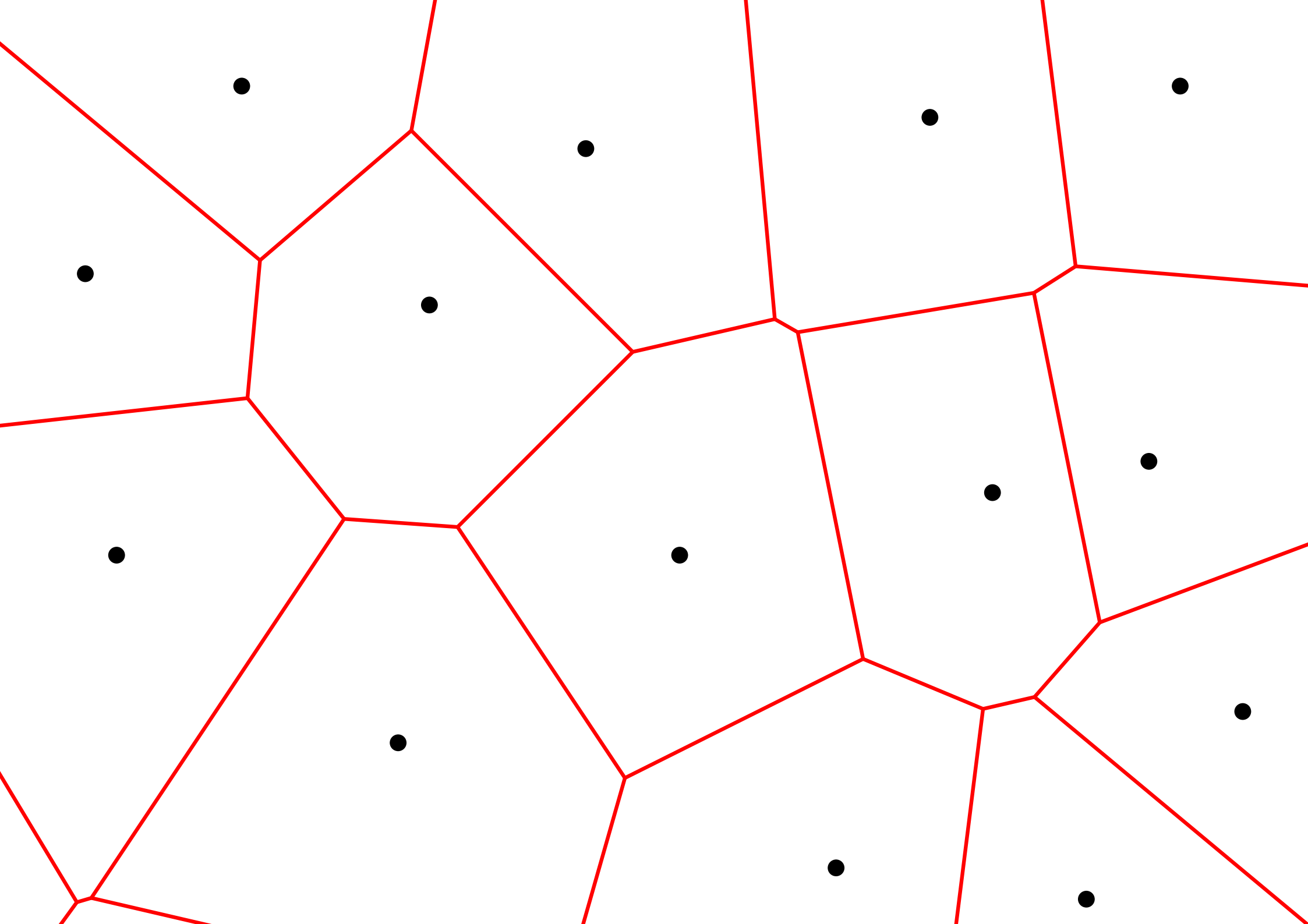


STORING THE VORONOI DIAGRAM

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Rodrigo Silveira

Research Group on
Discrete, Combinatorial and Computational Geometry
Universitat Politècnica de Catalunya



Storing the Voronoi diagram

Possible options, advantages and disadvantages

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Storing the list of all the edges of the diagram

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Disadvantage: it suffices to draw the diagram, but it does not contain the proximity information. For example, given a site p_i , finding its neighbors or reporting the vertices and edges of its Voronoi region is too expensive.

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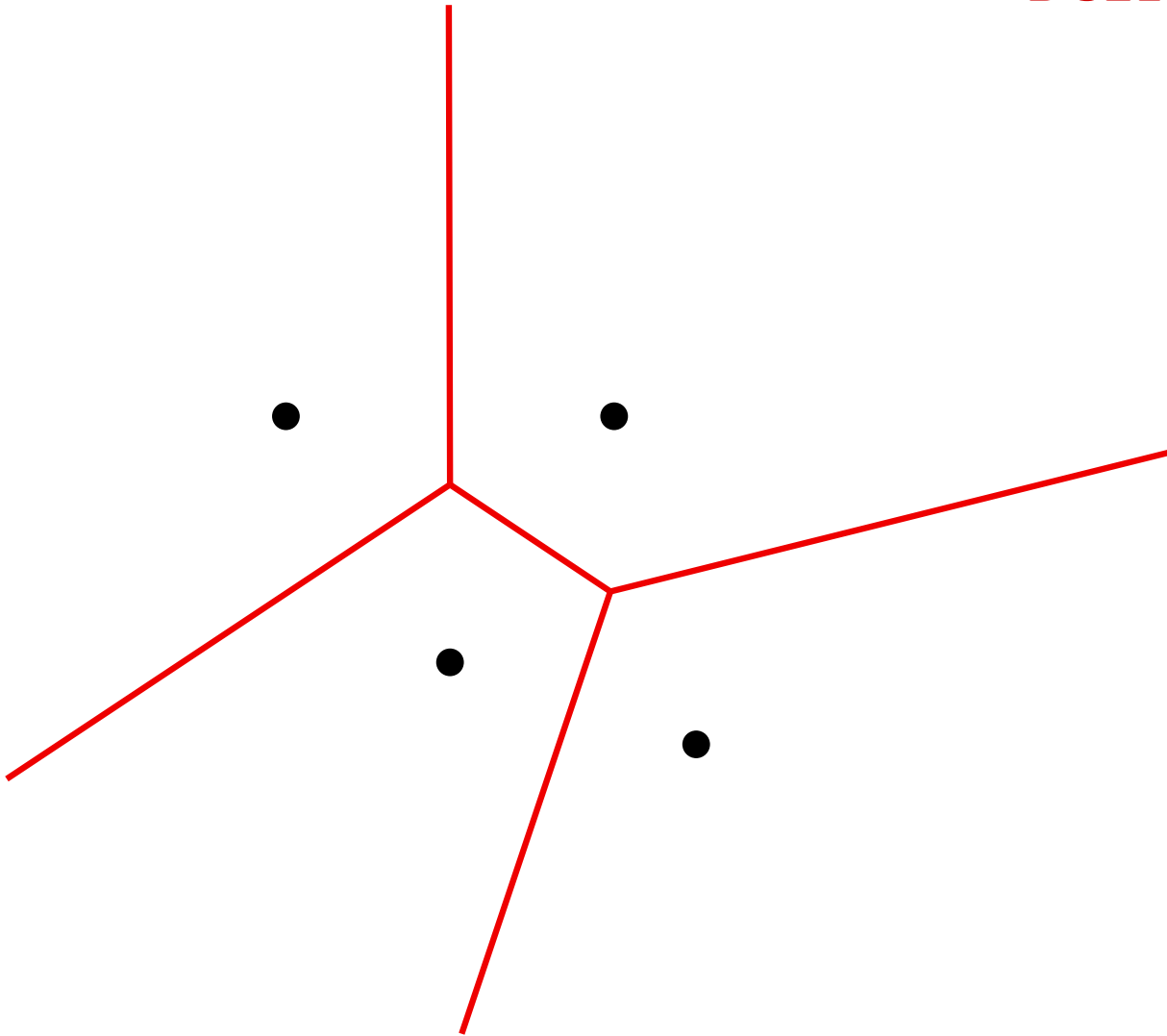
Disadvantage: the stored data is redundant and it uses more space than required.

The data structure which is most frequently used to store Voronoi diagrams is the DCEL (doubly connected edge list).

The DCEL is also used to store plane partitions, polyhedra, meshes, etc.

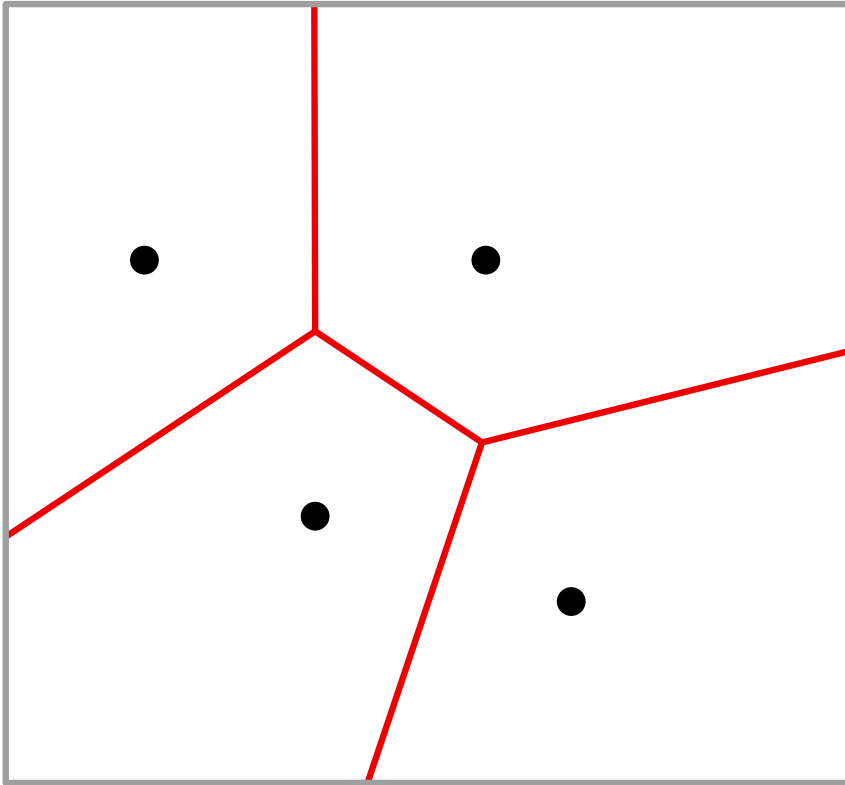
Storing the Voronoi diagram

DCEL



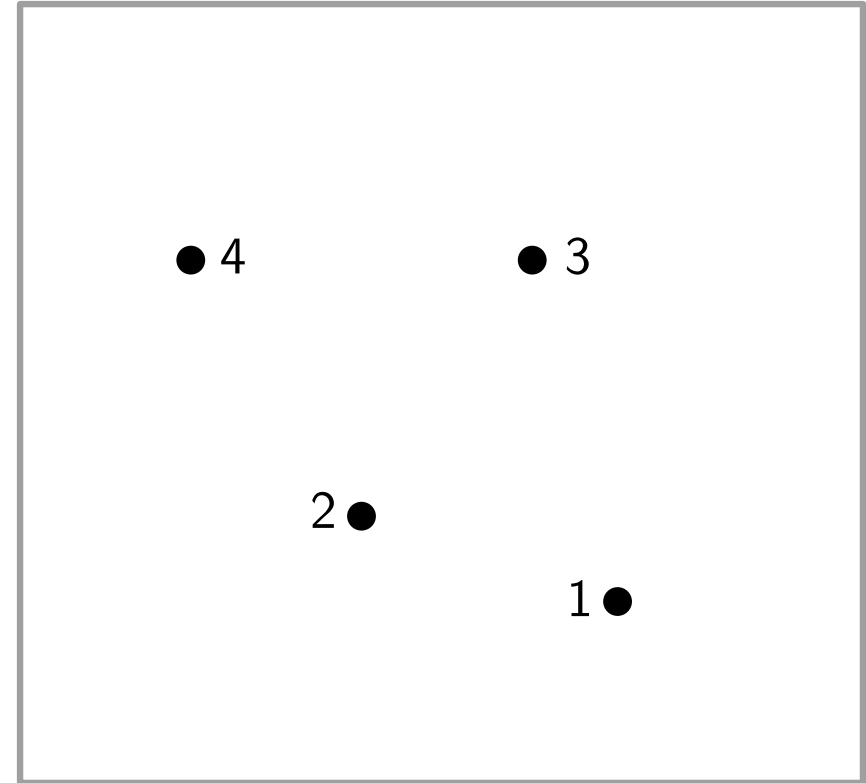
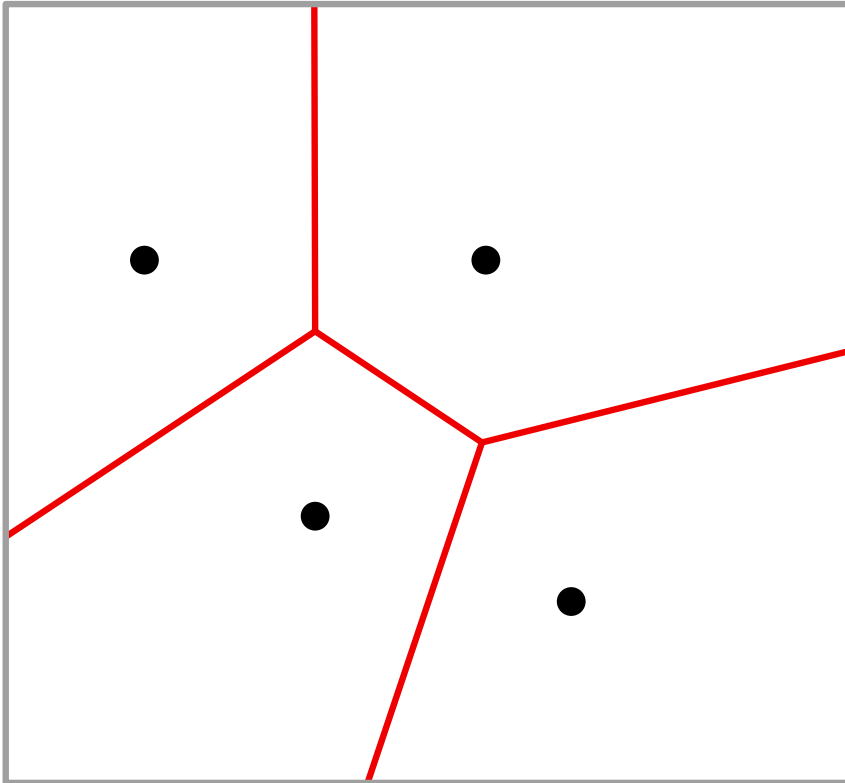
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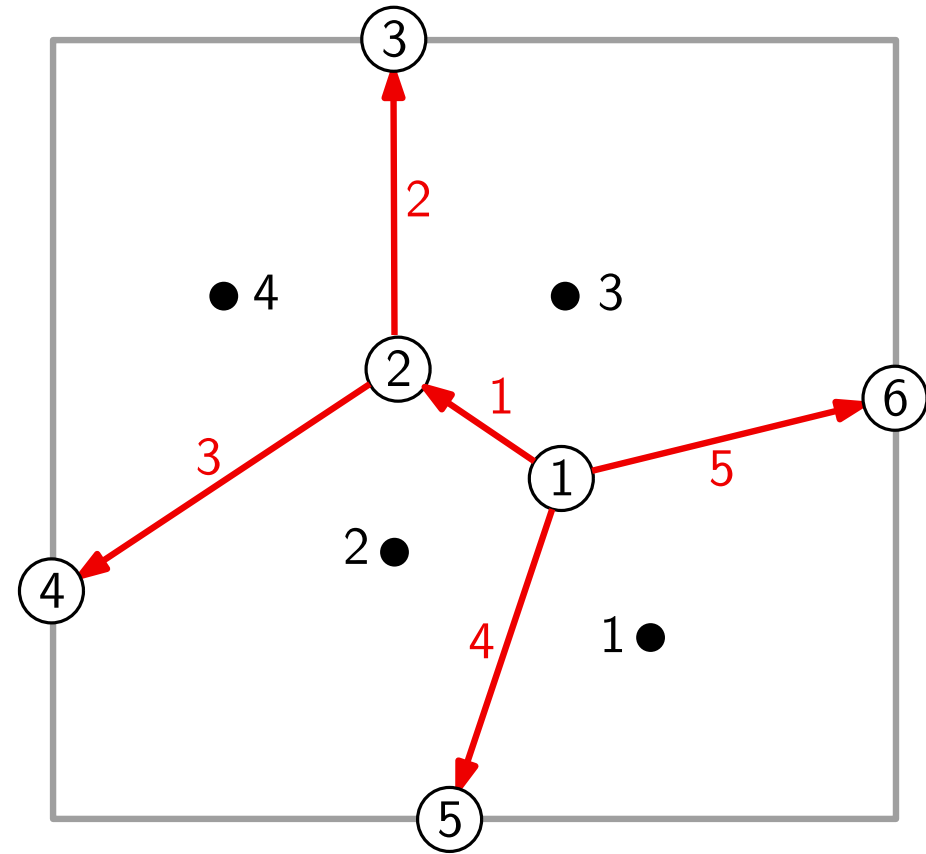
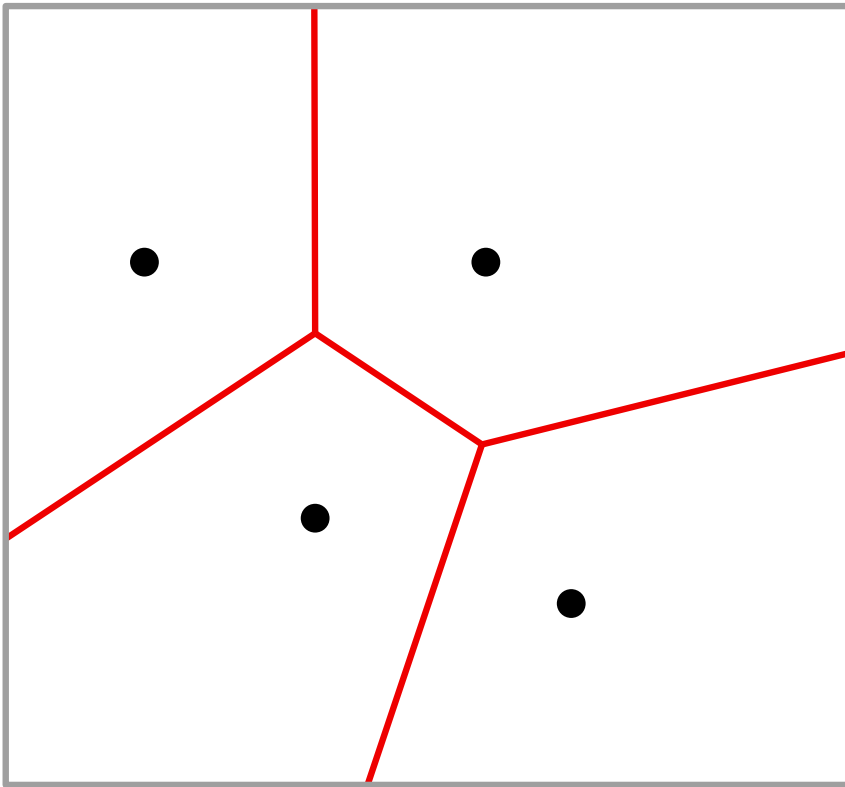
Storing the Voronoi diagram

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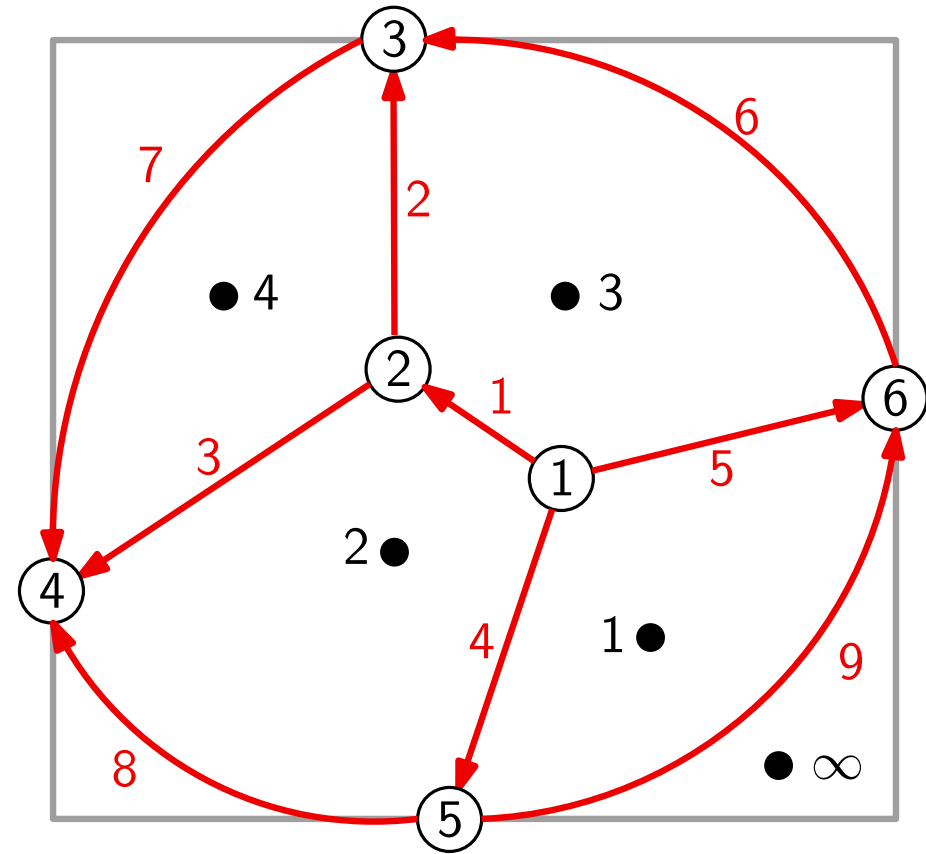
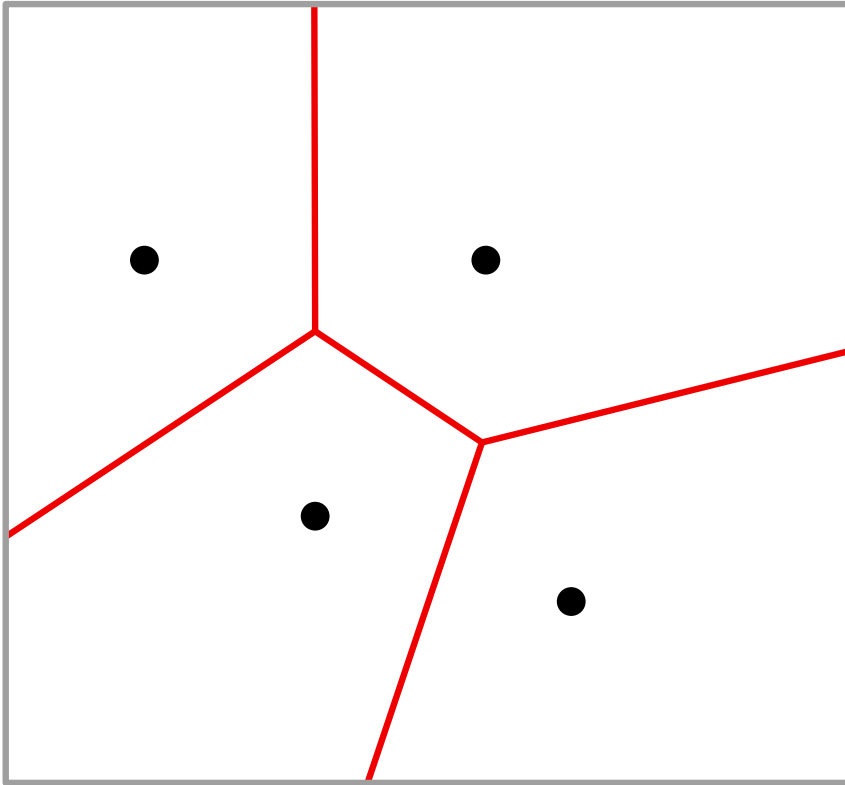
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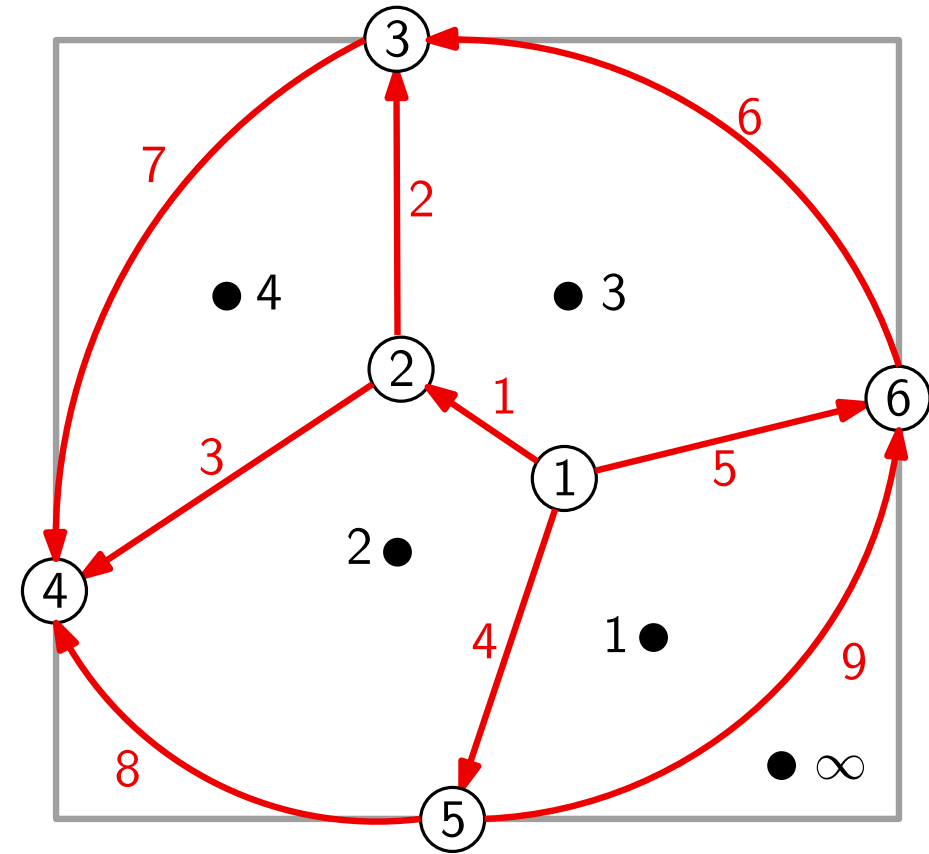
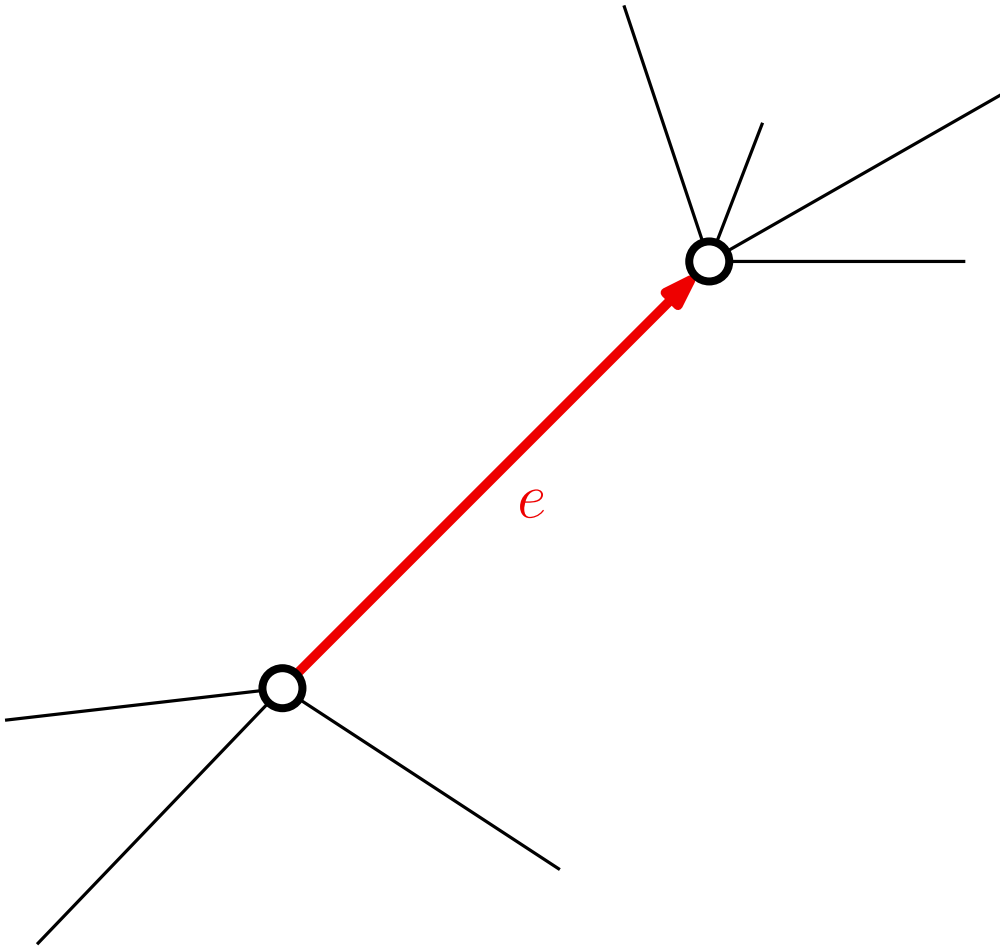
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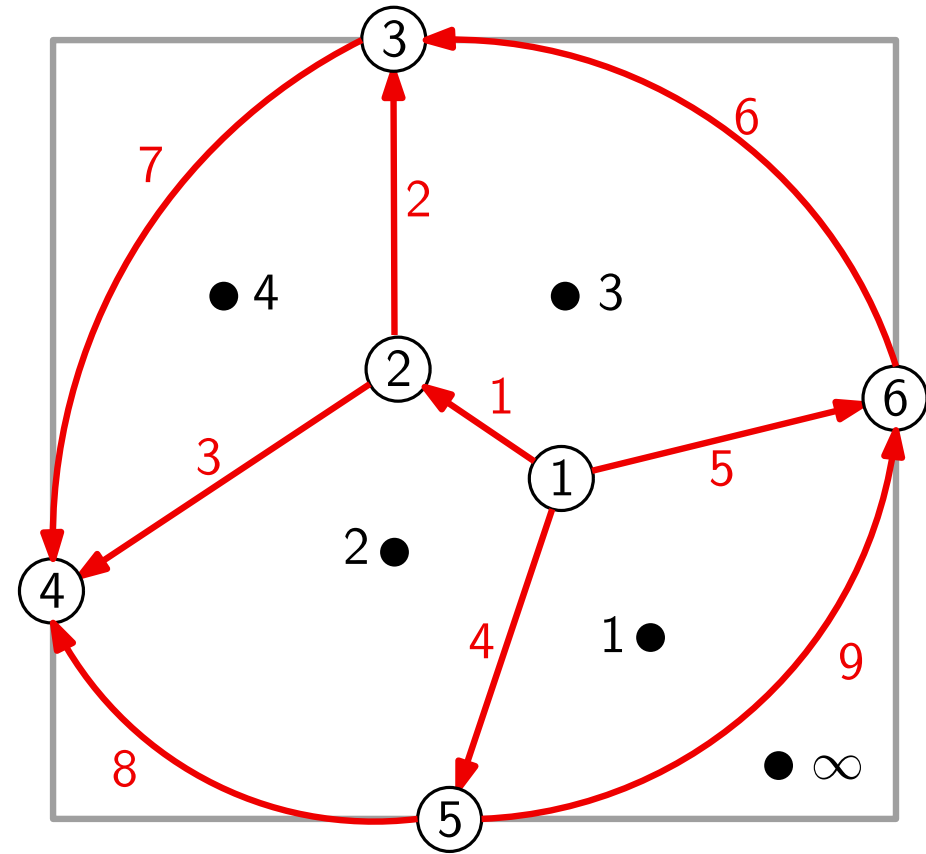
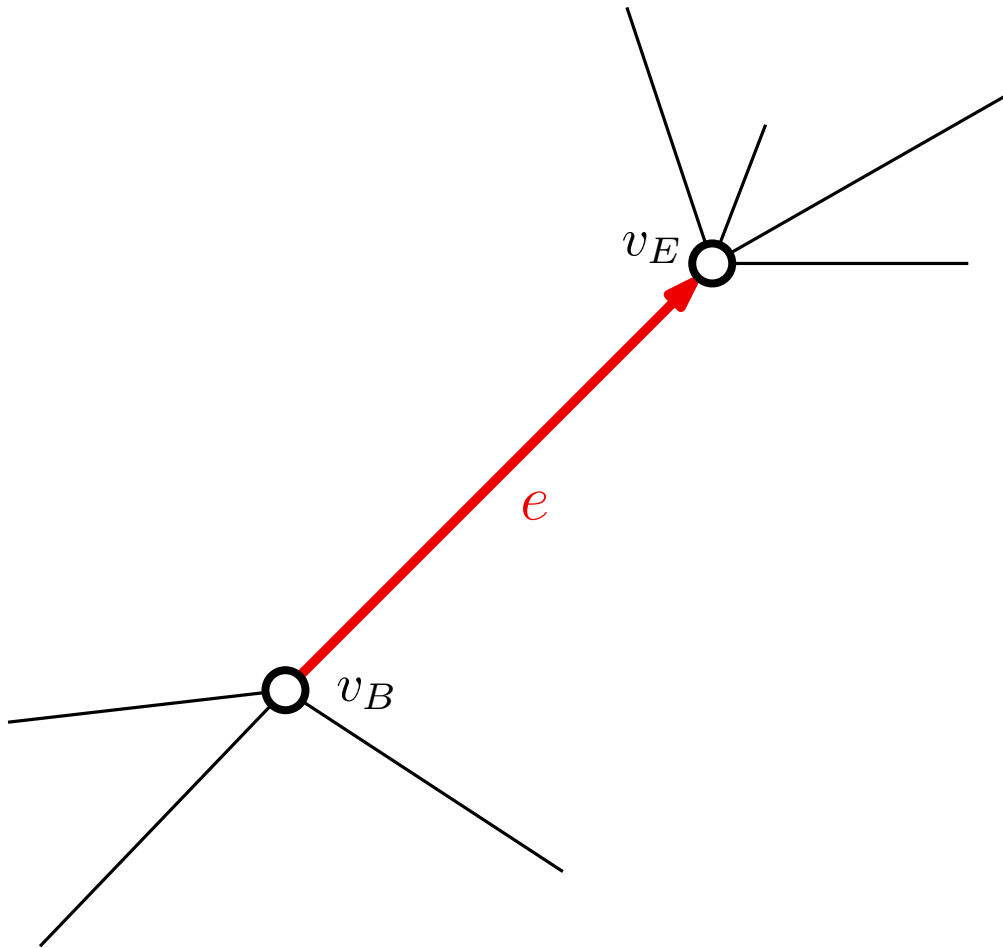
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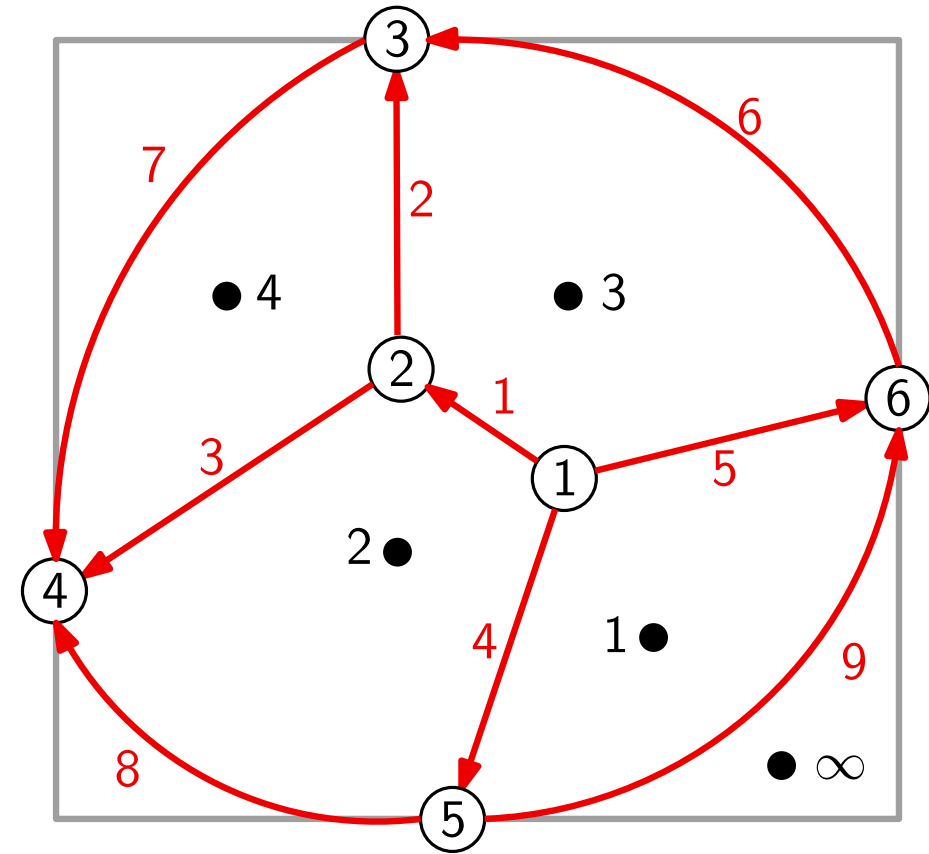
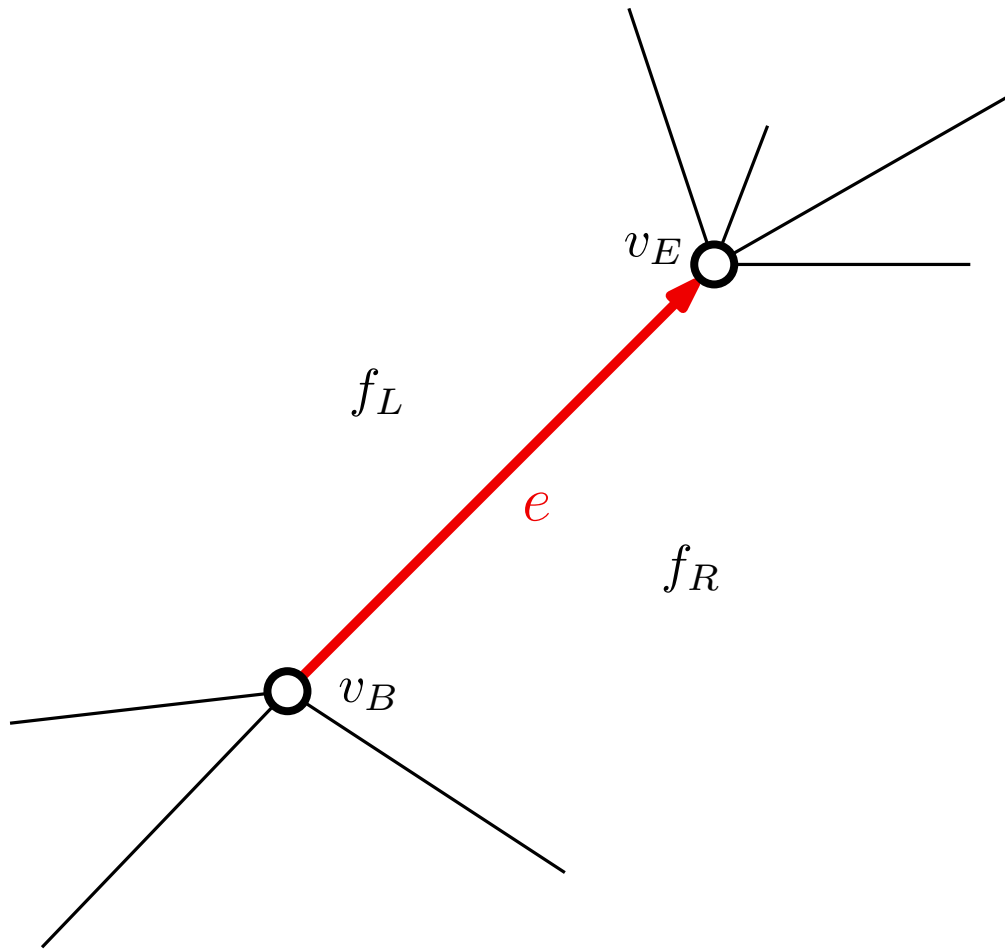
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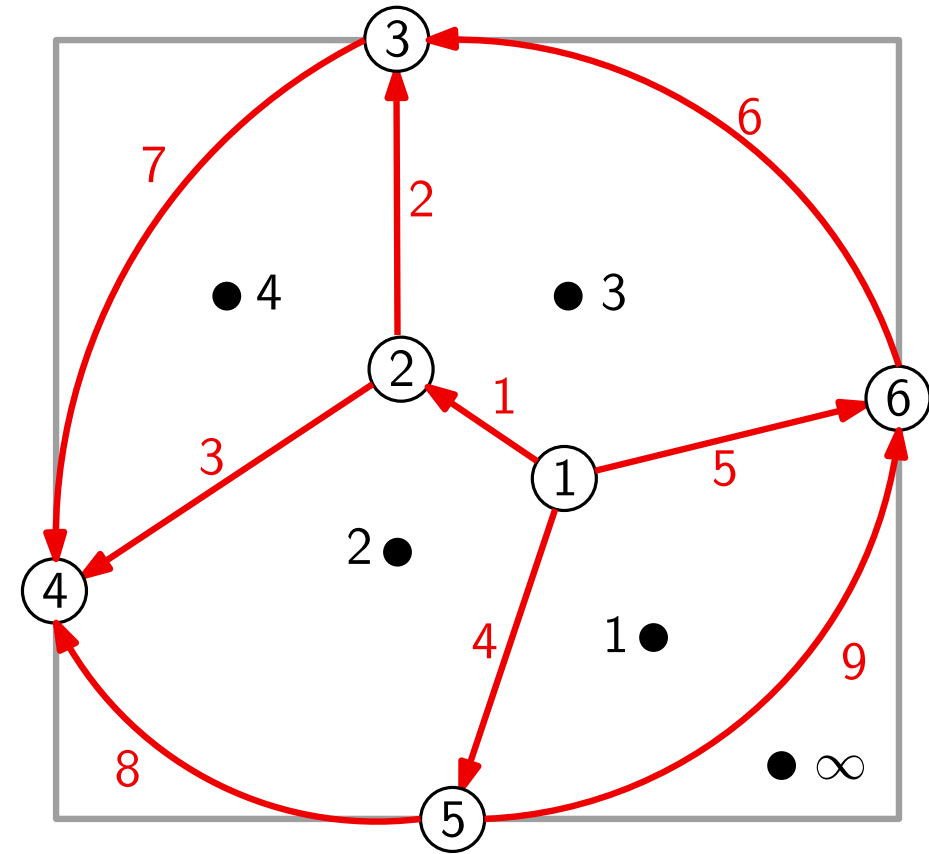
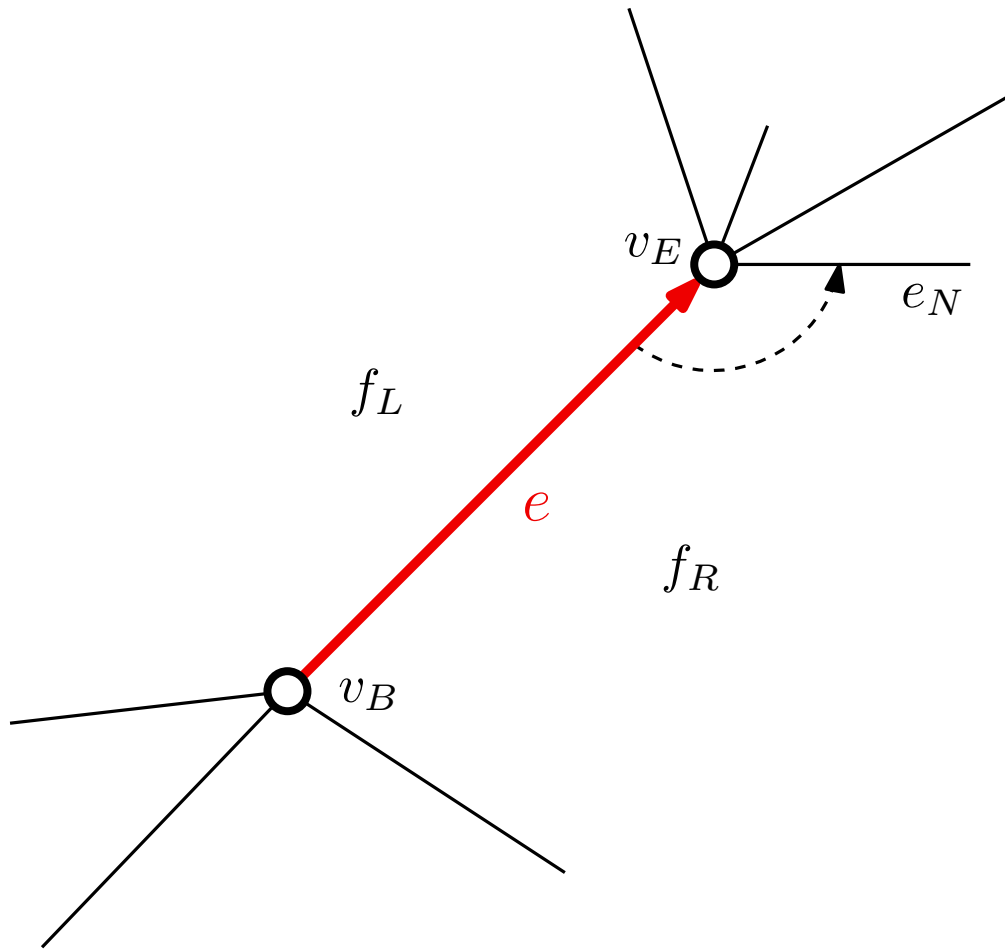
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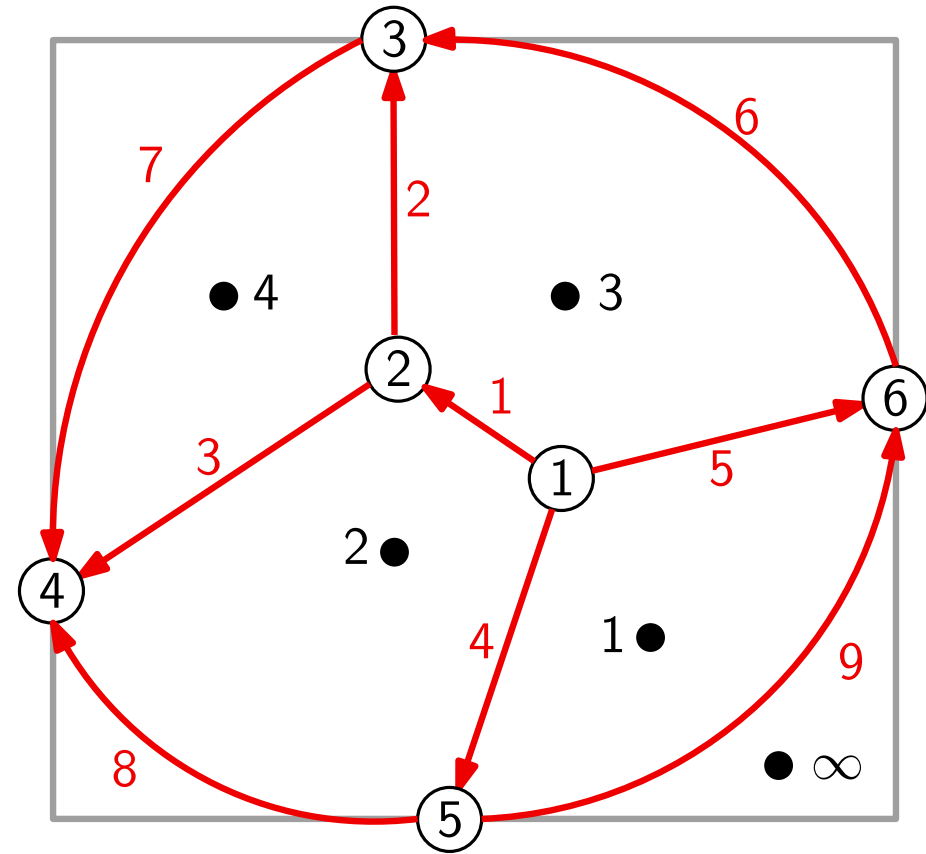
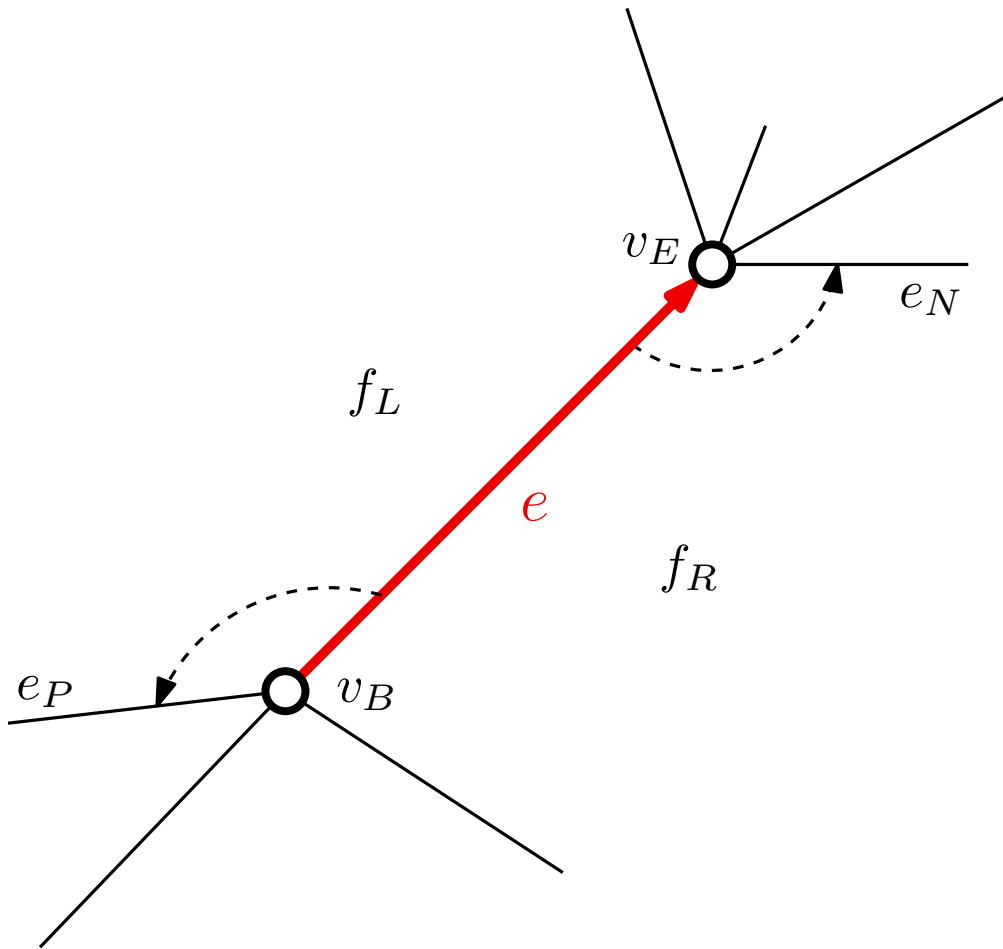
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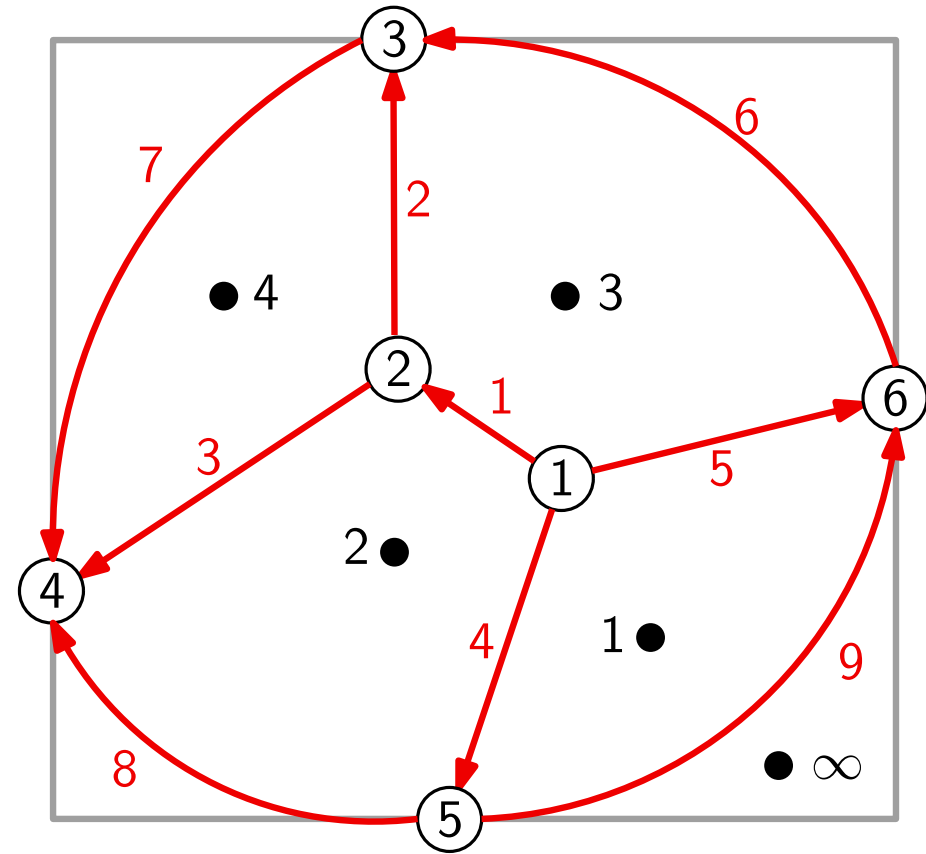


Storing the Voronoi diagram

Table of faces

p	x	y	e
1	x_1	y_1	4
2	x_2	y_2	4
3	x_3	y_3	1
4	x_4	y_4	3
∞	—	—	9

DCEL



Storing the Voronoi diagram

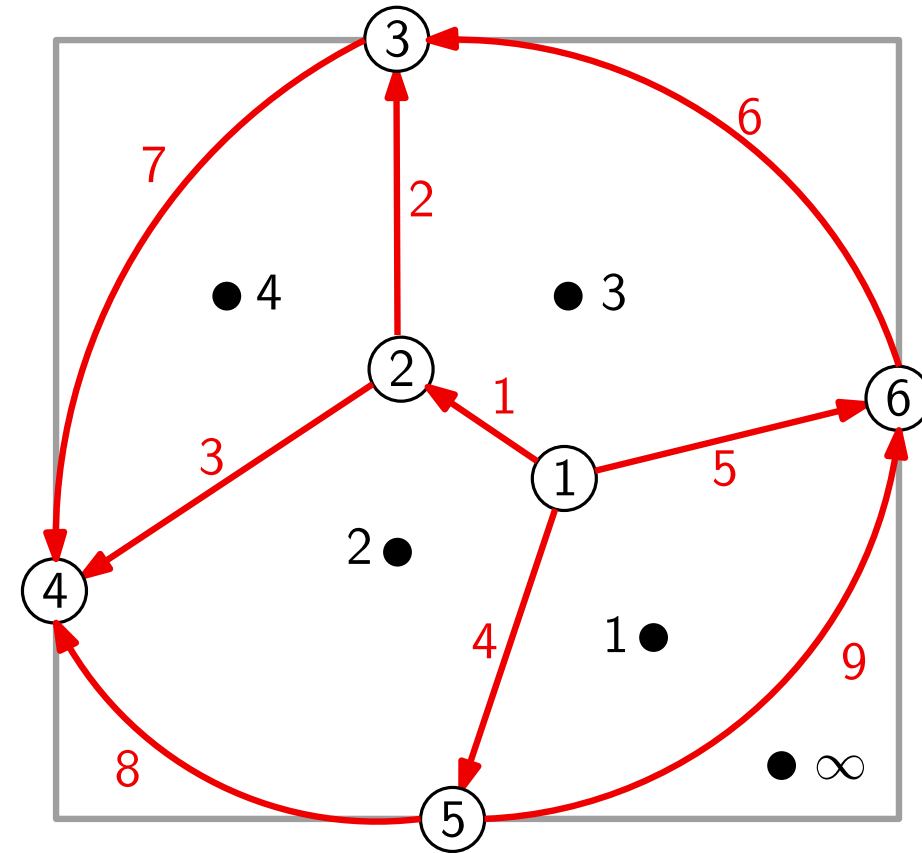
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Table of vertices

DCEL

v	x	y	e	original?
1	x_1	y_1	1	1
2	x_2	y_2	1	1
3	x_3	y_3	2	0
4	x_4	y_4	8	0
5	x_5	y_5	4	0
6	x_6	y_6	9	0



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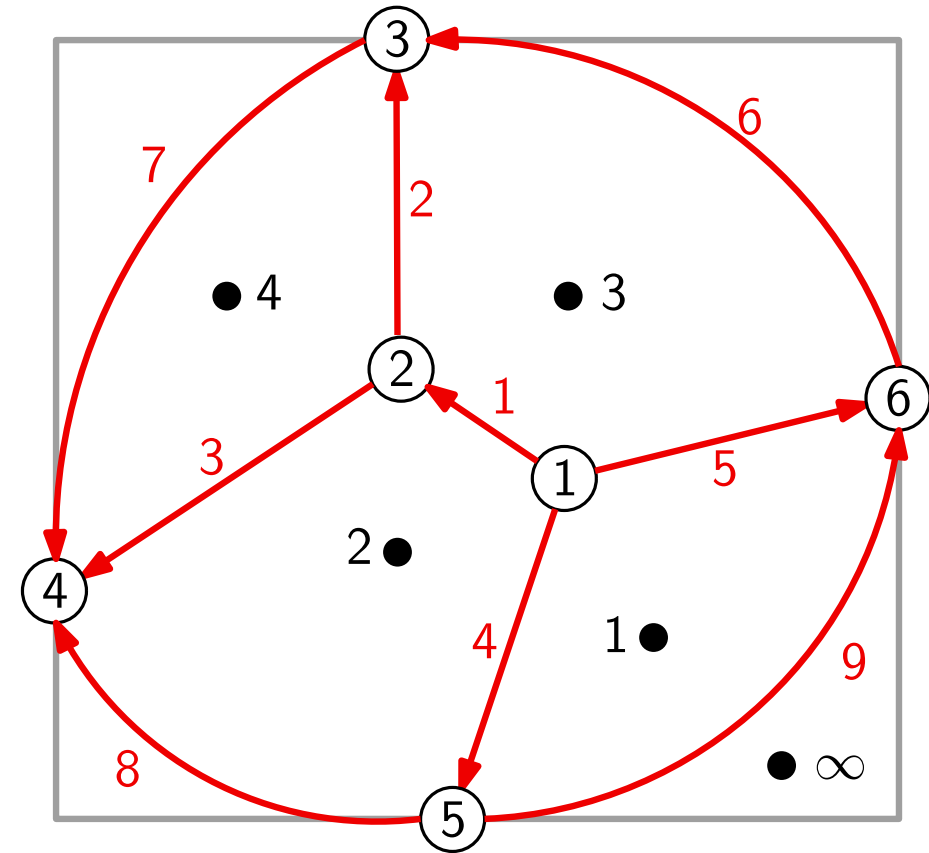
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Table of edges

e	v_B	v_E	f_L	f_R	e_P	e_N
1	1	2	2	3	4	2
2	2	3	4	3	3	6
3	2	4	2	4	1	7
4	1	5	1	2	5	8
5	1	6	3	1	1	9
6	6	3	3	∞	5	7
7	3	4	4	∞	2	8
8	5	4	∞	2	9	3
9	5	6	1	∞	4	6



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5	1	6	3	1	1	9
6	6	3	3	∞	5	7
7	3	4	4	∞	2	8
8	5	4	∞	2	9	3
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Storage space

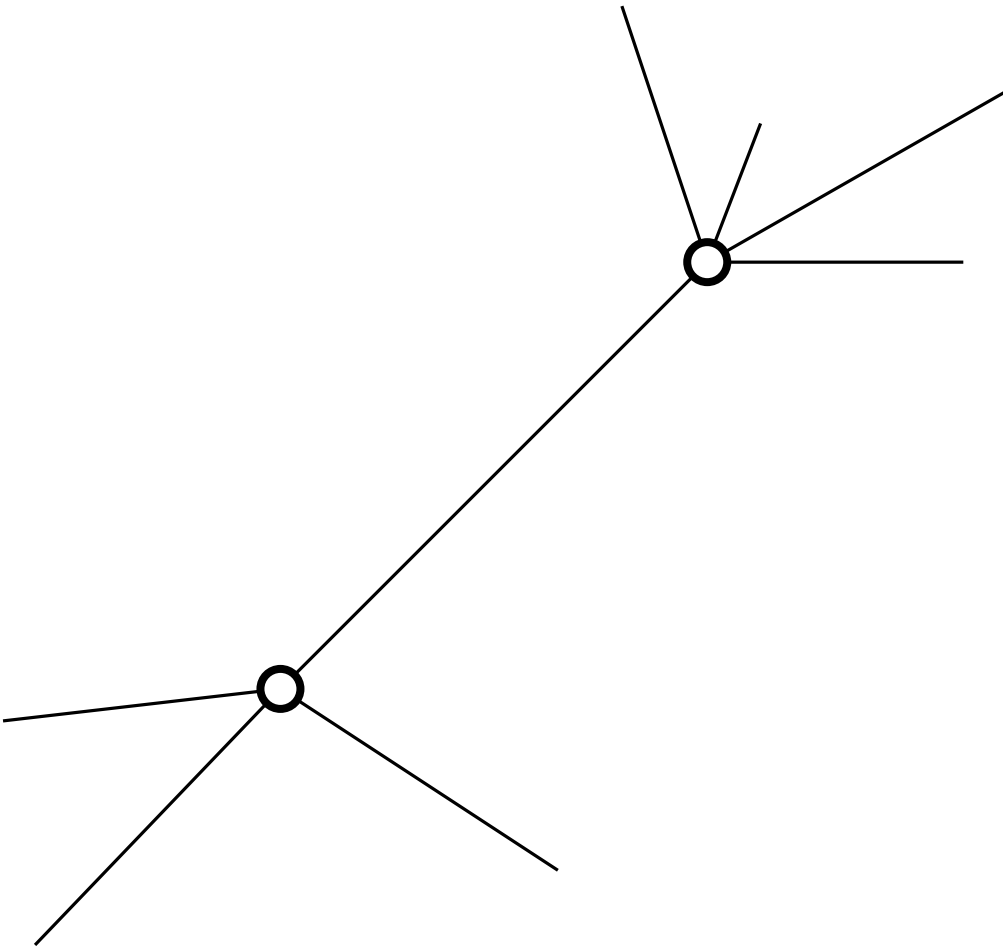
- For each face:
2 coordinates + 1 pointer/index.
- For each vertex:
2 coordinates + 1 pointer/index + 1 bit.
- For each edge:
6 pointers/indices.

In total, the storage space is $O(n)$.

Storing the Voronoi diagram

DCEL

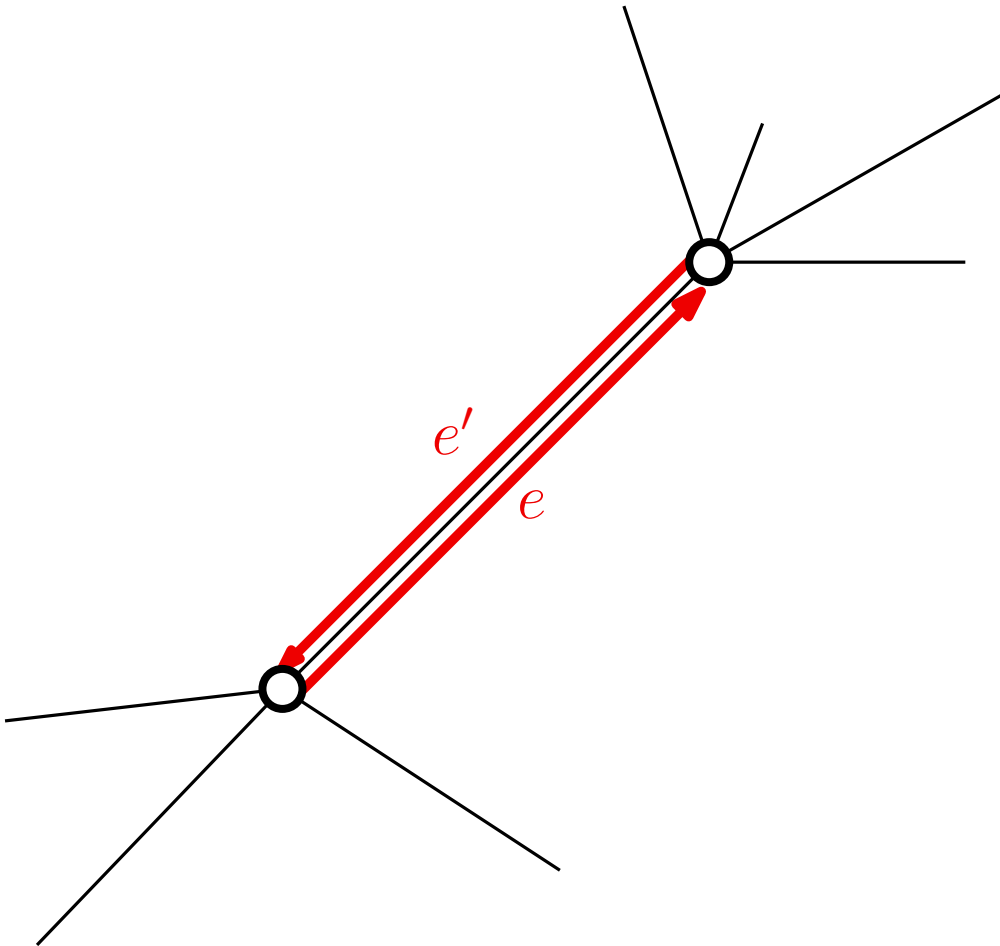
We can also use the DCEL variant with duplicated edges:



Storing the Voronoi diagram

DCEL

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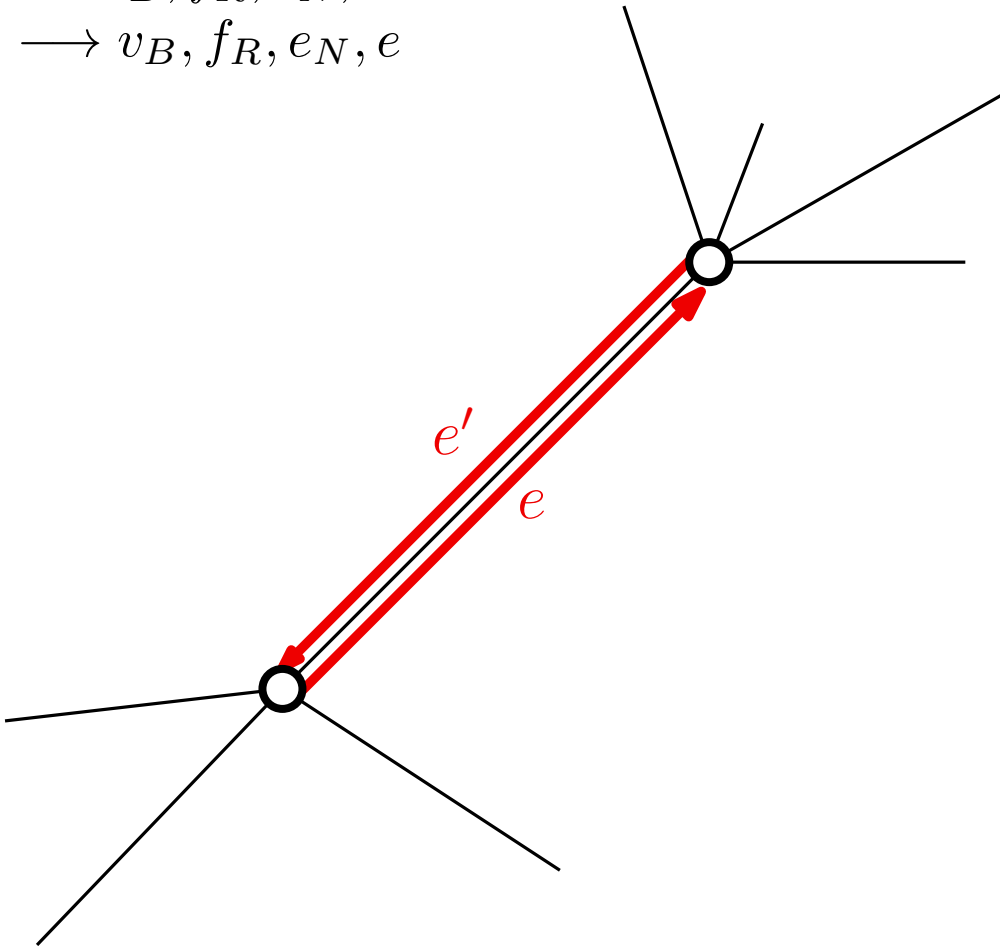
Storing the Voronoi diagram

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$$e \longrightarrow v_B, f_R, e_N, e'$$

$$e' \longrightarrow v_B, f_R, e_N, e$$



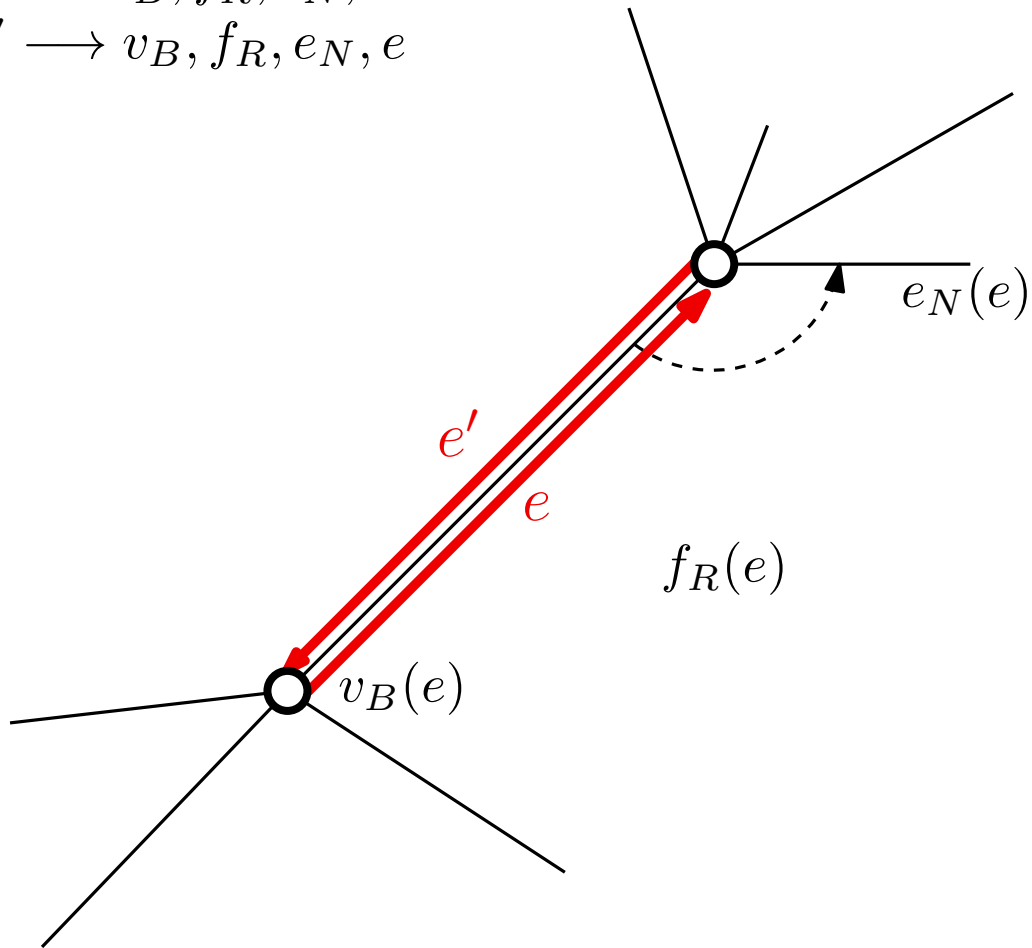
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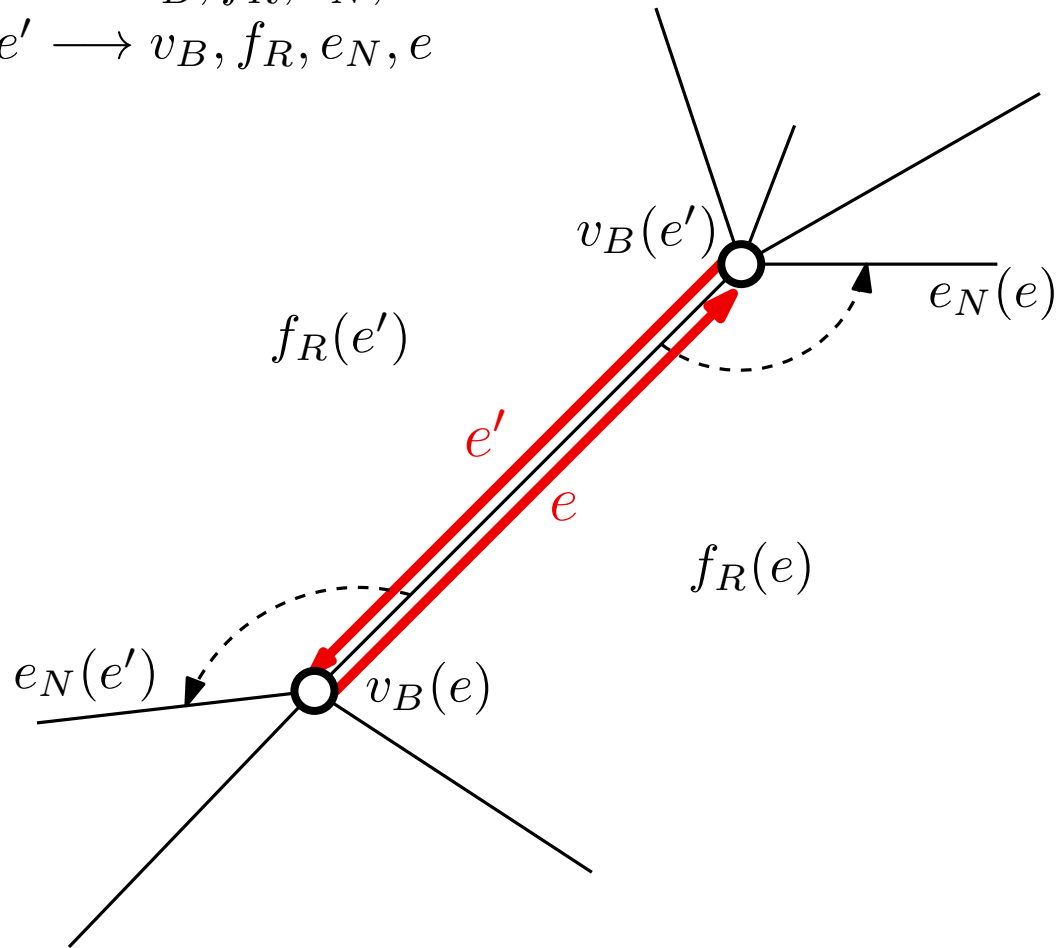


Storing the Voronoi diagram

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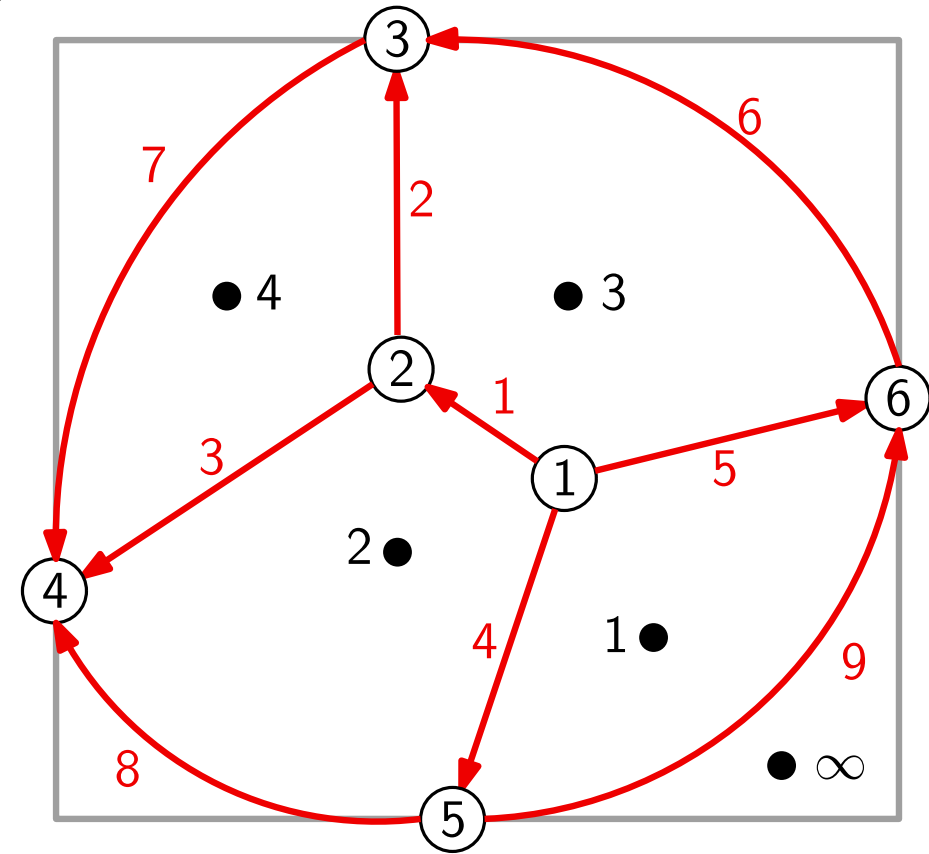
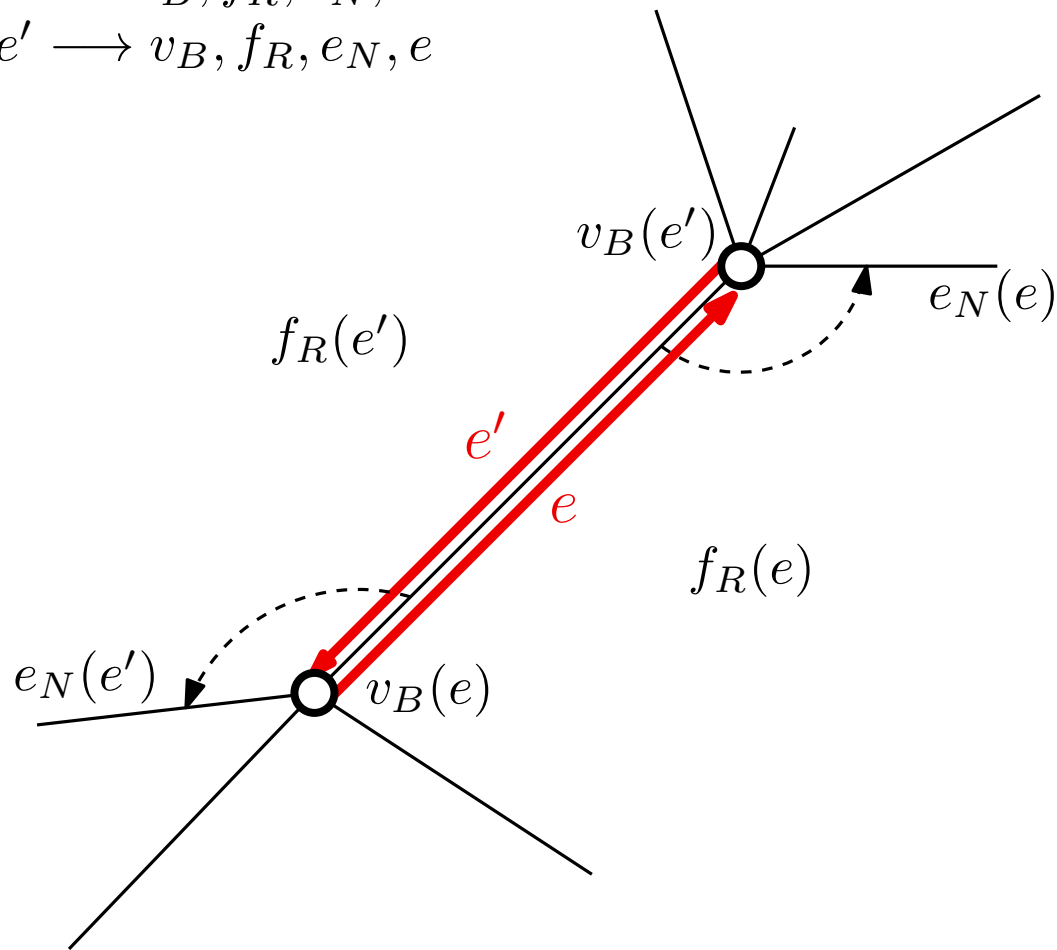


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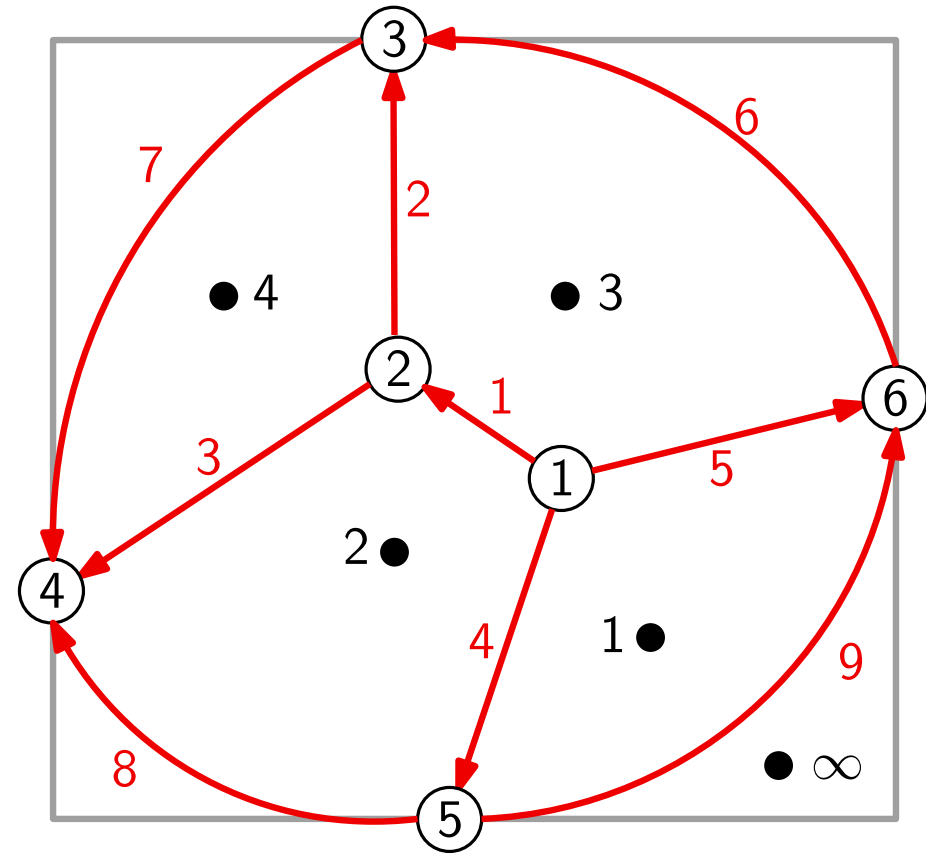
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Storing the Voronoi diagram

e	v_B	v_E	f_L	f_R	e_P	e_N
1	1	2	2	3	4	2
2	2	3	4	3	3	6
3	2	4	2	4	1	7
4	1	5	1	2	5	8
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9	5	6	1	∞	4	6

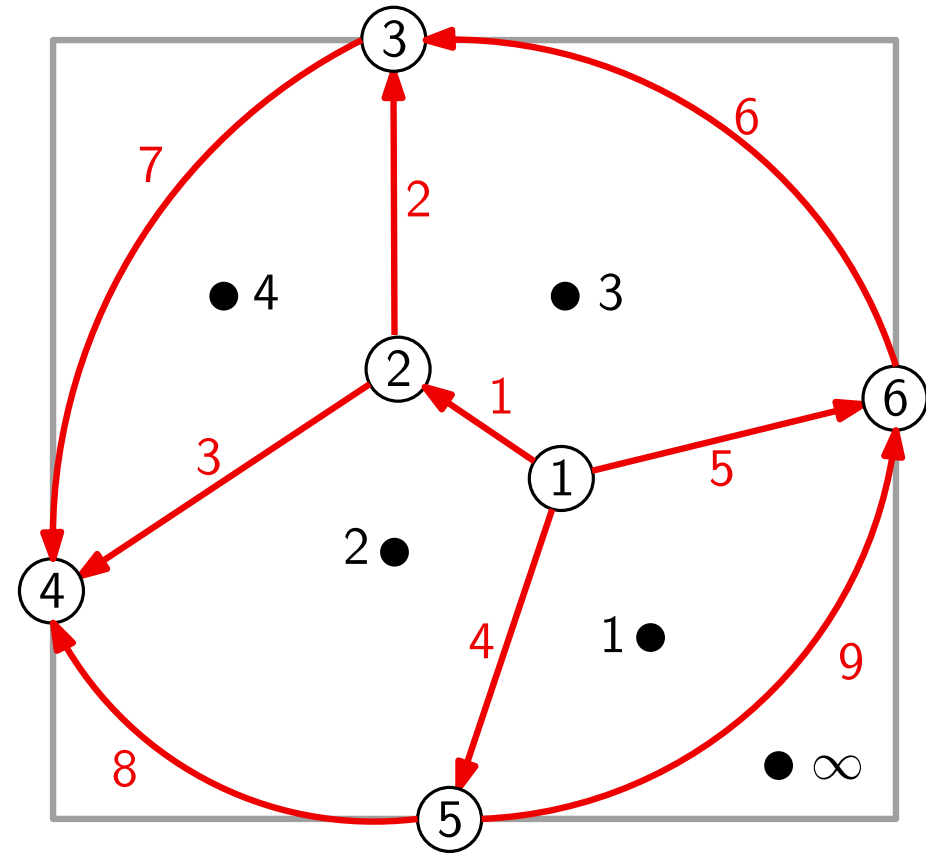
DCEL



Storing the Voronoi diagram

DCEL

e	v_B	f_R	e_N	e'
1	1	3	2	1'
2	2	3	6	2'
3	2	4	7	3'
4	1	2	8	4'
5	1	1	9	5'
6	6	∞	7	6'
7	3	∞	8	7'
8	5	2	3	8'
9	5	∞	6	9'
1'	2	2	4	1
2'	3	4	3	2
3'	4	2	1	3
4'	5	1	5	4
5'	6	3	1	5
6'	3	3	5	6
7'	4	4	2	7
8'	4	∞	9	8
9'	6	1	4	9



Voronoi diagram storage

How to obtain information from the DCEL

Voronoi diagram storage

How to obtain information from the DCEL

Sorted list of the edges and faces incident to a given Voronoi vertex

Voronoi diagram storage

How to obtain information from the DCEL

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Input: v_i , a Voronoi vertex

Output: $listE$ and $listF$, sorted in counterclockwise order

Voronoi diagram storage

How to obtain information from the DCEL

Sorted list of the edges and faces incident to a given Voronoi vertex

Input: v_i , a Voronoi vertex

Output: $listE$ and $listF$, sorted in counterclockwise order

Procedure:

Initialization

$listE = \{ \}, listF = \{ \}, e = e(v_i)$

Advance

Add e to $listE$

If $i = v_B(e)$, then

add $f_L(e)$ to $listF$

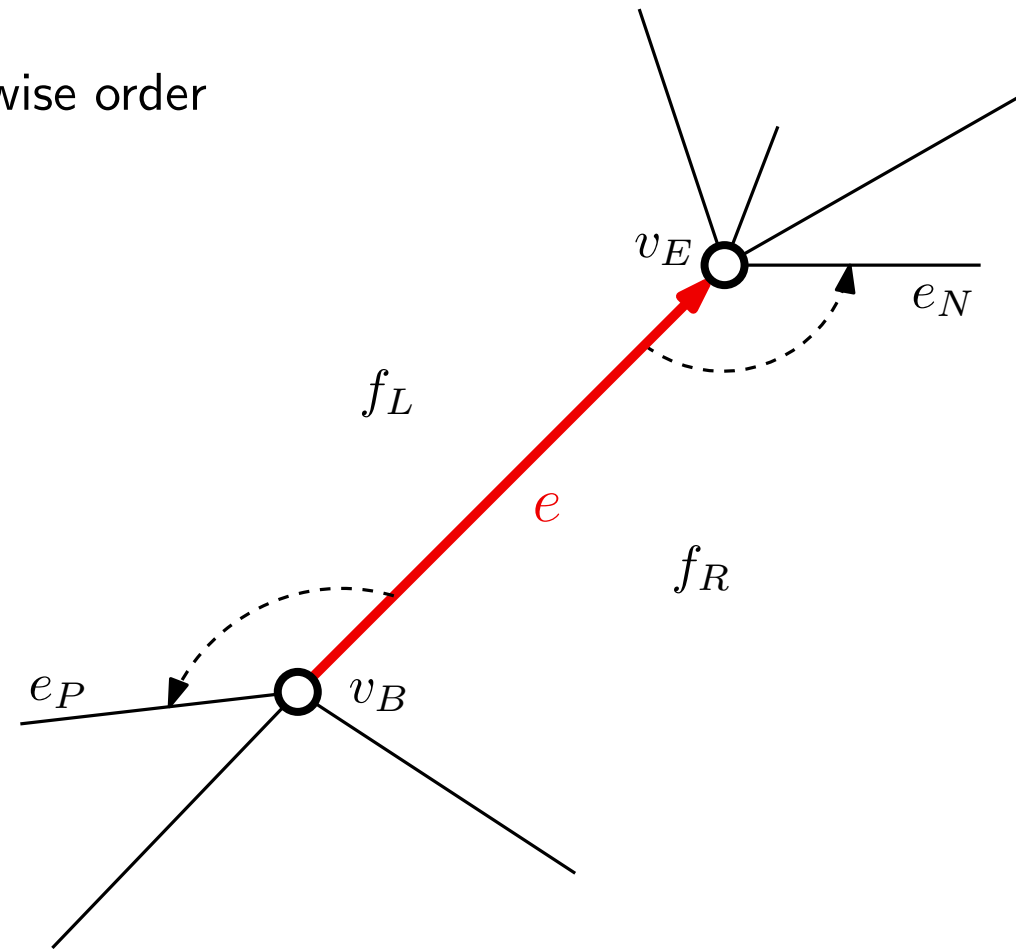
$e = e_P(e)$

else

add $f_R(e)$ to $listF$

$e = e_N(e)$

Repeat until e coincides again with $e(v_i)$



Voronoi diagram storage

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Sorted list of the edges and faces incident to a given Voronoi vertex

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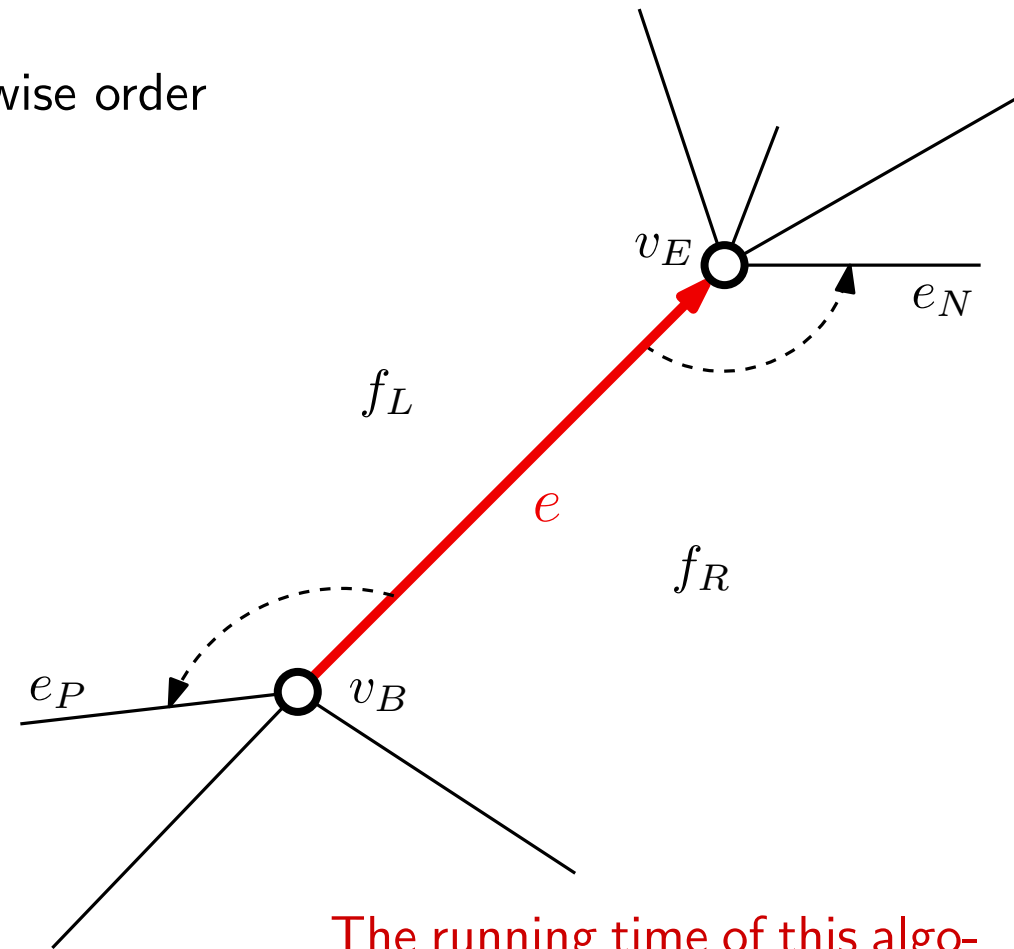
$e = e_P(e)$

else

add $f_R(e)$ to $listF$

$e = e_N(e)$

Repeat until e coincides again with $e(v_i)$



The running time of this algorithm is linear in the number of edges (faces) incident to v_i

Voronoi diagram storage

How to obtain information from the DCEL

Sorted list of vertices and edges of a Voronoi region

Voronoi diagram storage

How to obtain information from the DCEL

Sorted list of vertices and edges of a Voronoi region

Input: p_i , a site

Output: $listE$ and $listV$, sorted in clockwise order

Voronoi diagram storage

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Sorted list of vertices and edges of a Voronoi region

Input: p_i , a site

Output: $listE$ and $listV$, sorted in clockwise order

Procedure:

Initialization

$listE = \{ \}, listV = \{ \}, e = e(p_i)$

Advance

Add e to $listE$

If $i = f_L(e)$, then

add $v_B(e)$ to $listV$

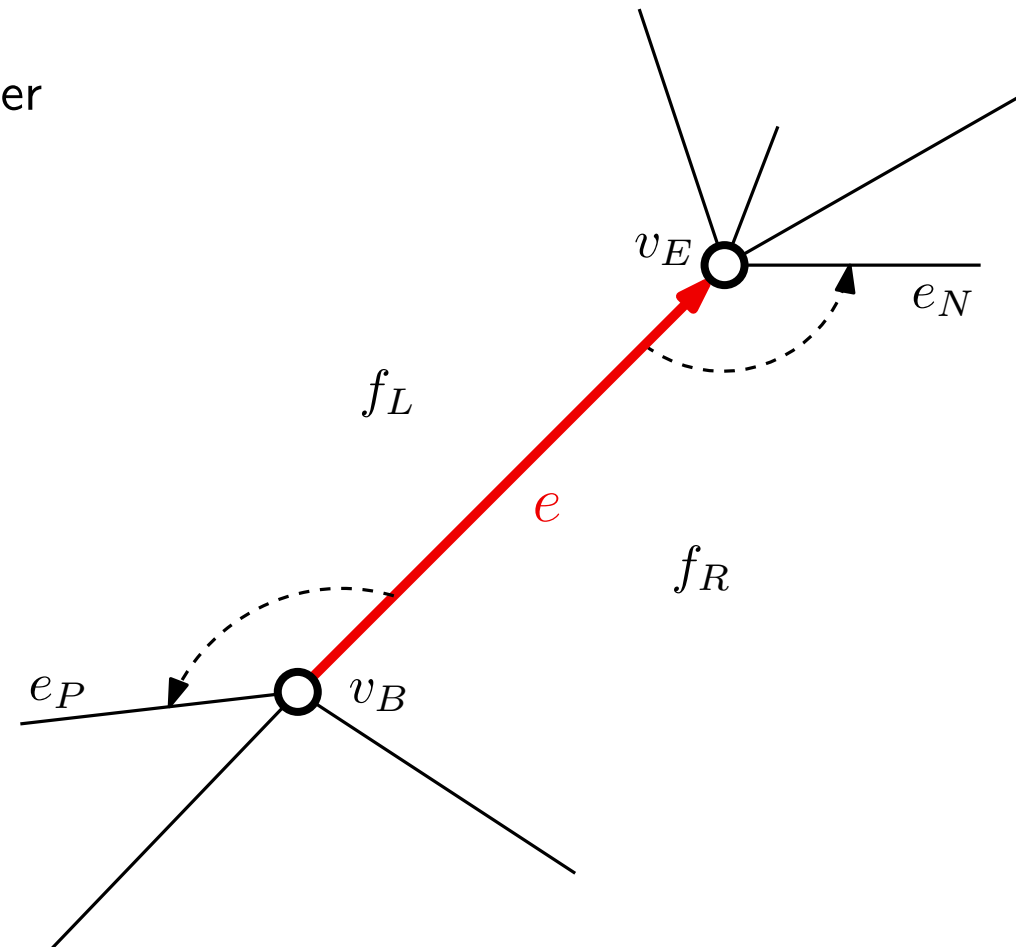
$e = e_P(e)$

else

add $v_E(e)$ to $listV$

$e = e_N(e)$

Repeat until e coincides again with $e(v_i)$



Voronoi diagram storage

How to obtain information from the DCEL

Sorted list of vertices and edges of a Voronoi region

Input: p_i , a site

Output: $listE$ and $listV$, sorted in clockwise order

Procedure:

Initialization

$listE = \{ \}, listV = \{ \}, e = e(p_i)$

Advance

Add e to $listE$

If $i = f_L(e)$, then

add $v_B(e)$ to $listV$

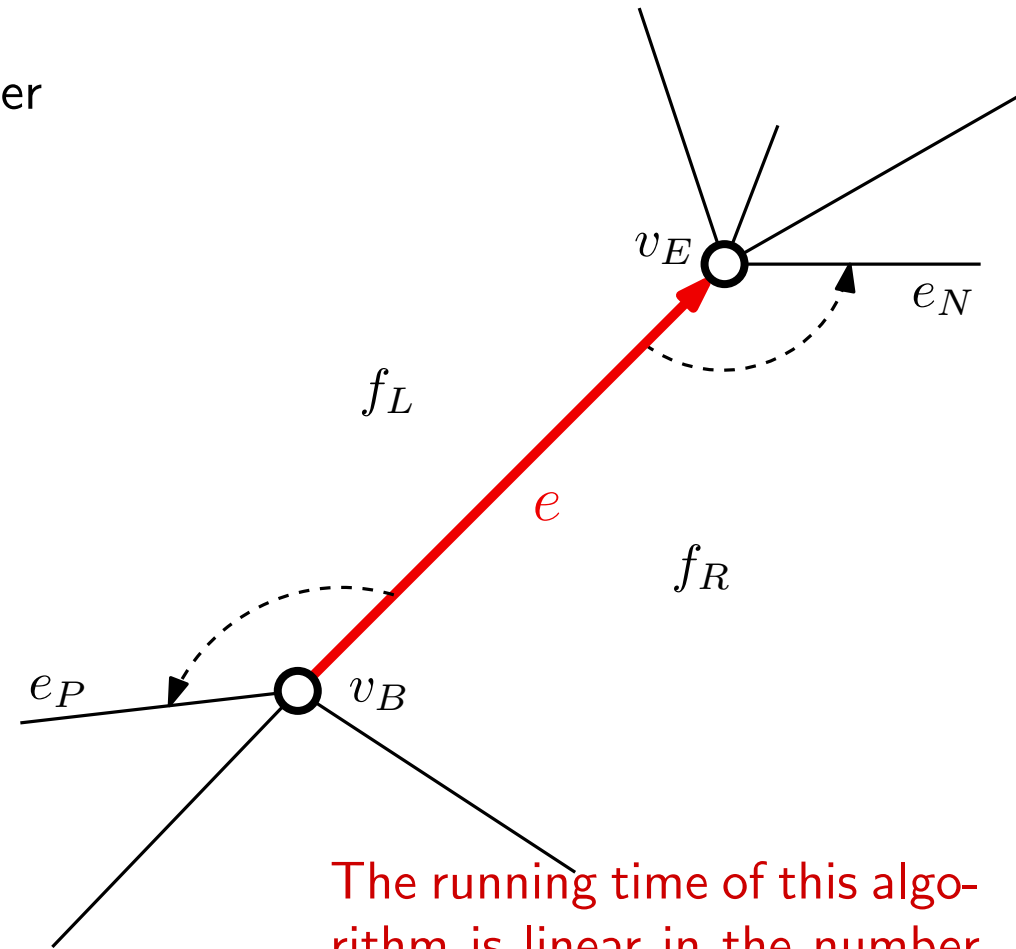
$e = e_P(e)$

else

add $v_E(e)$ to $listV$

$e = e_N(e)$

Repeat until e coincides again with $e(v_i)$

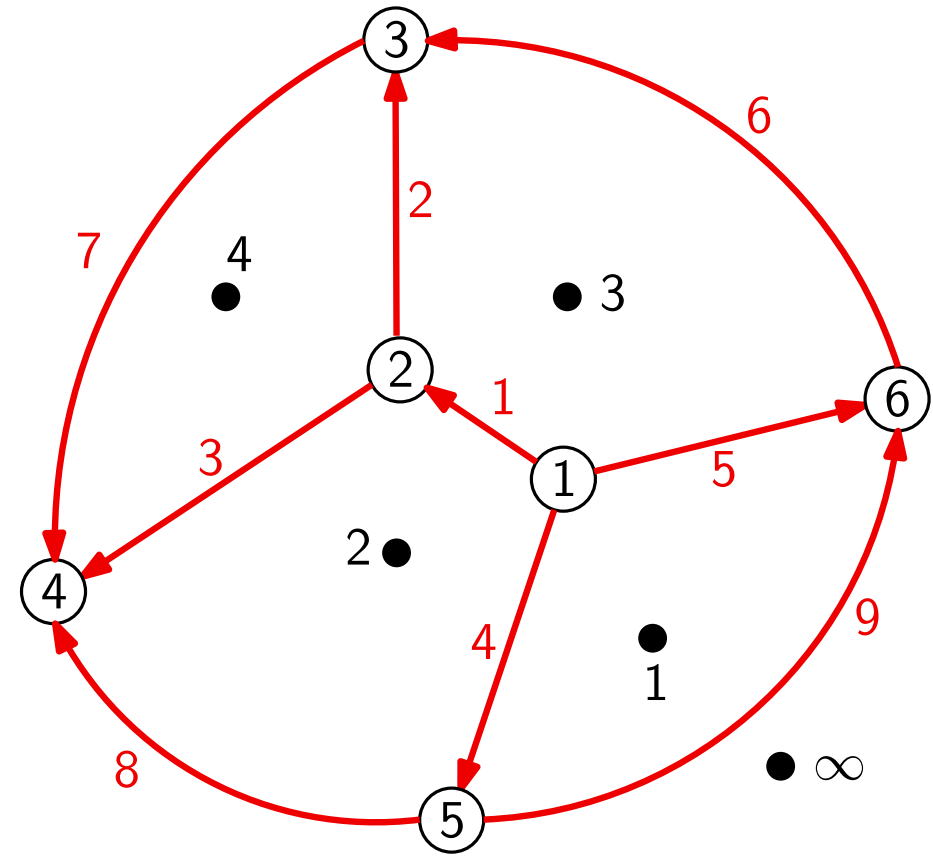


The running time of this algorithm is linear in the number of edges (vertices) of the Voronoi region of p_i

Voronoi diagram storage

How to obtain information from the DCEL

Convex hull of P

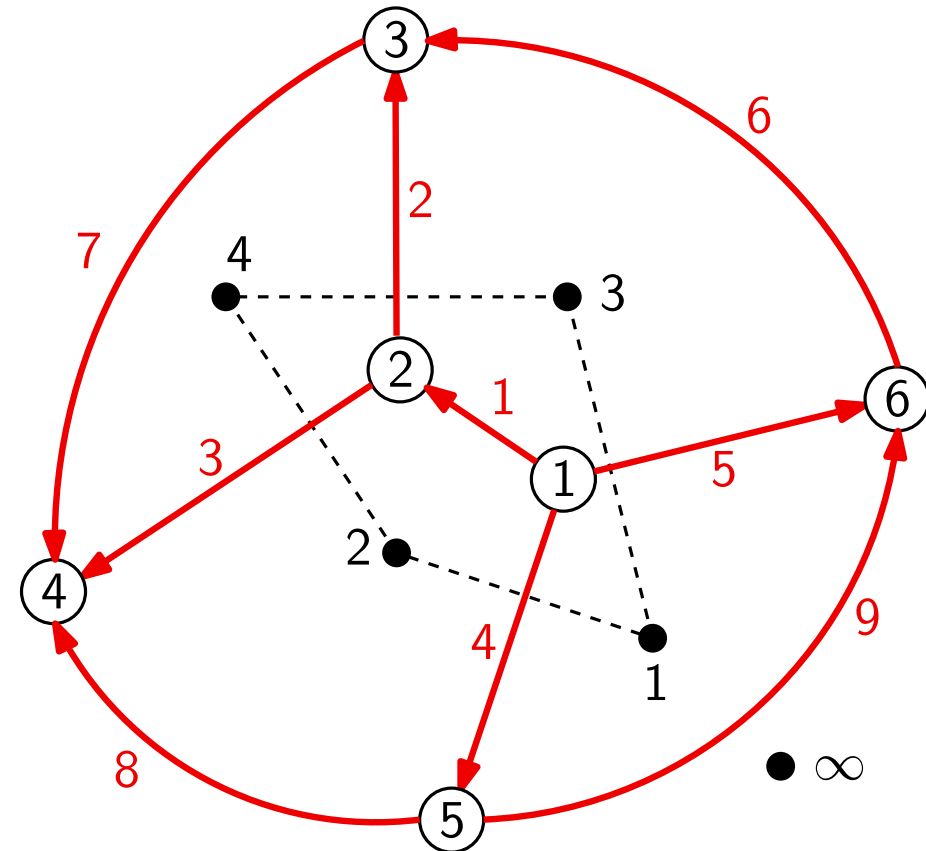


Voronoi diagram storage

How to obtain information from the DCEL

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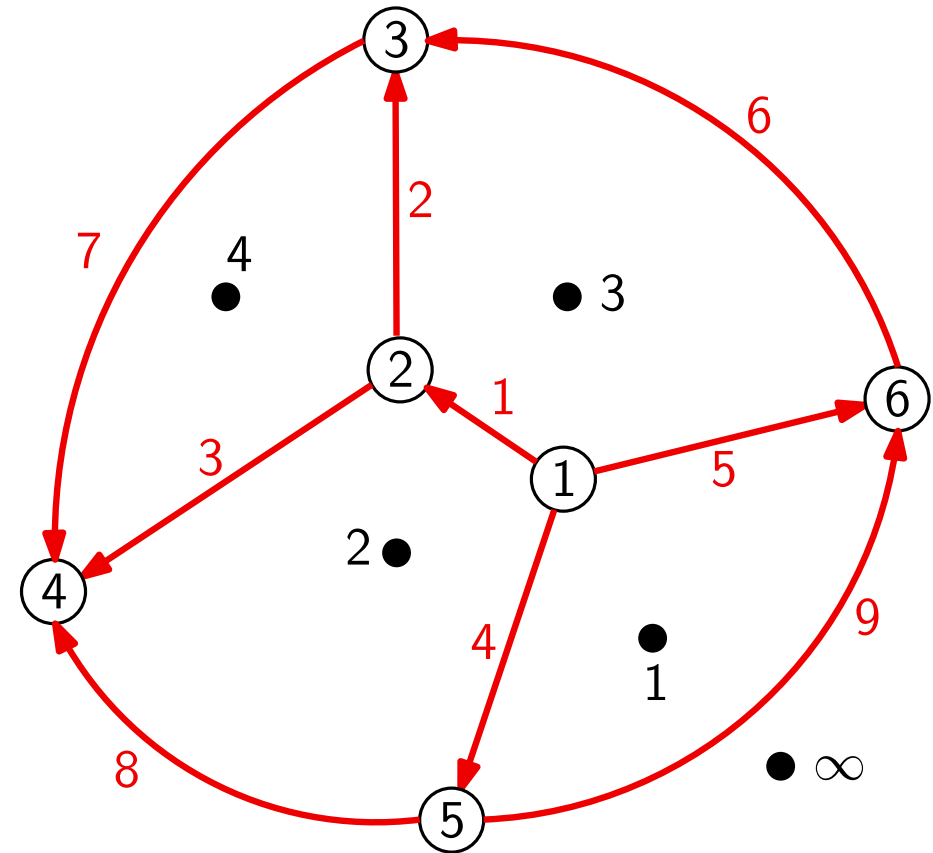
When $p_i = \infty$, the previous algorithm returns, in counterclockwise order, the (fictitious) edges of the Voronoi region of this (fictitious) point. For each obtained edge, reporting its other adjacent Voronoi face will produce the sorted list of the convex hull vertices of P , in time proportional to its size.



Voronoi diagram storage

How to obtain information from the DCEL

Delaunay diagram

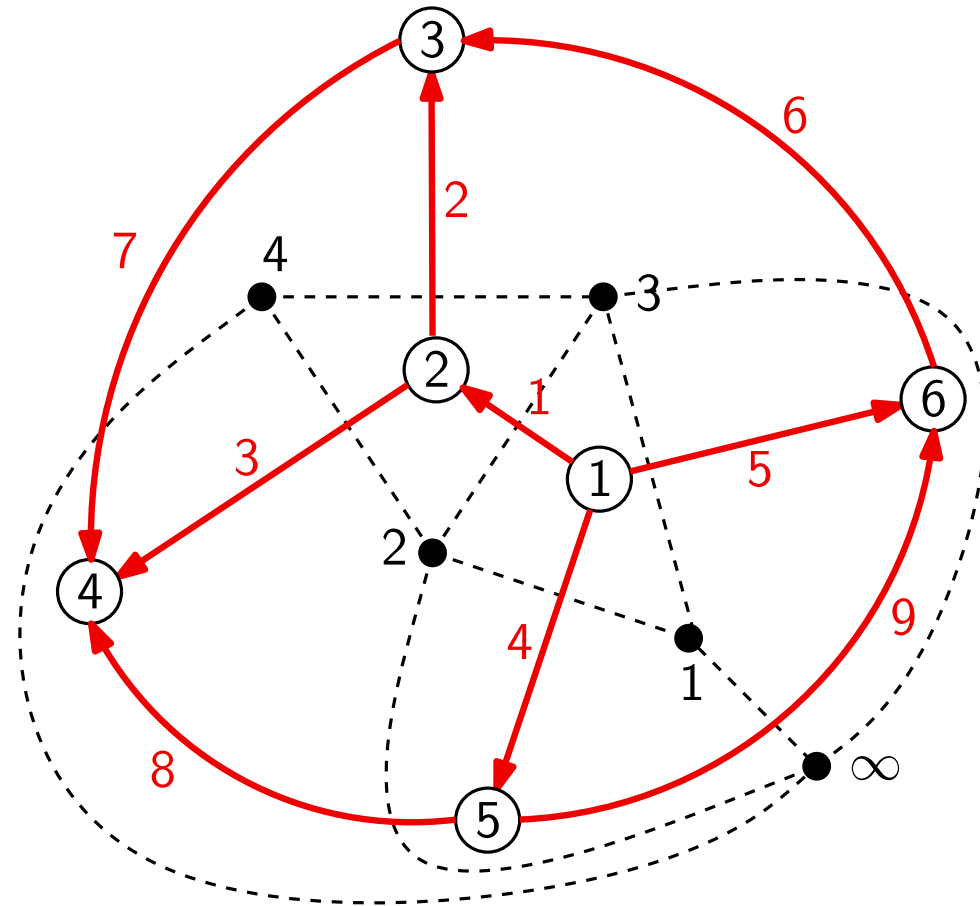


Voronoi diagram storage

How to obtain information from the DCEL

Delaunay diagram

The DCEL storing the Voronoi diagram information and the DCEL storing the Delaunay triangulation information are the same, we just need to do some “dual reading”:



Voronoi diagram storage

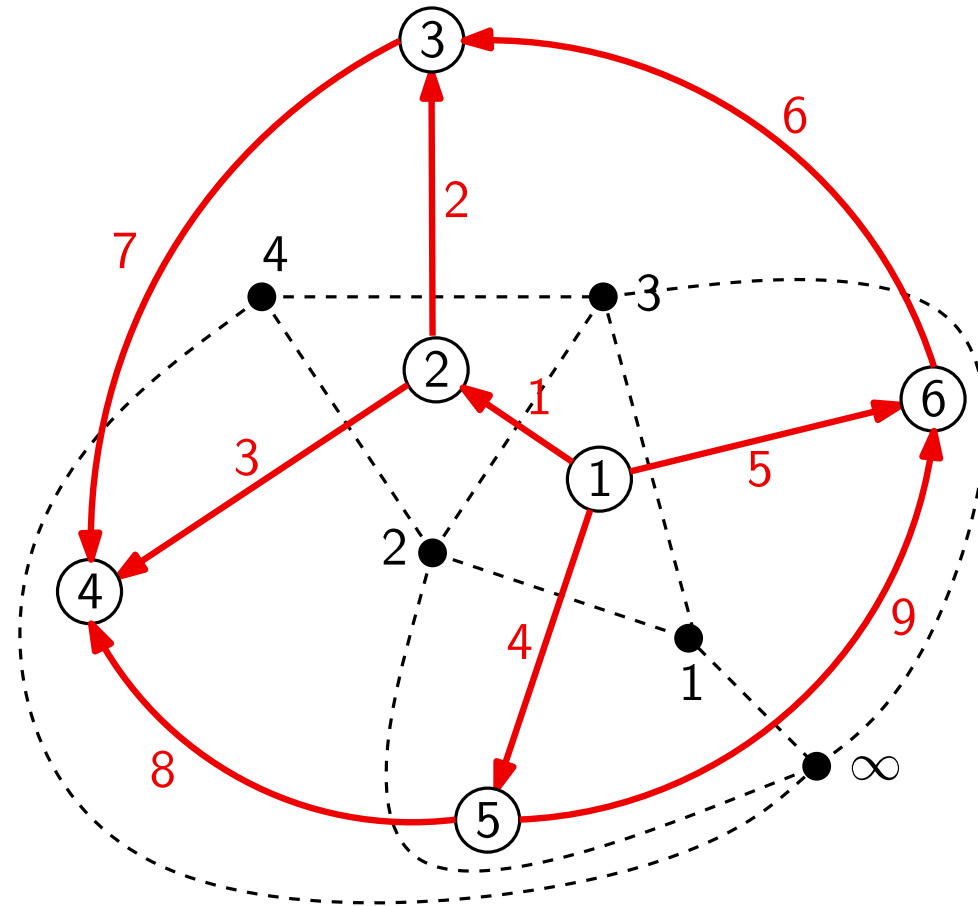
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Voronoi:

Delaunay:



Voronoi diagram storage

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Delaunay diagram

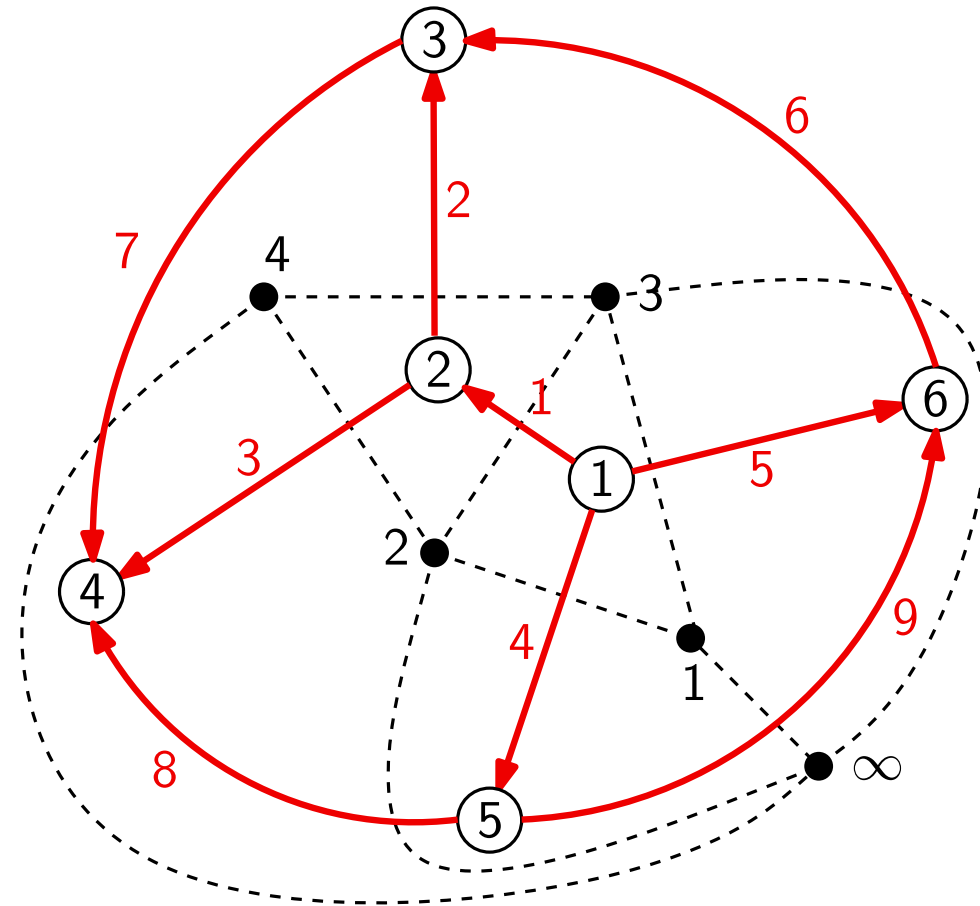
The DCEL storing the Voronoi diagram information and the DCEL storing the Delaunay triangulation information are the same, we just need to do some “dual reading”:

Voronoi: faces

p	x	y	e
-----	-----	-----	-----

Delaunay: vertices

p	x	y	e
			incident



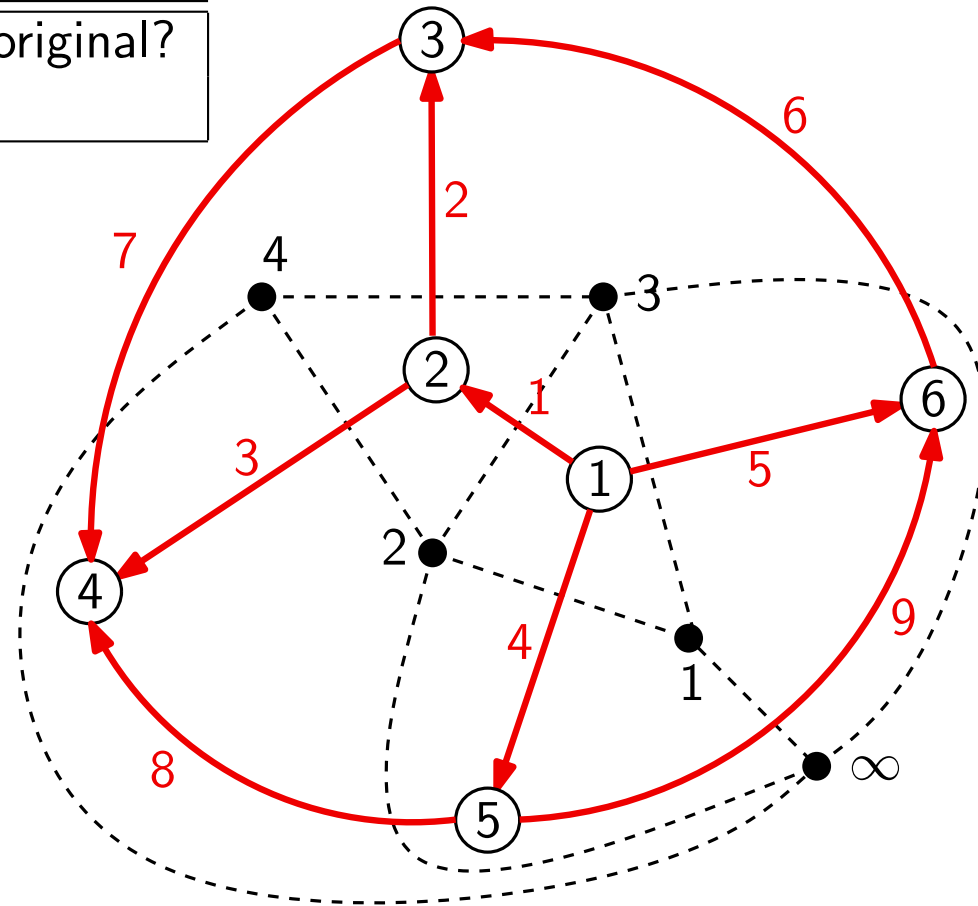
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Voronoi:	vertices	<table border="1"><tr><td>v</td><td>x</td><td>y</td><td>e</td><td>original?</td></tr></table>	v	x	y	e	original?					
v	x	y	e	original?								
Delaunay:	triangles	<table border="1"><tr><td>v</td><td>x</td><td>y</td><td>e</td><td>original?</td></tr><tr><td></td><td>circumcenter</td><td></td><td>edge</td><td></td></tr></table>	v	x	y	e	original?		circumcenter		edge	
v	x	y	e	original?								
	circumcenter		edge									



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Voronoi: edges

e	v_B	v_E	f_L	f_R	e_P	e_N
-----	-------	-------	-------	-------	-------	-------

Delaunay: edges

e	f_L	f_R	v_E	v_B	e_N	e_P
dual					clockwise	

