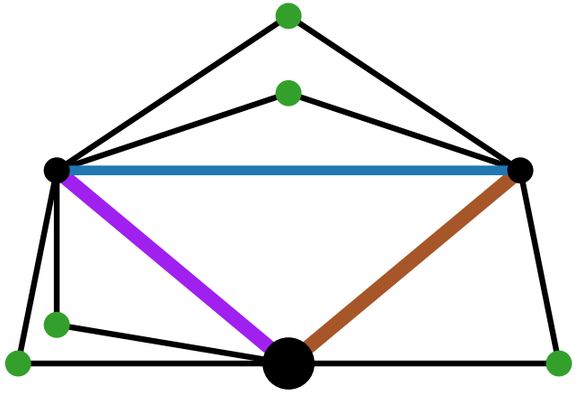


(General) Outside-Obstacle Representation

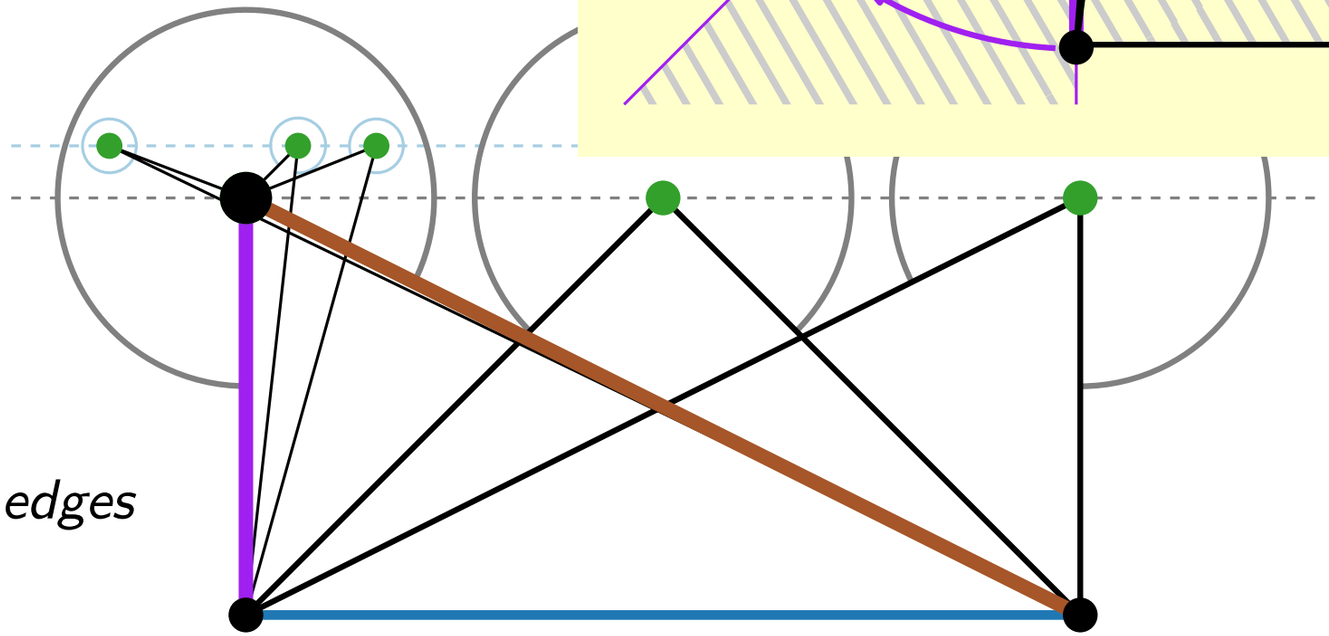
Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.



inactive vertices ● ● *active vertices*



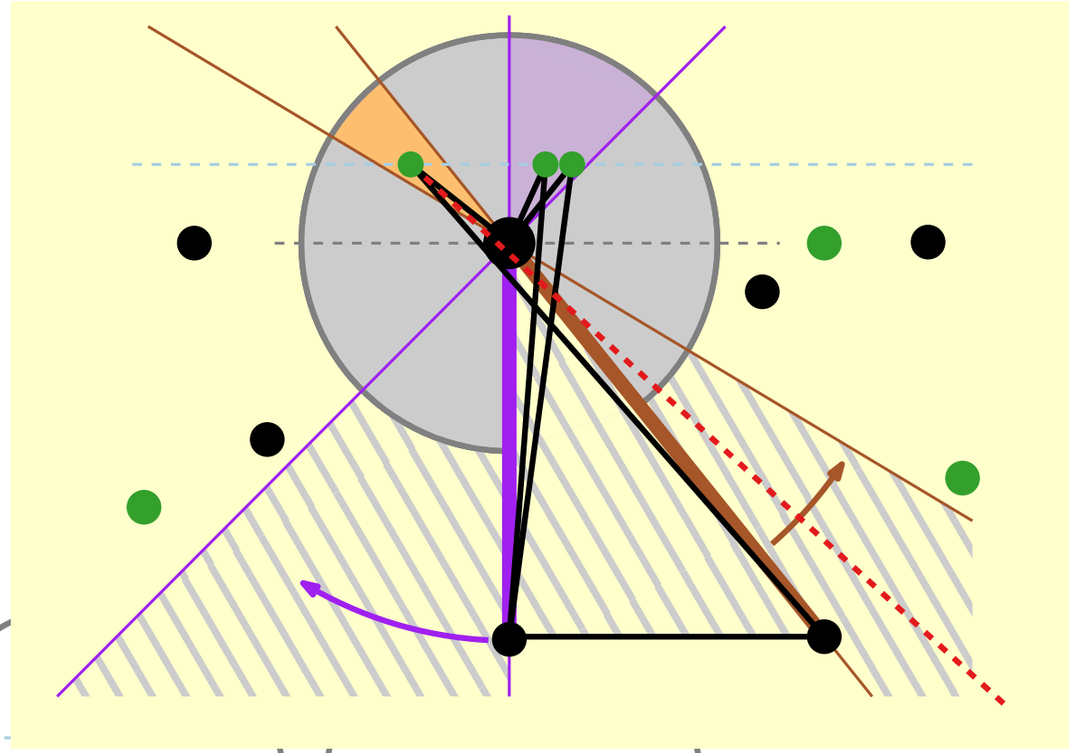
base edge



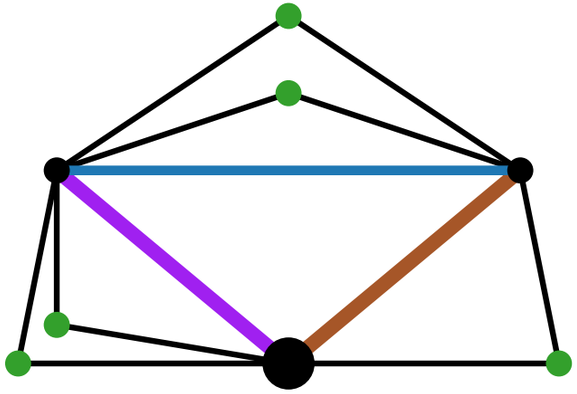
parent edges

(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

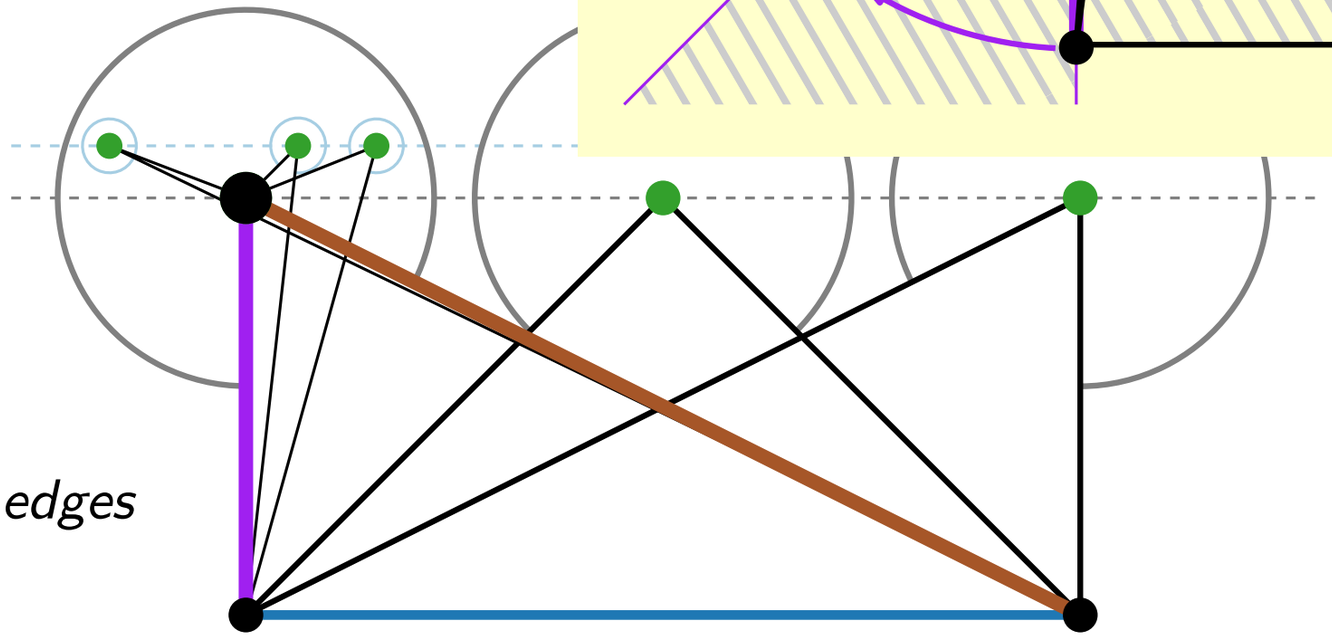


inactive vertices ● ● *active vertices*



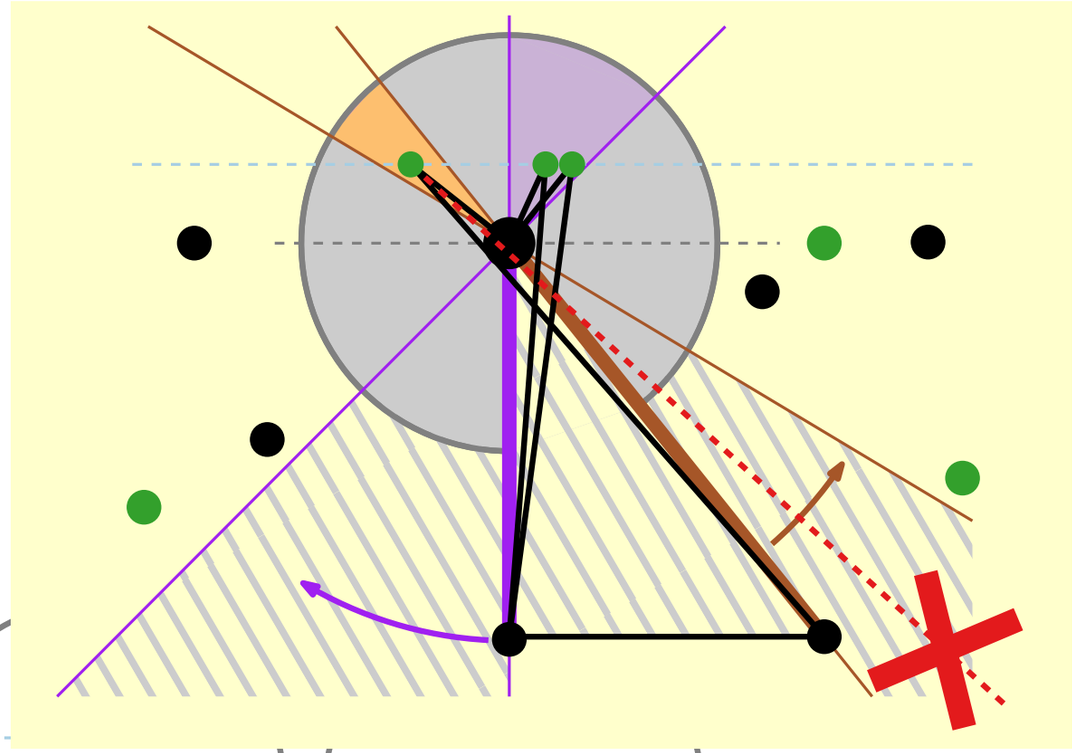
base edge

parent edges

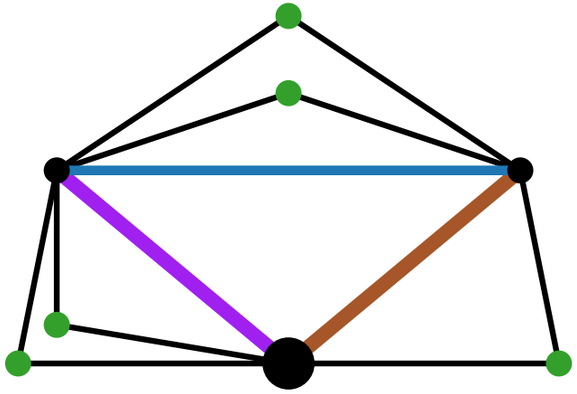


(General) Outside-Obstacle Representation

Theorem.
Every **2-tree** admits a reducible outside-obstacle representation with all vertices on the outer face.

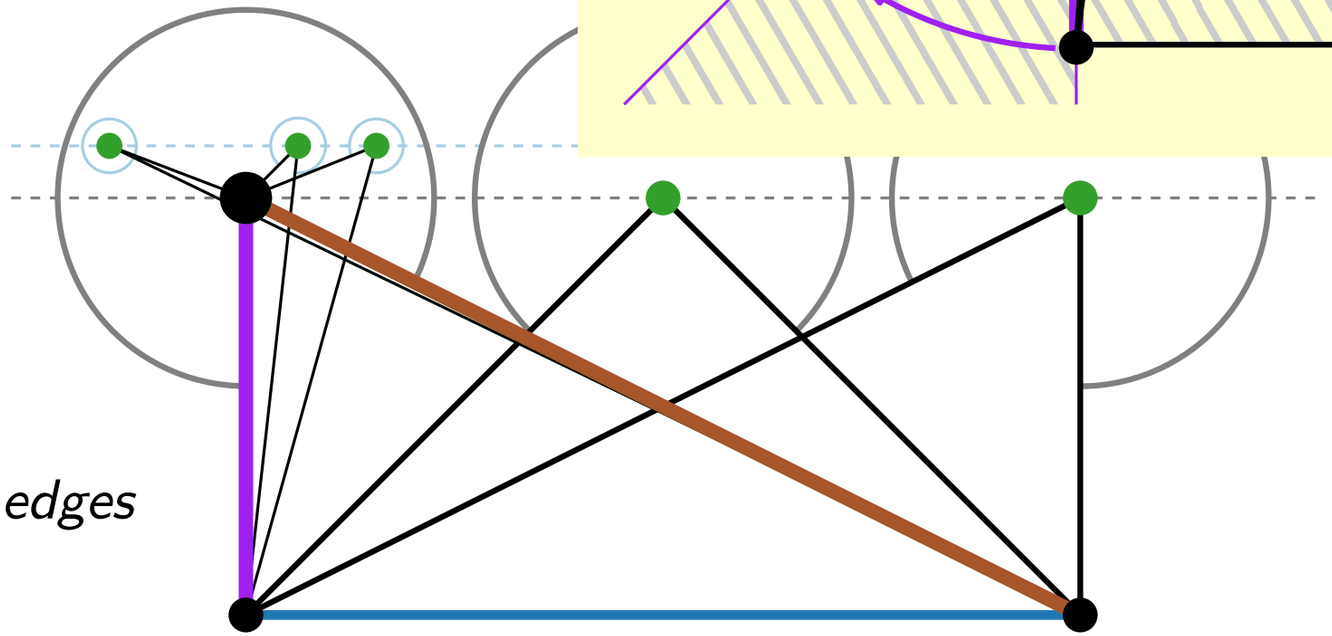


inactive vertices ● ● *active vertices*



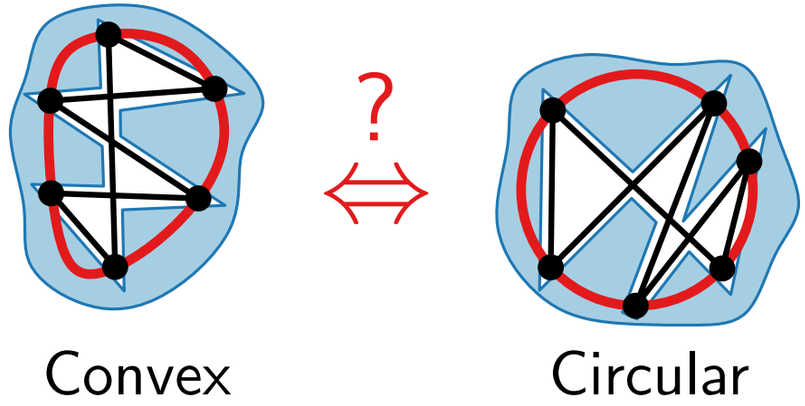
base edge

parent edges



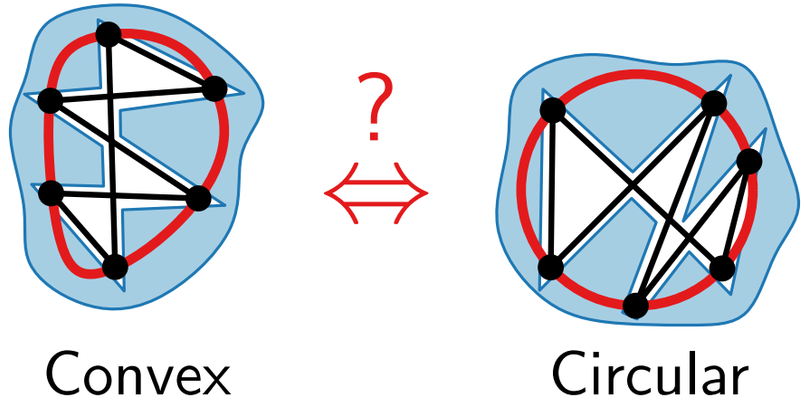
Open Problems

- Does every graph that admits a **convex** outside-obstacle representation also admit a **circular** outside-obstacle representation?



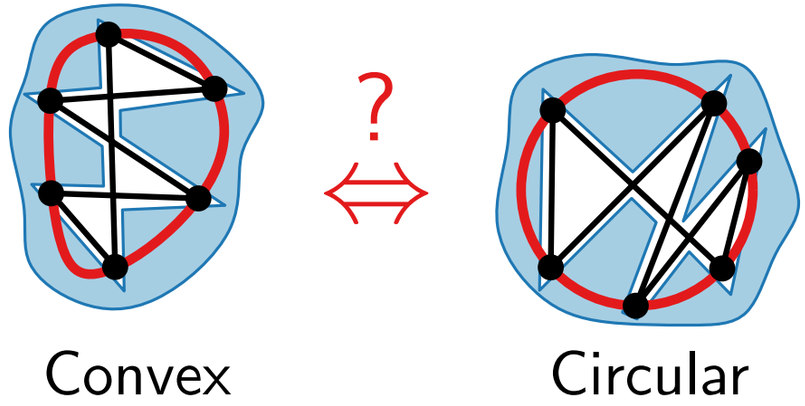
Open Problems

- Does every graph that admits a **convex** outside-obstacle representation also admit a **circular** outside-obstacle representation?
- Does every outerplanar graph admit a **convex** outside-obstacle representation?



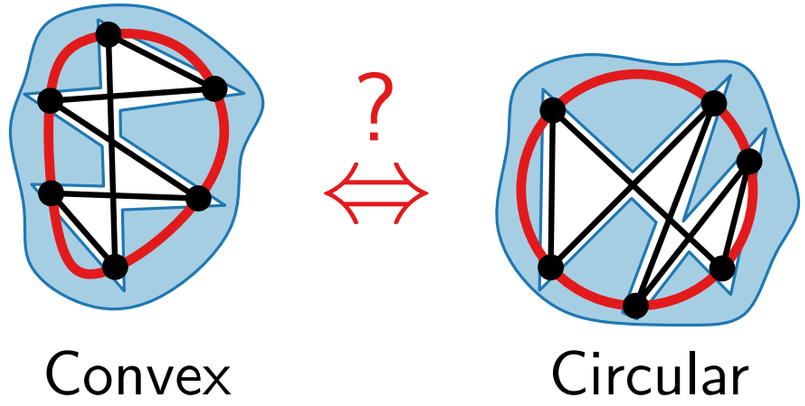
Open Problems

- Does every graph that admits a **convex** outside-obstacle representation also admit a **circular** outside-obstacle representation?
- Does every outerplanar graph admit a **convex** outside-obstacle representation?
- What is the **complexity** of deciding whether a given graph admits an outside-obstacle representation?



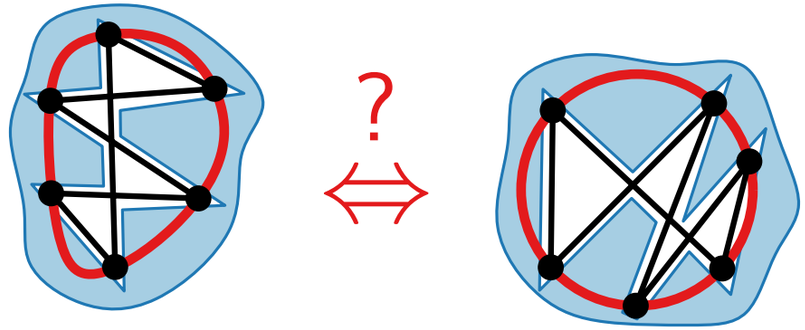
Open Problems

- Does every graph that admits a **convex** outside-obstacle representation also admit a **circular** outside-obstacle representation?
- Does every outerplanar graph admit a **convex** outside-obstacle representation?
- What is the **complexity** of deciding whether a given graph admits an outside-obstacle representation?
- Which **other classes** of graphs admit regular or circular outside-obstacle representations?



Open Problems

- Does every graph that admits a **convex** outside-obstacle representation also admit a **circular** outside-obstacle representation?
- Does every outerplanar graph admit a **convex** outside-obstacle representation?
- What is the **complexity** of deciding whether a given graph admits an outside-obstacle representation?
- Which **other classes** of graphs admit regular or circular outside-obstacle representations?



Convex Circular

Thank you!