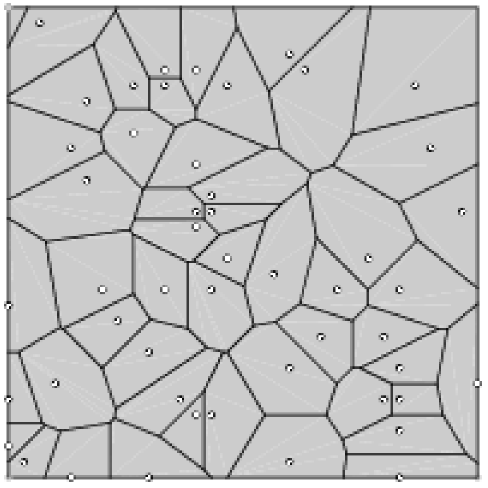
Voronoi Diagram



Sasanka Roy
Indian Institute of Science Education and Research

Organization of the Talk

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1. Preliminaries
2. Generic Definition
3. Some Technical Details
4. Conclusion

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What are we going to talk about?

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We have some data

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Geometric Data

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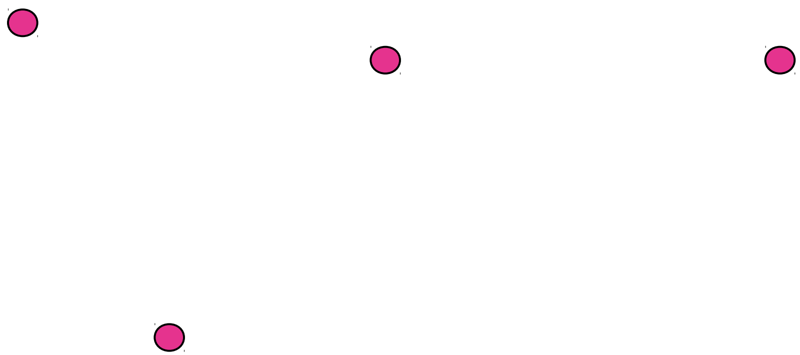

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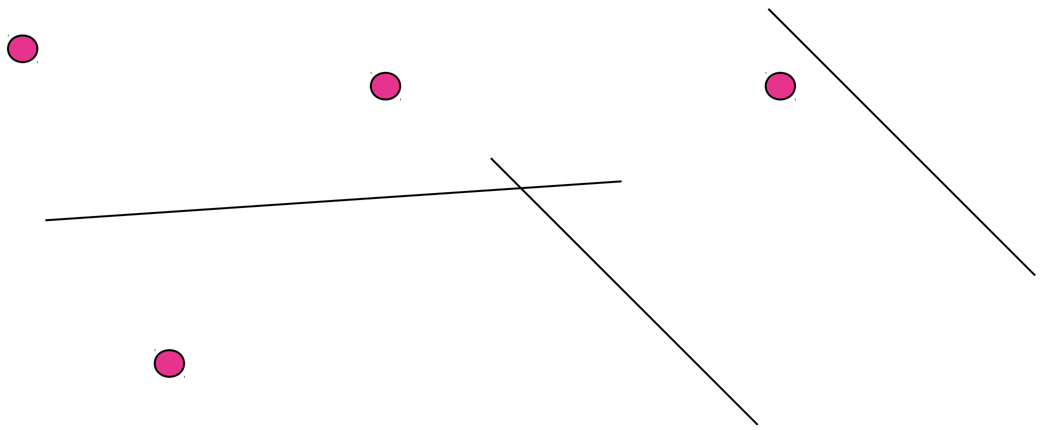
I mean: we have points, line segments,



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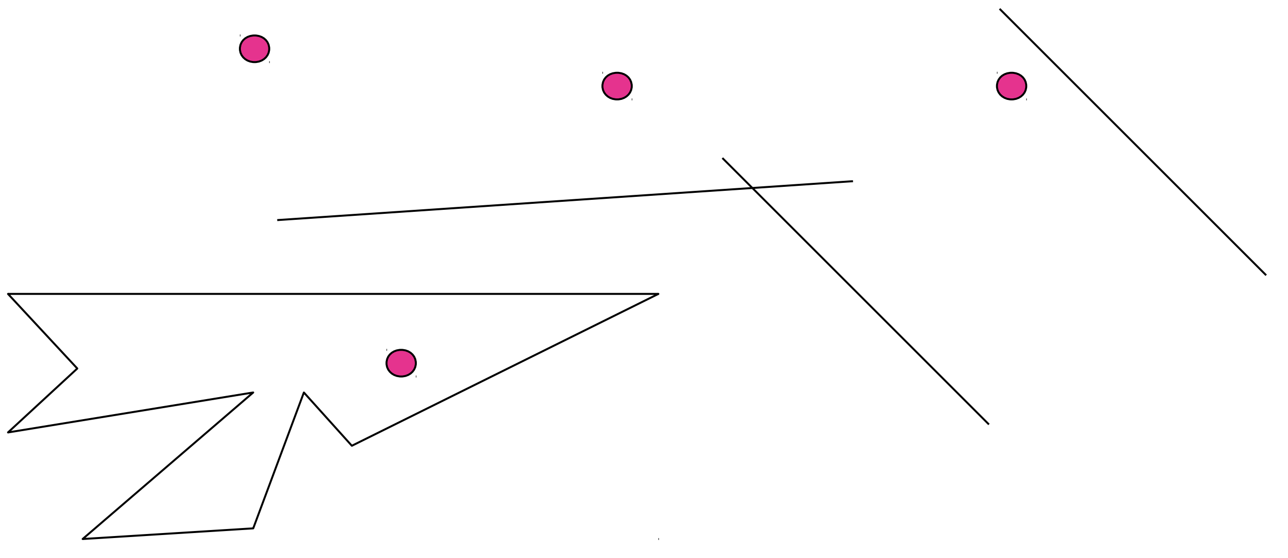

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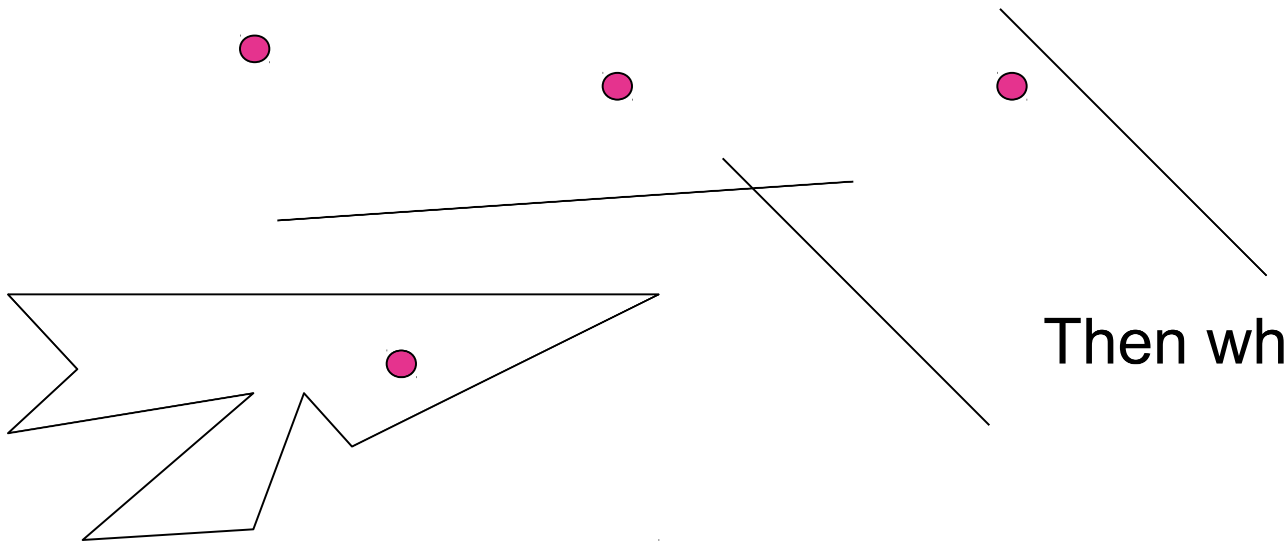

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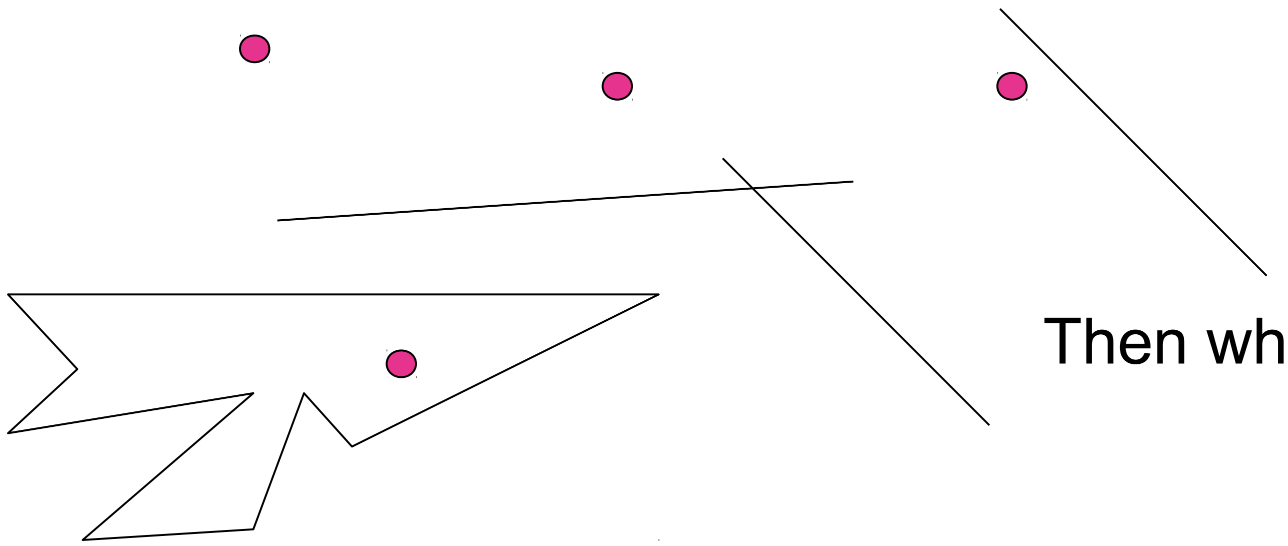

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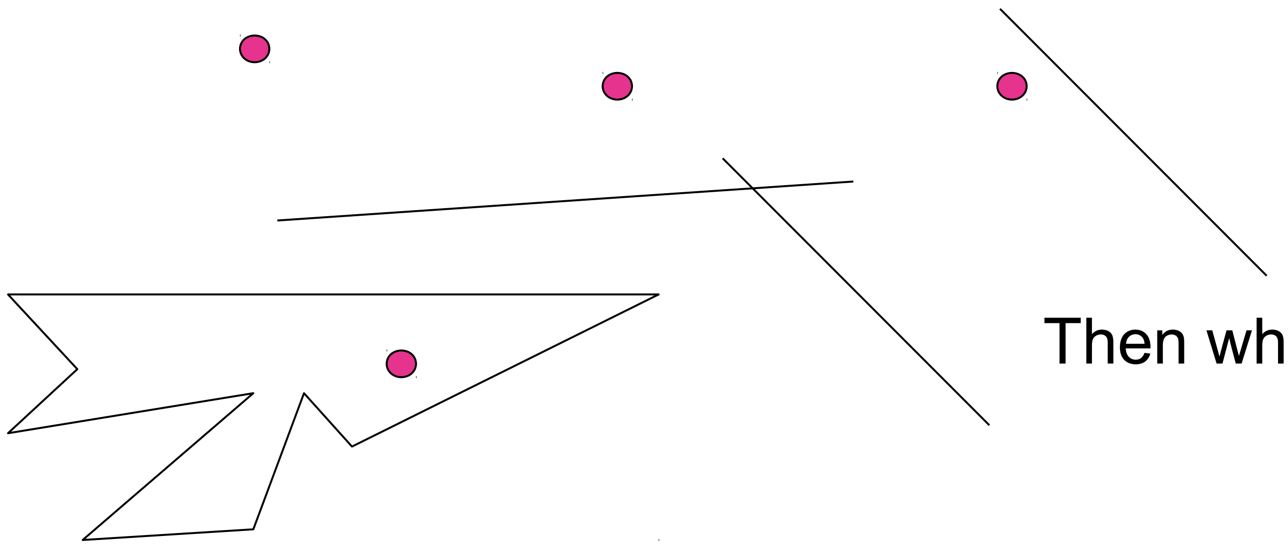

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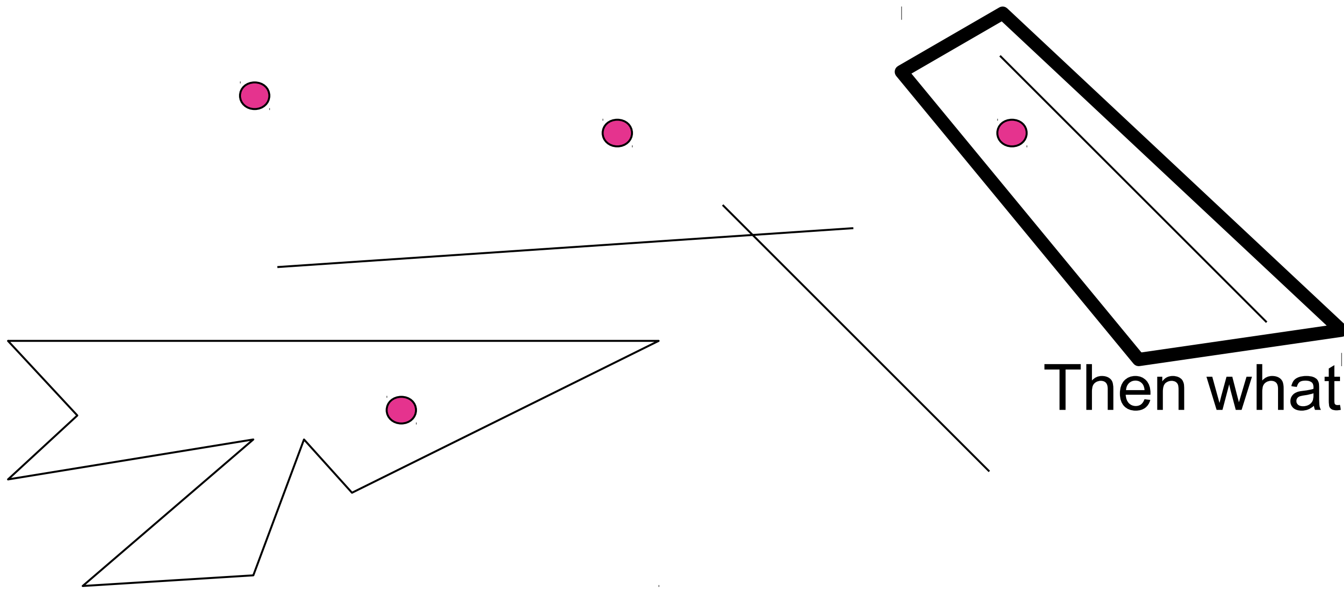

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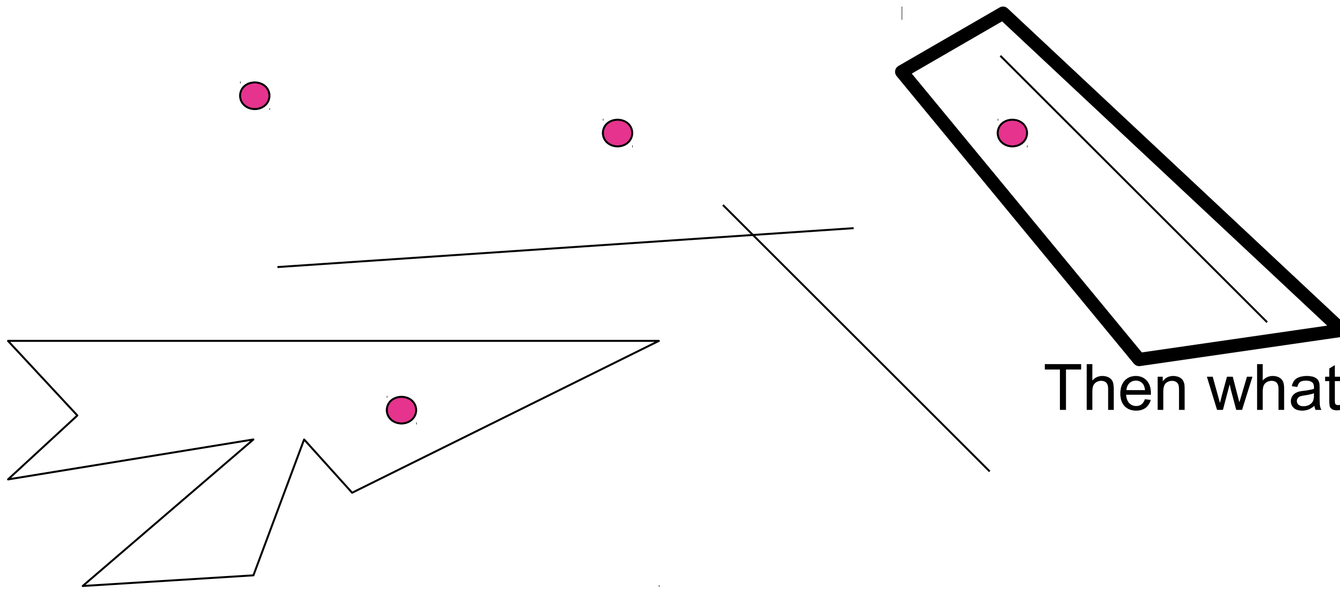

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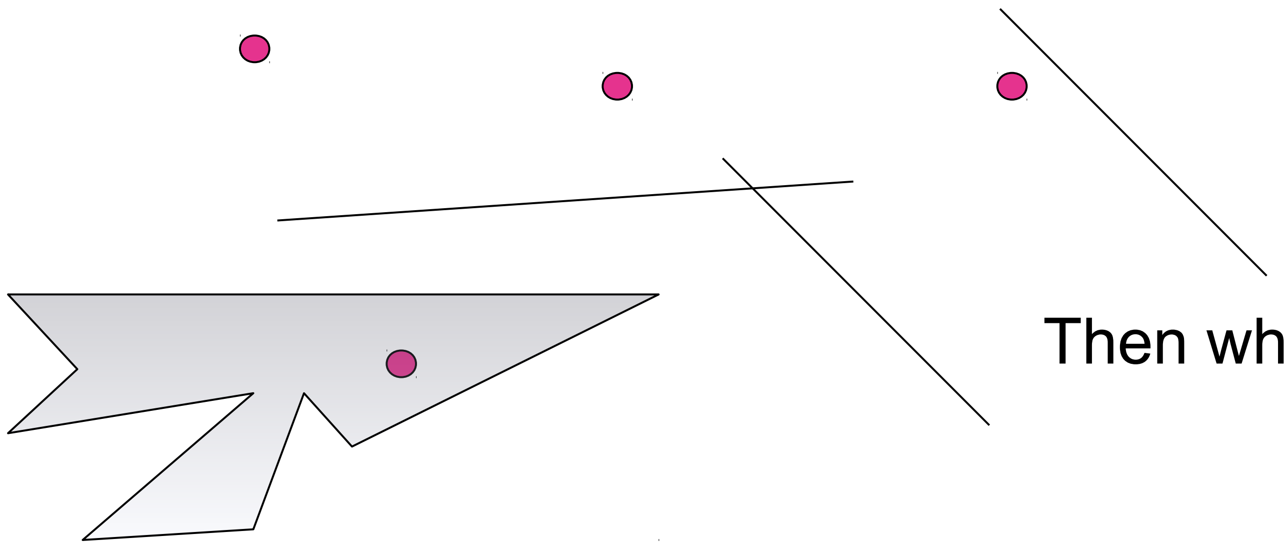

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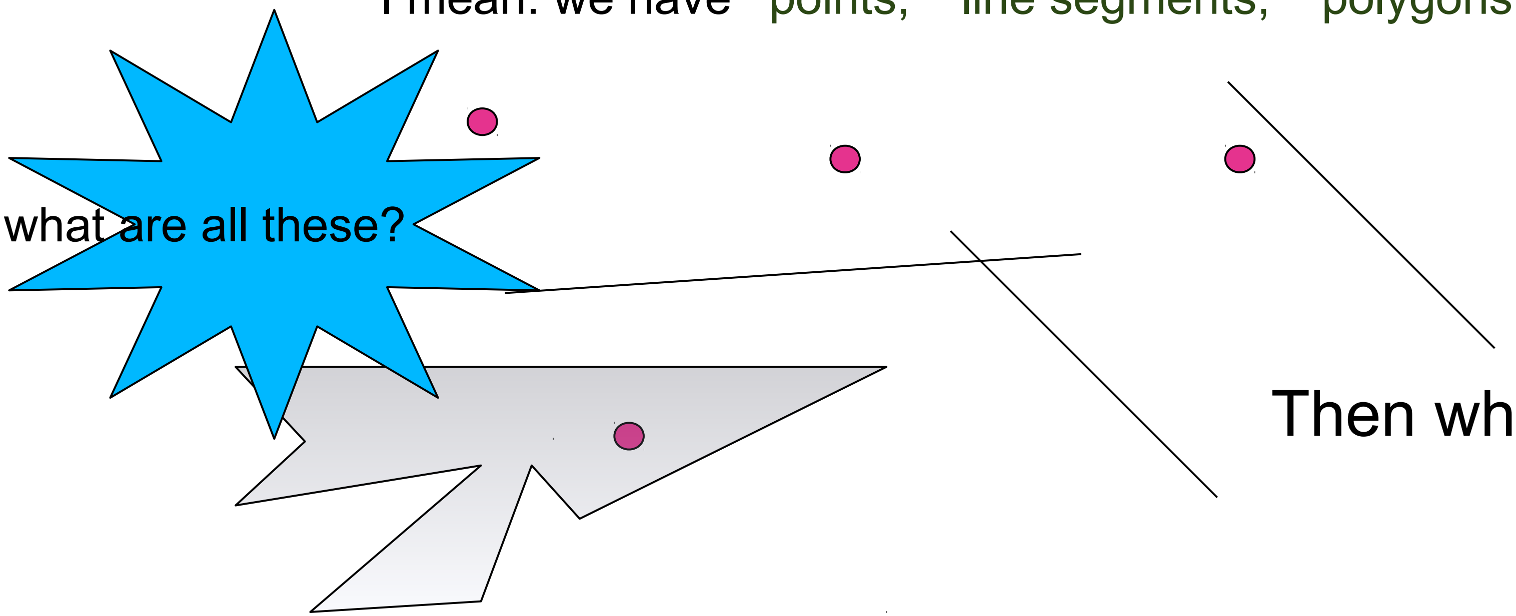

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Can you be a bit Practical??

Planar Point Location

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Which state has the site/point with

Latitude= 26° 11' 0" N

Longitude= 91° 44' 0"E

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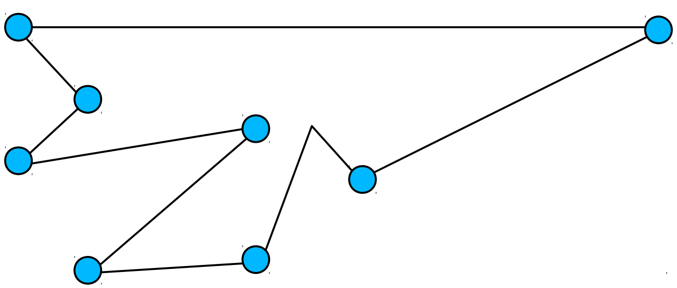

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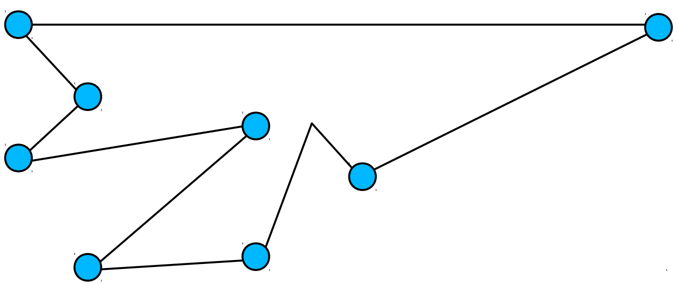

simple polygon: Closed region whose boundary is formed by non-intersecting line segments

Planar Point Location

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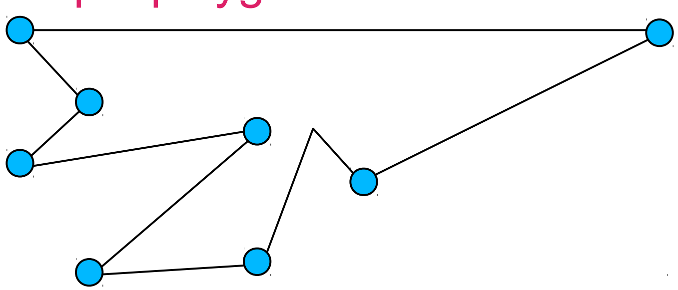
Longitude= 91° 44' 0"E

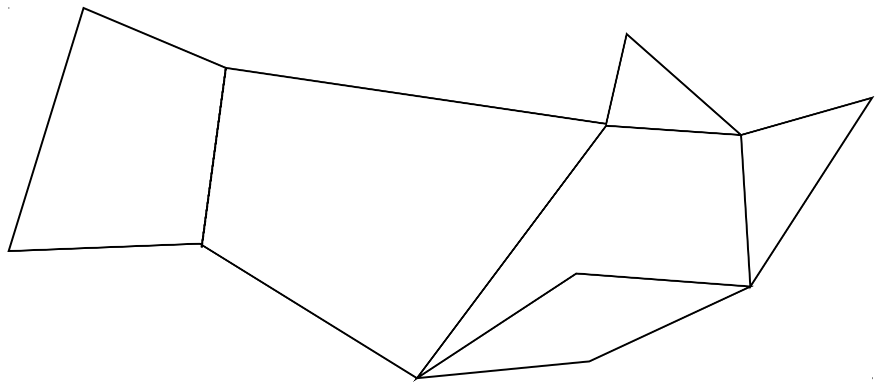
Can we view States as simple polygon? Yes



simple polygon: Closed region whose boundary is formed by non-intersecting line segments

Formally Planar Point Location

Given a planar subdivision S of O(n) vertices/faces/edges



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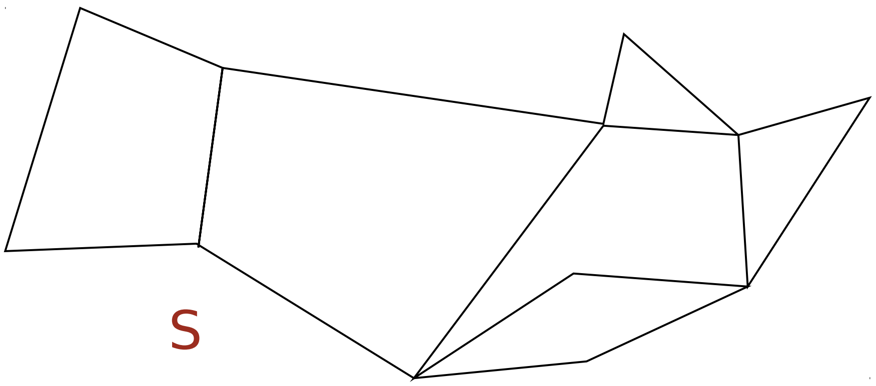

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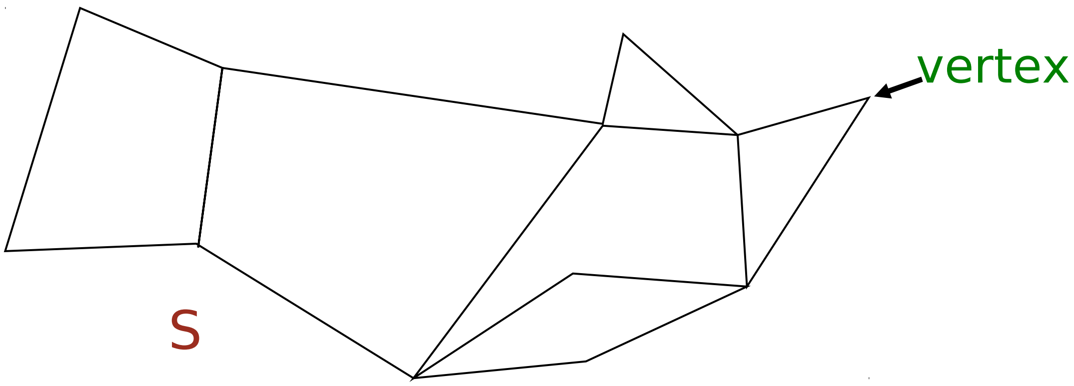

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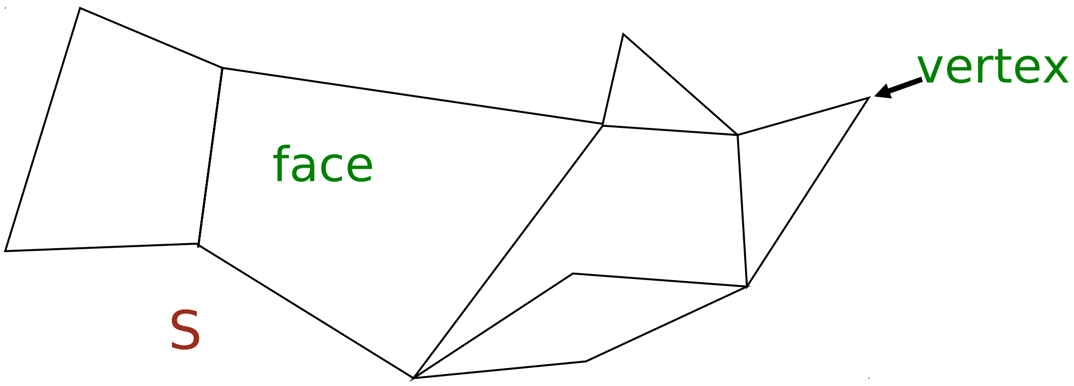

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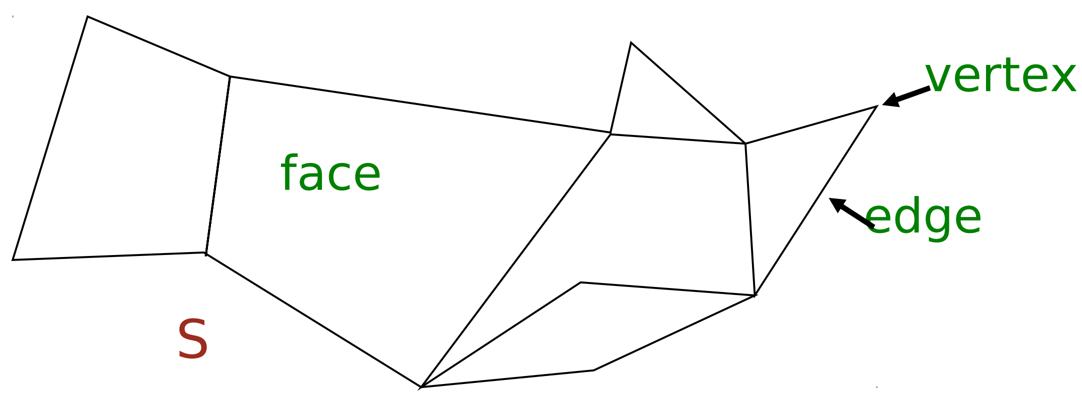

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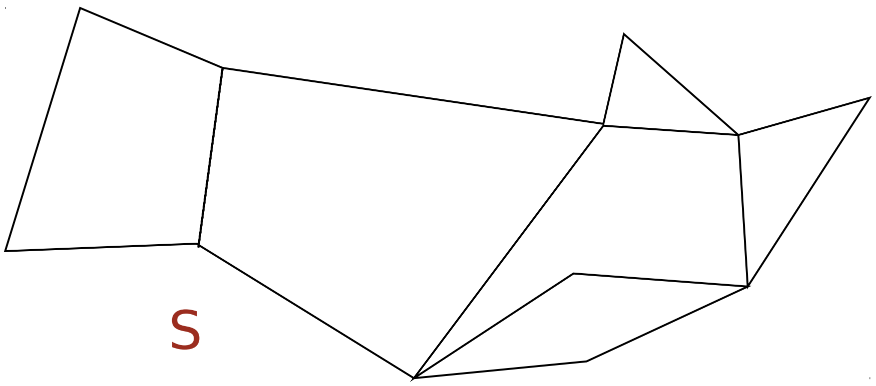
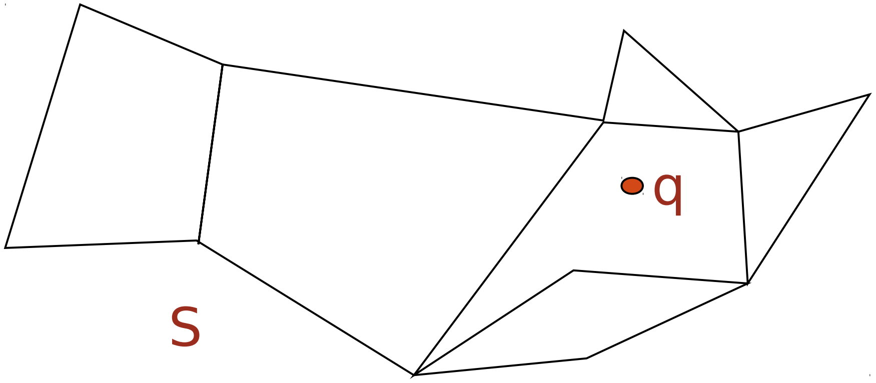


S

Preprocess S such that:

Formally Planar Point Location

Given a planar subdivision S



Preprocess S such that:

For any query point q,

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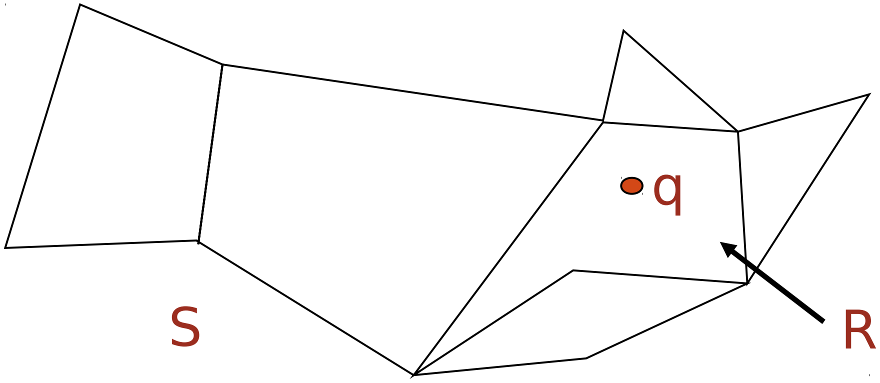

Preprocess S such that:

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The region/face R containing q can be reported efficiently.

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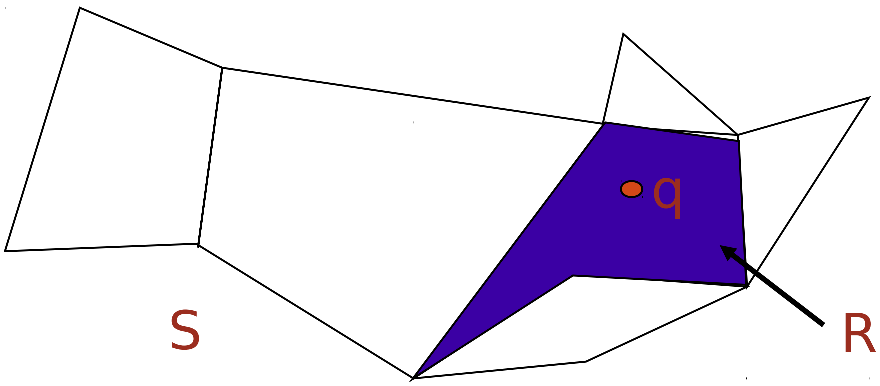

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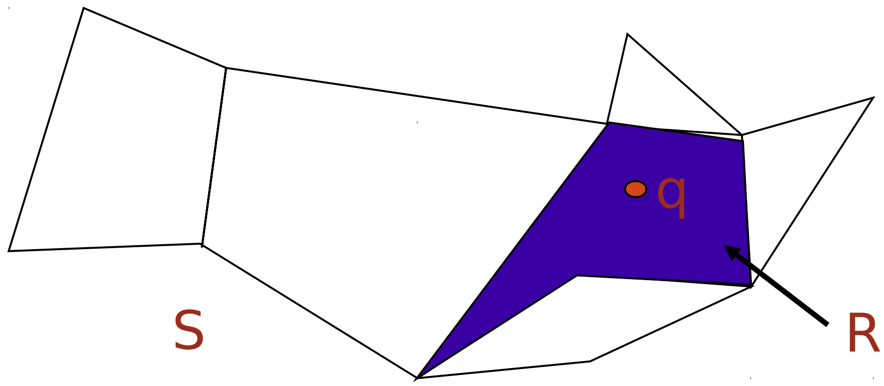

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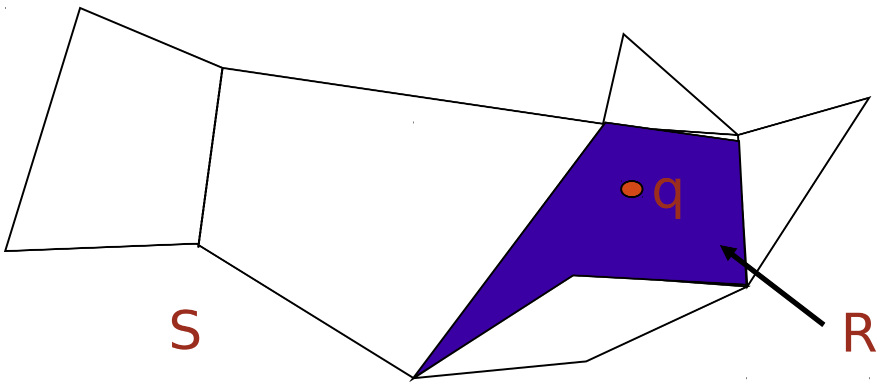
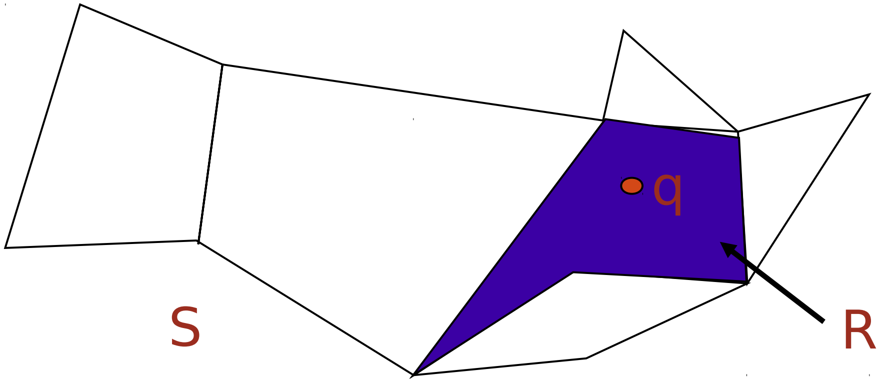


Preprocessing Time:

Questions?



Preprocessing Time:

Preprocessing space requirement:

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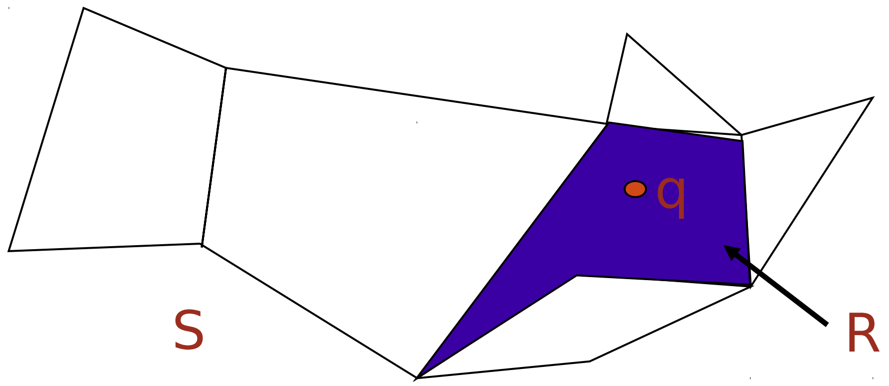

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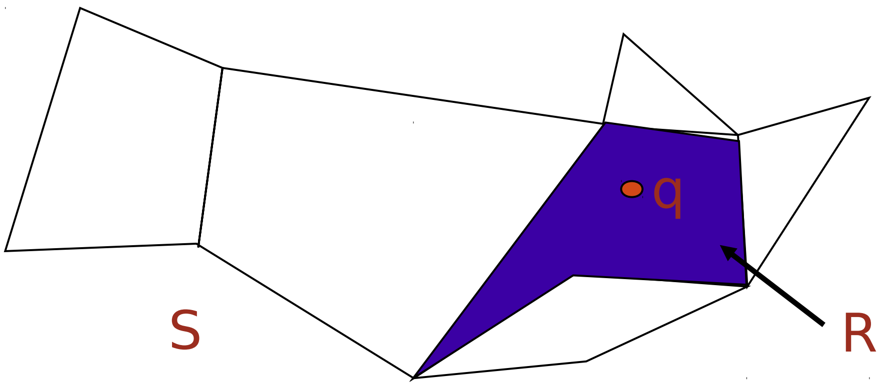

Preprocessing Time: O(n)

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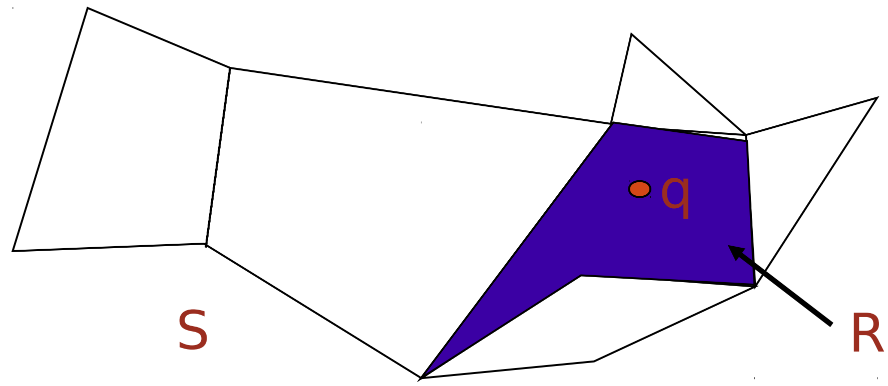

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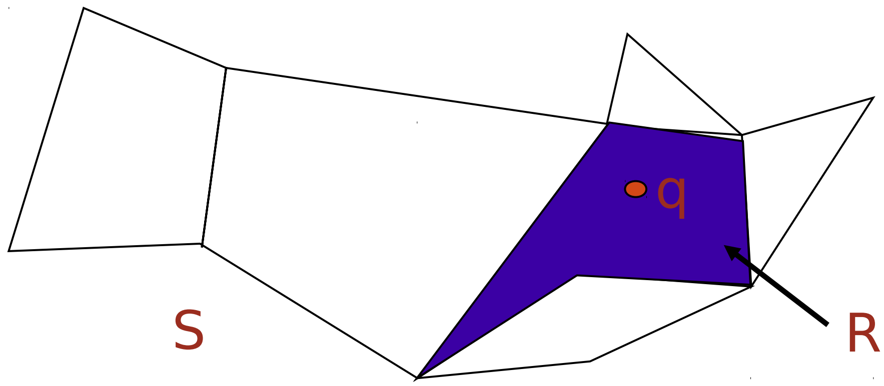
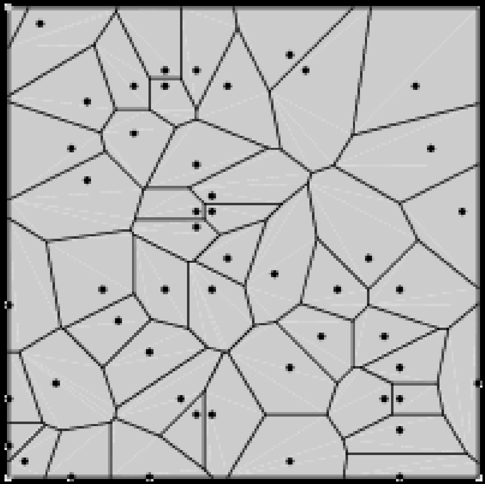


Preprocessing Time: O(n)

Preprocessing space requirement: O(n)

Query Time: O(log n)

Back to Voronoi Diagram



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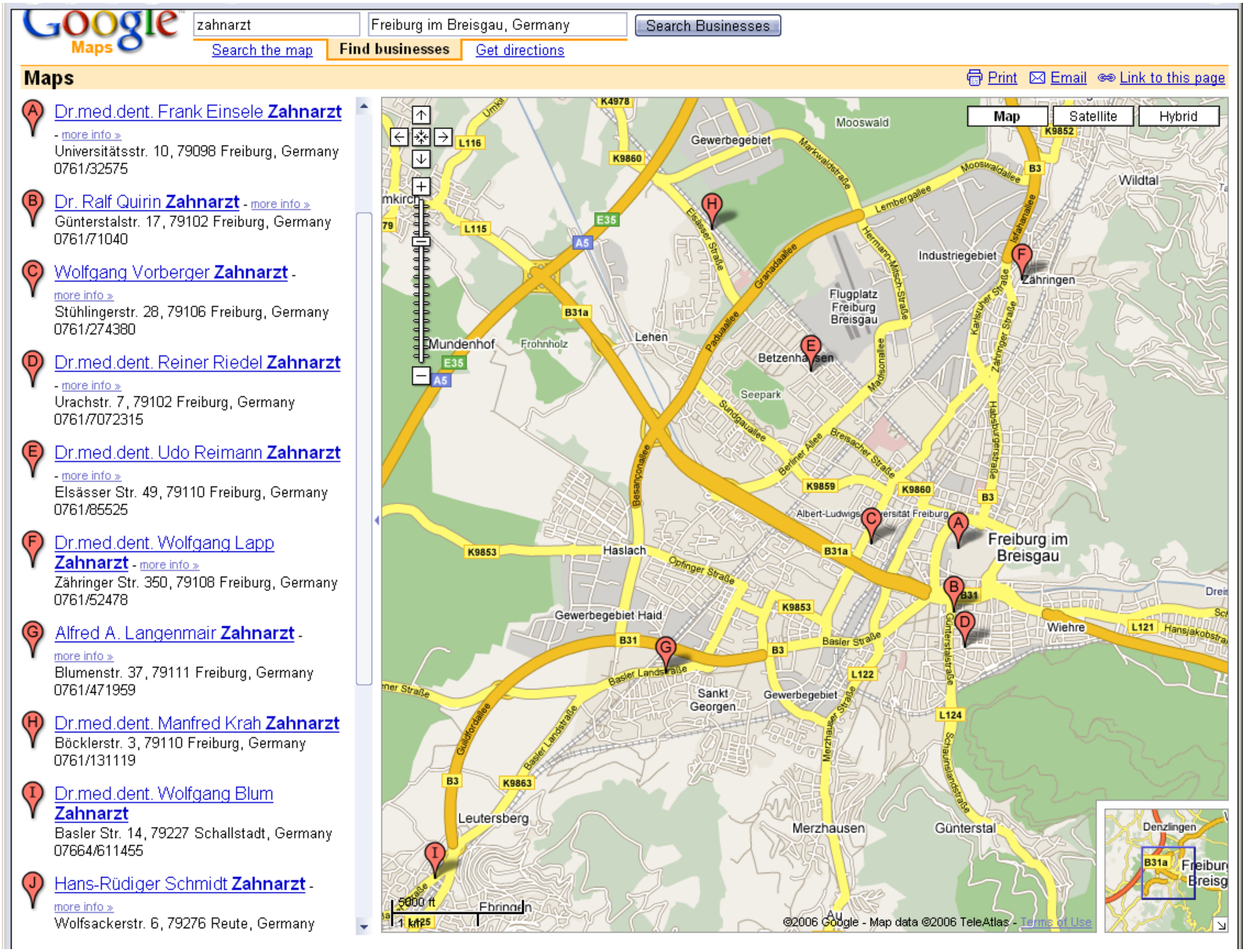

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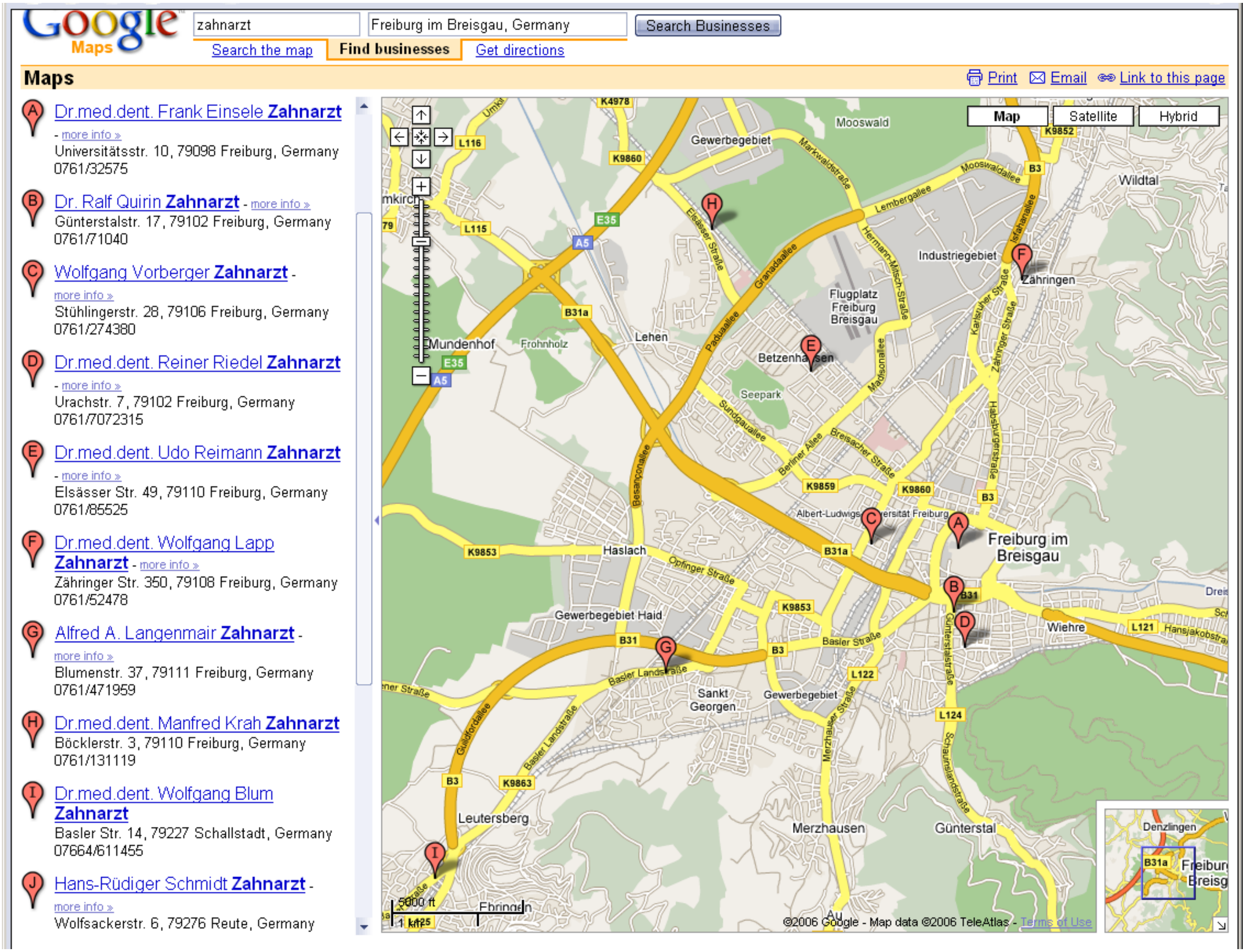
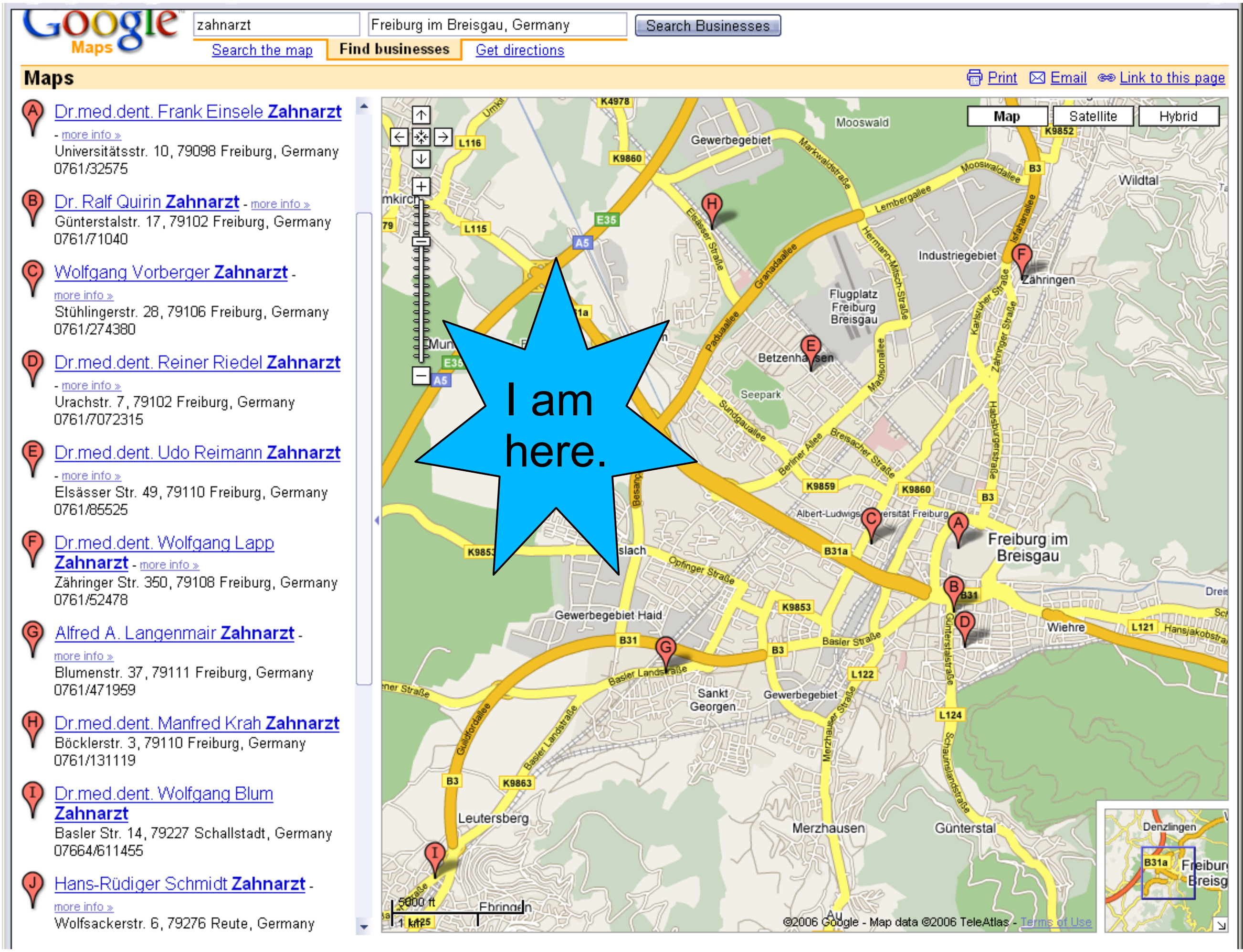


Viewpoint 1: Locate the nearest dentistry.

Viewpoint 2: Find the ‘service area’ of potential customers for each dentist.

Thank you Google



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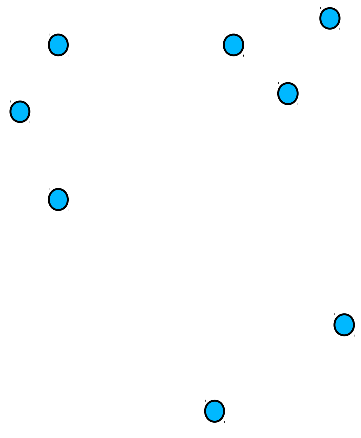

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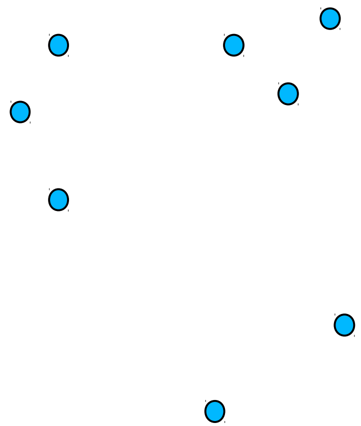
Preprocess P such that closest point $x \in P$ of any query point q can be found efficiently



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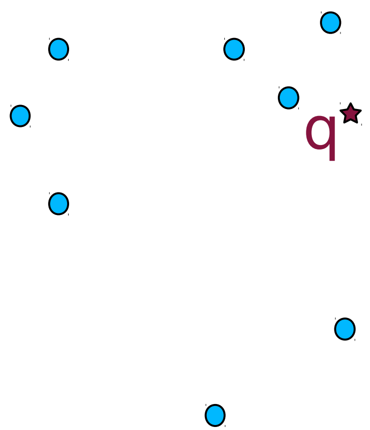

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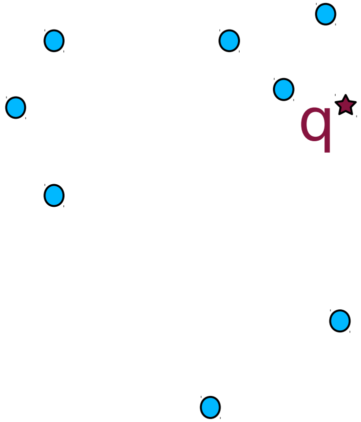

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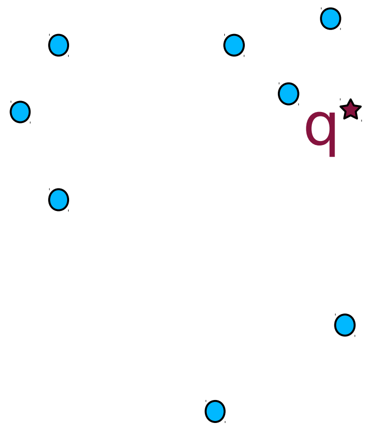
Subdivision of the plane into n cells such that



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Subdivision of the plane into n cells such that

- each cell contains exactly one site,
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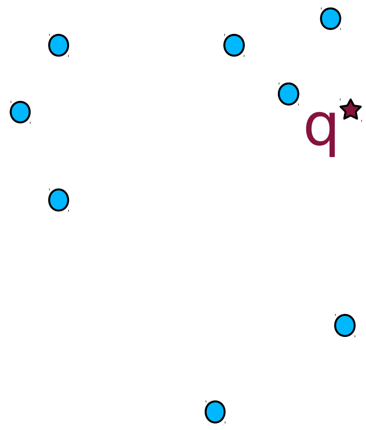

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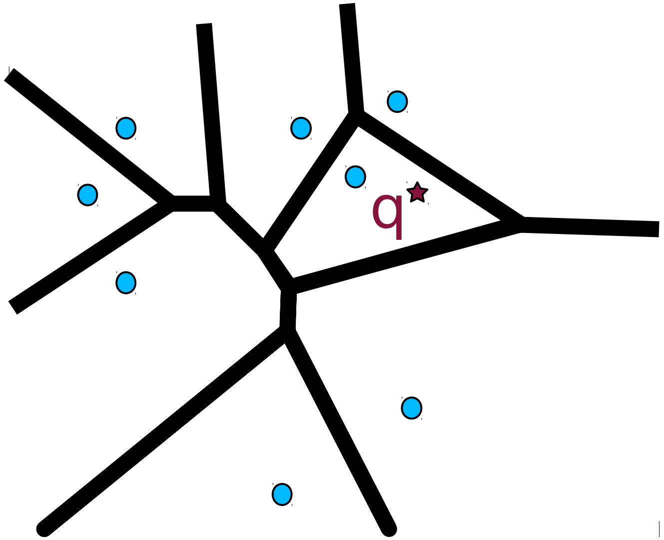

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Voronoi diagram of P:

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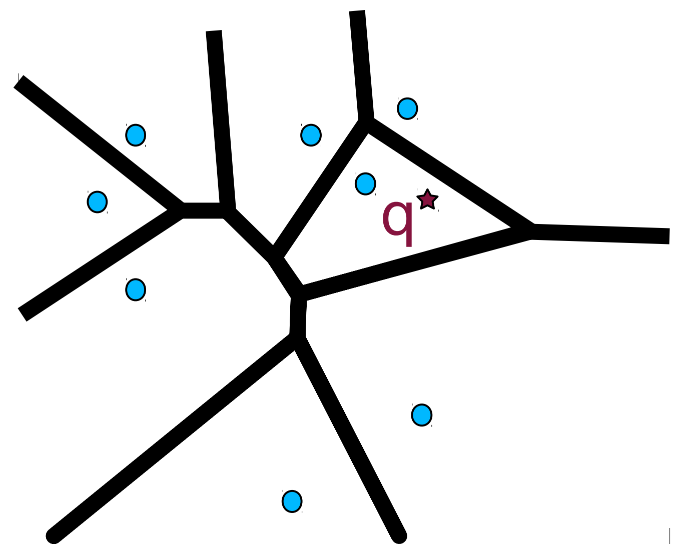

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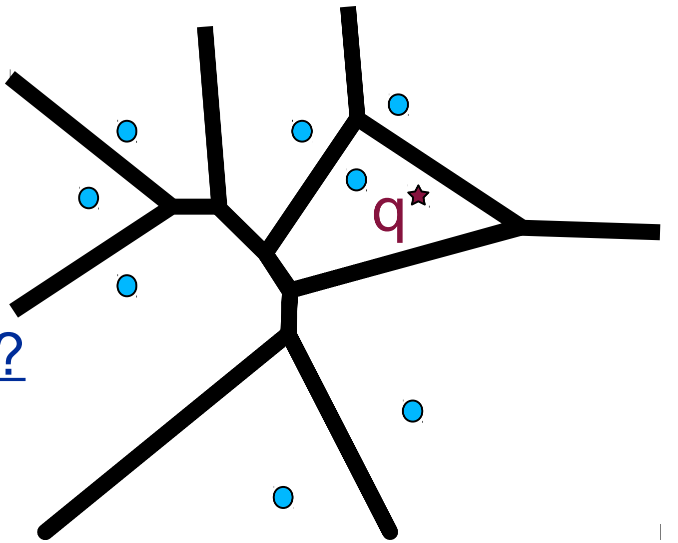

This is Planar Subdivision so what can we do?

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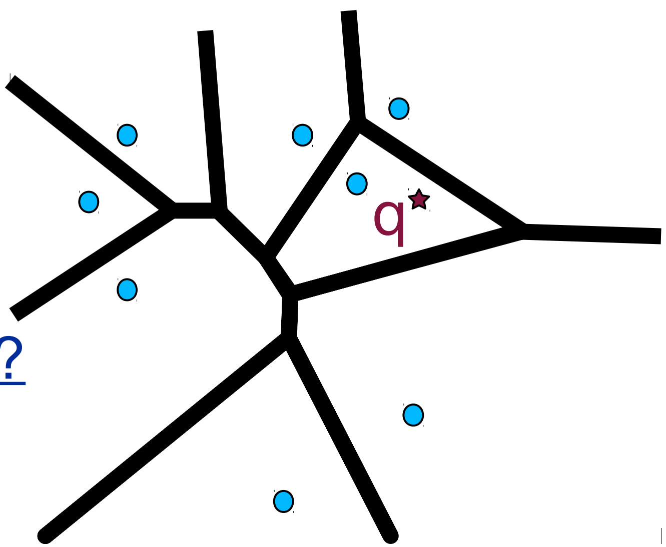

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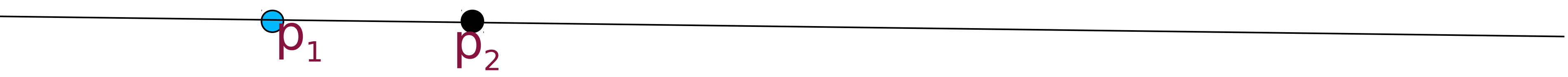
Planar point location

Computing the Voronoi Diagram

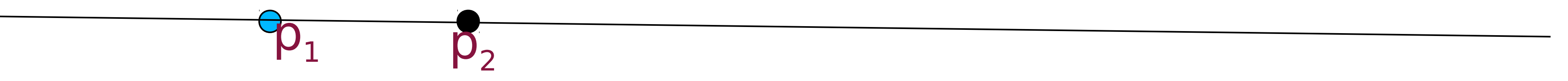
Input: A set of points on a line (special case)



Computing the Voronoi Diagram

Input: A set of points on a line (special case)

Output: A partitioning of the plane into regions of nearest neighbors



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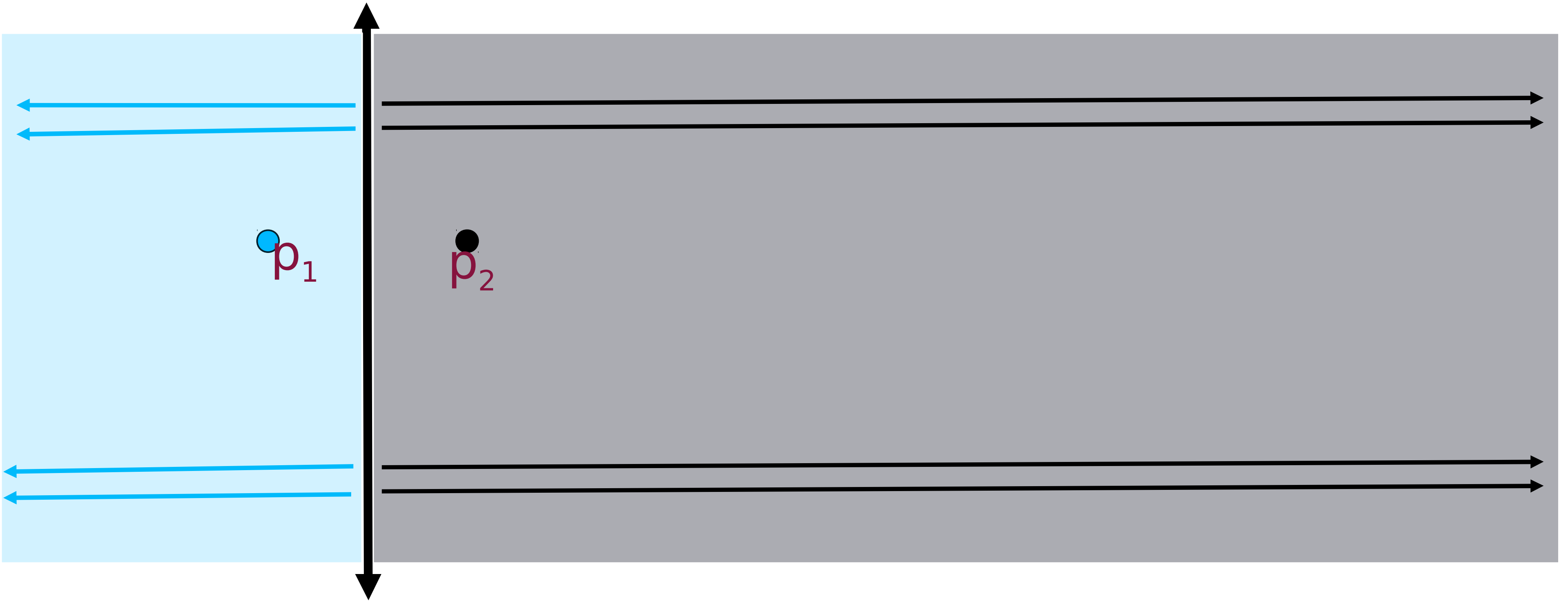

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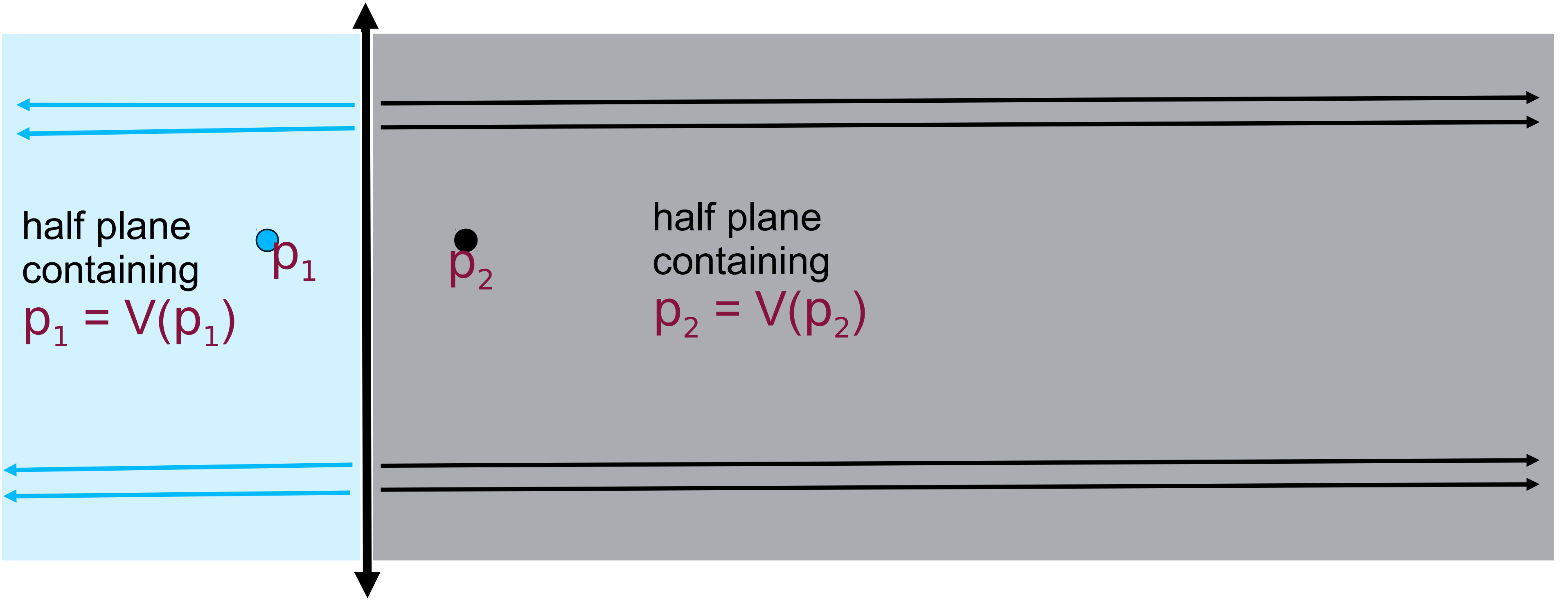

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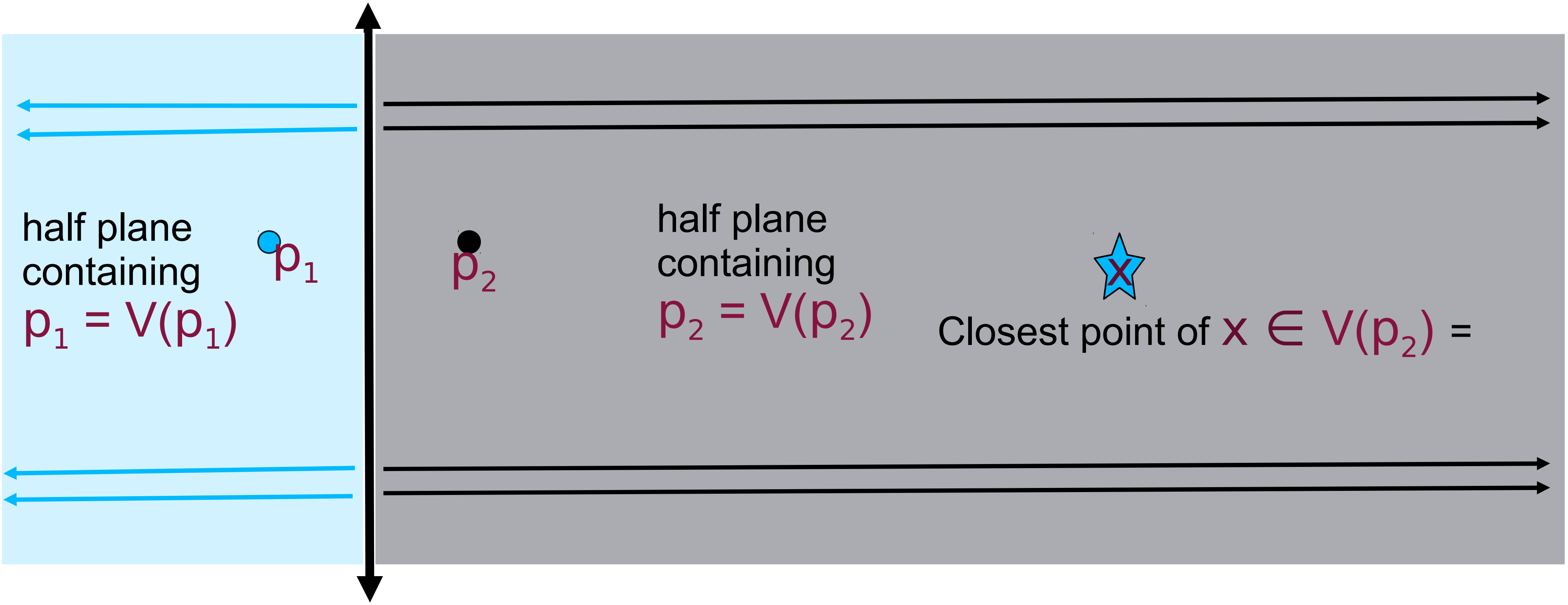

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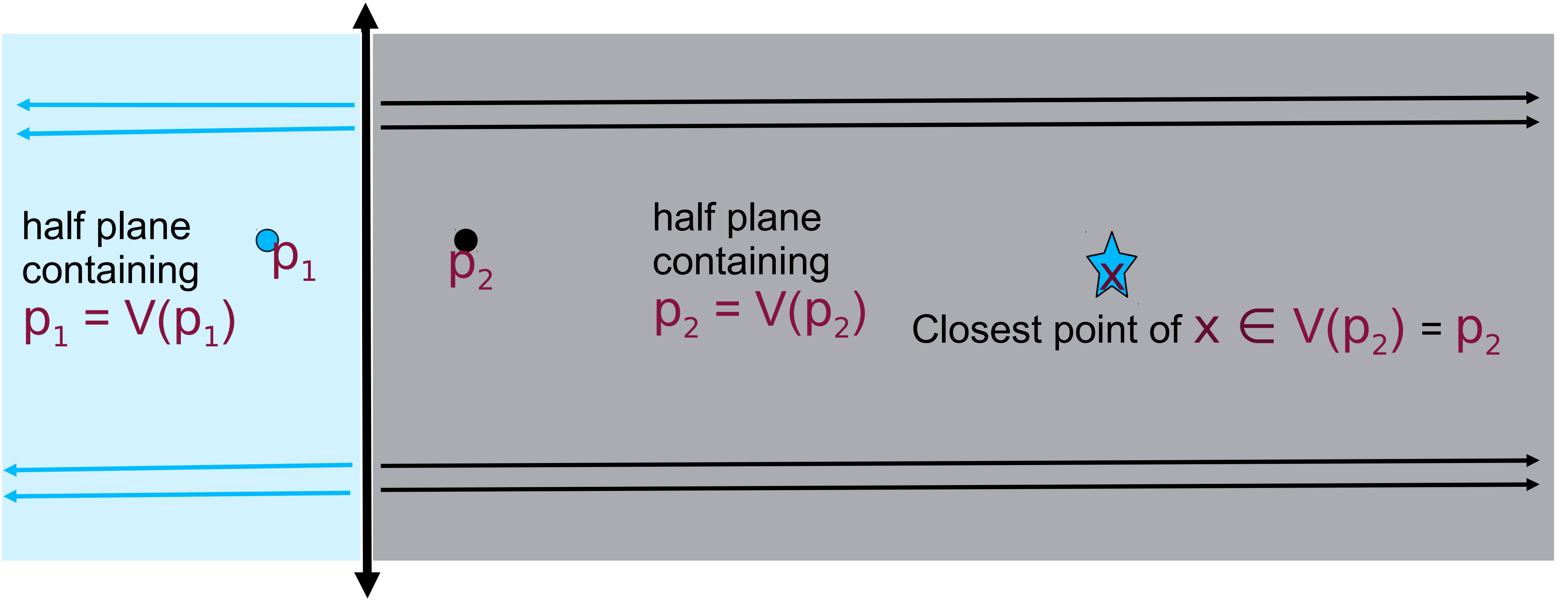

Computing the Voronoi Diagram

Input: A set of points on a line (special case)

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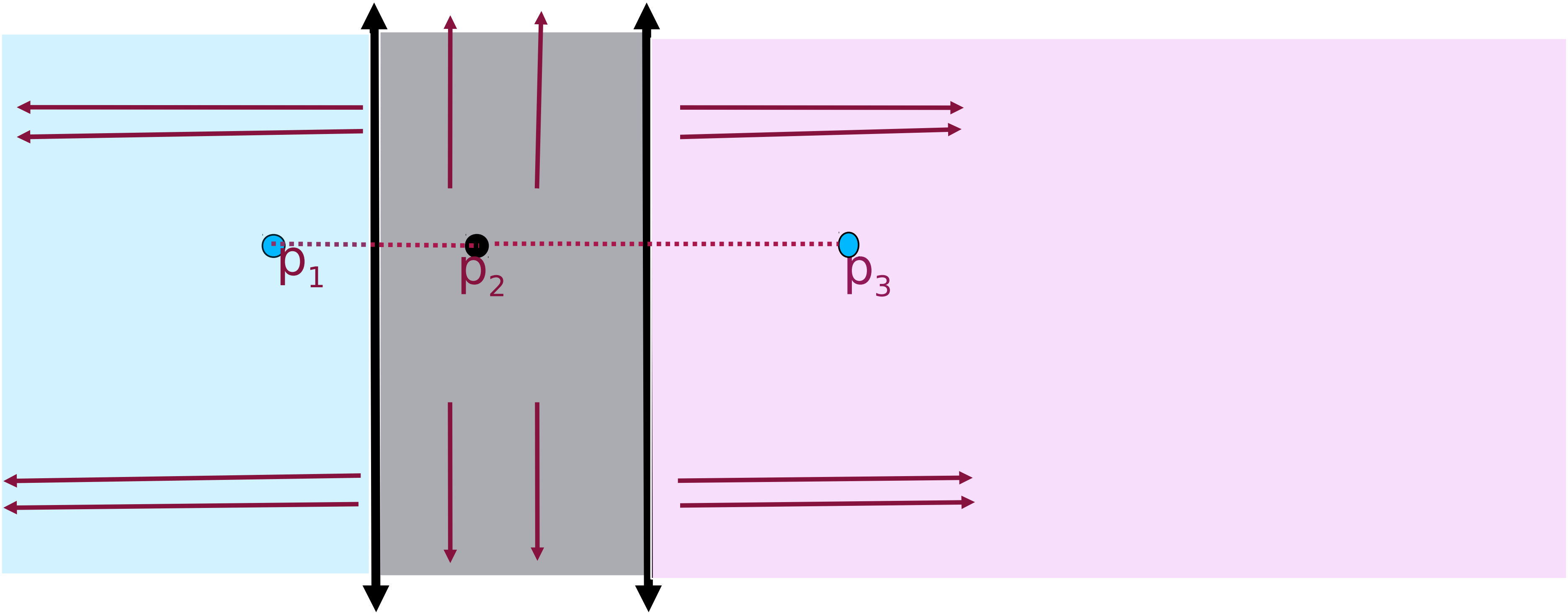

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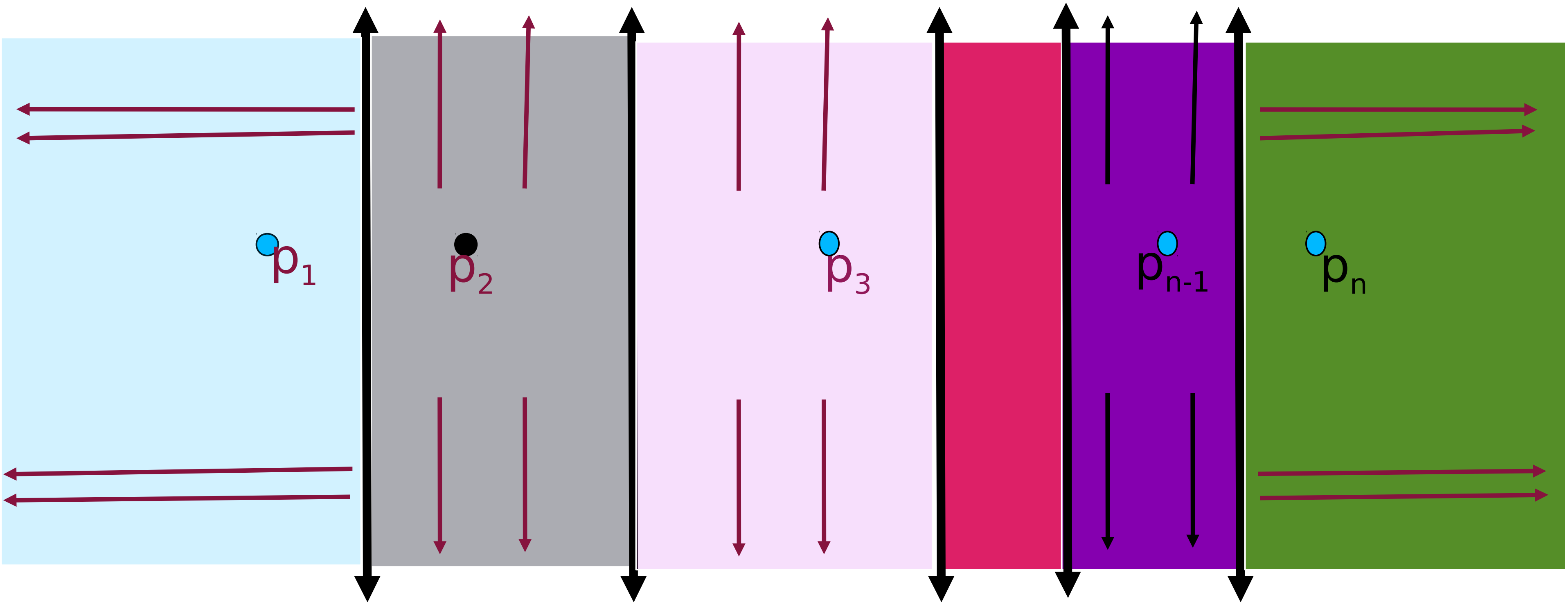

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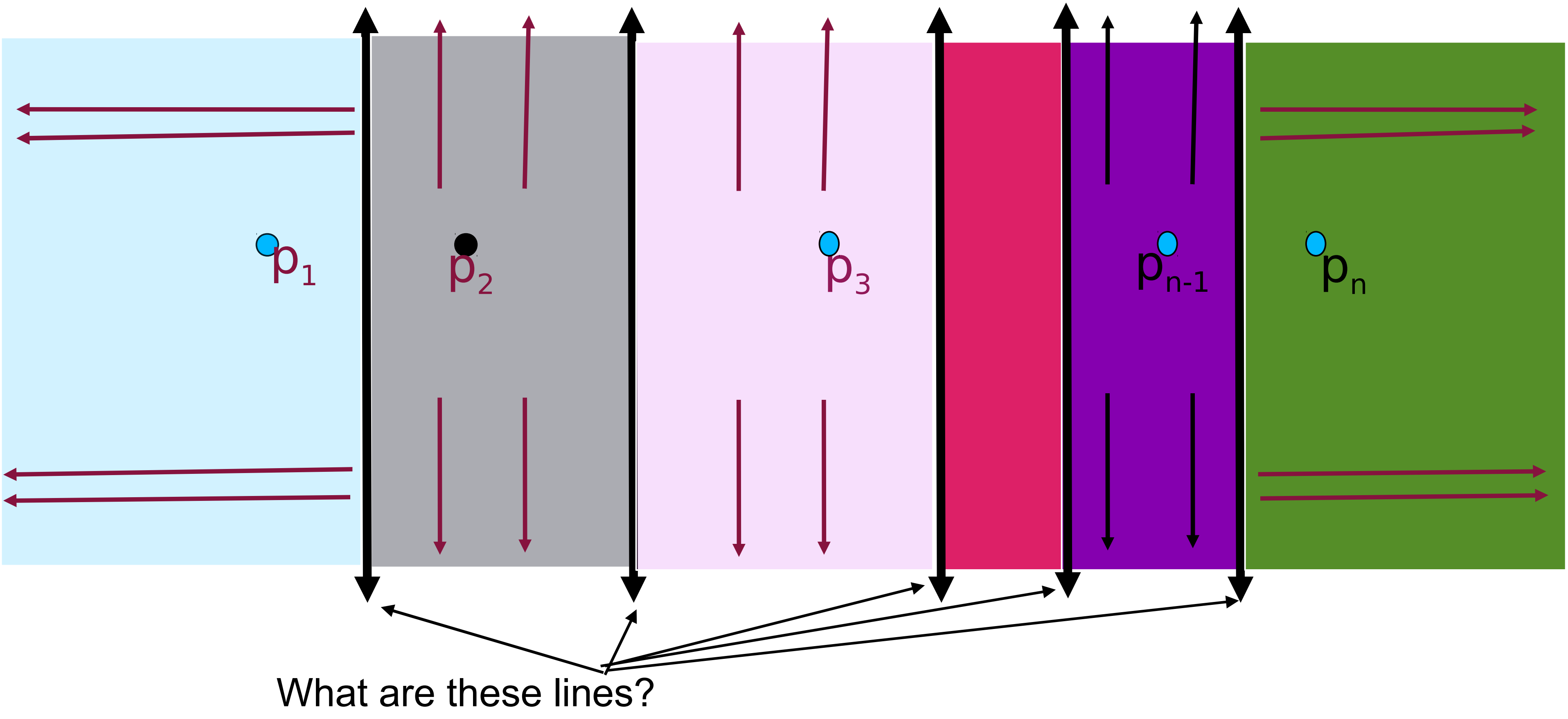

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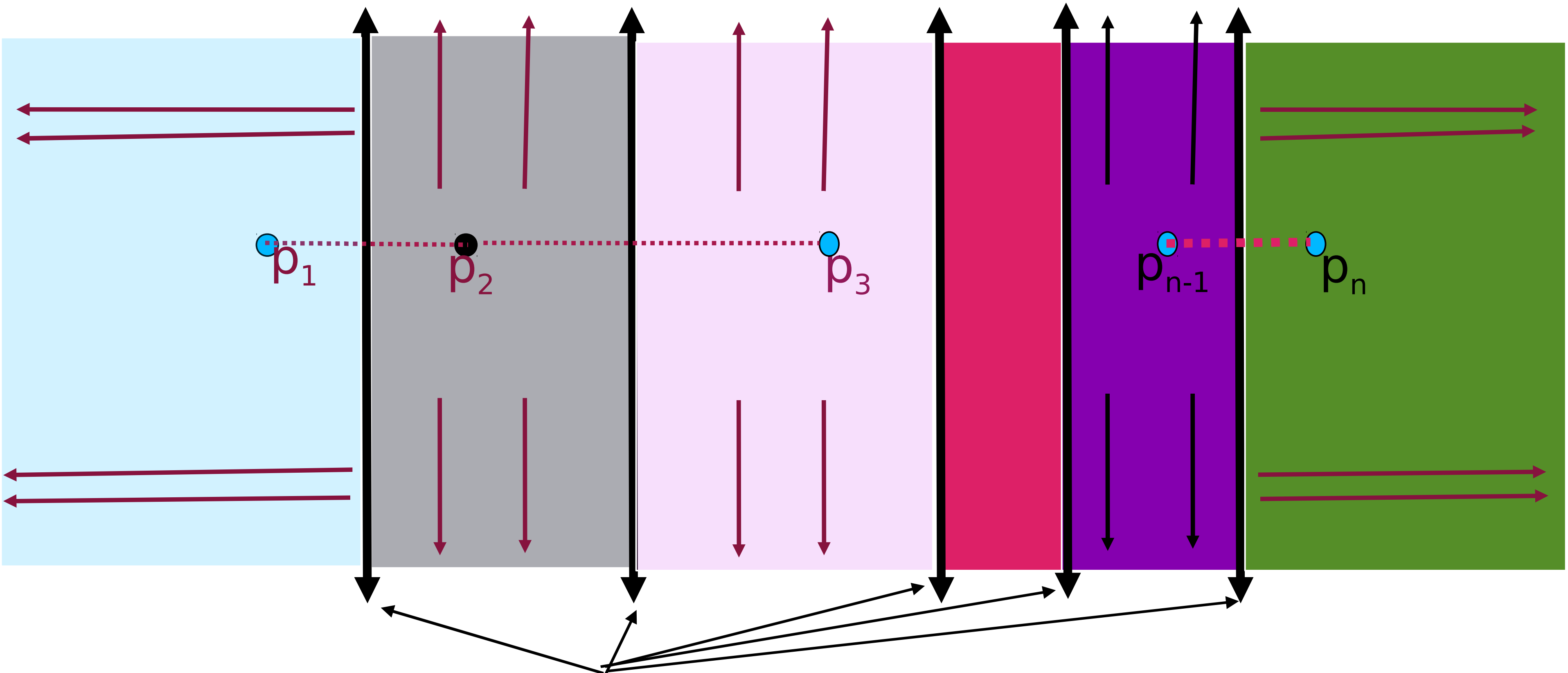

What are these lines? Perpendicular bisector of line segment [p_i p_{i+1}]

Computing the Voronoi Diagram

Computing the Voronoi Diagram

Input: A set of points $P=(p_1, p_2, \ldots, p_n)$ on a line (special case)

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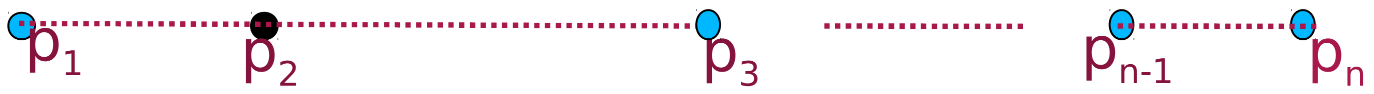

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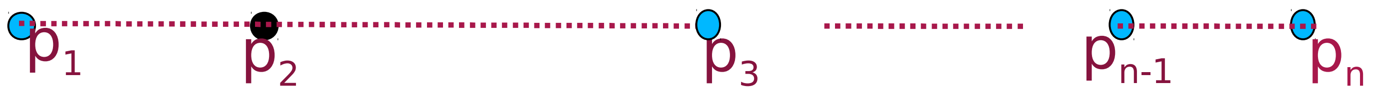

Find Perpendicular bisector l_i of line segment $[\, p_i \; p_{i+1} \,]$

Computing the Voronoi Diagram

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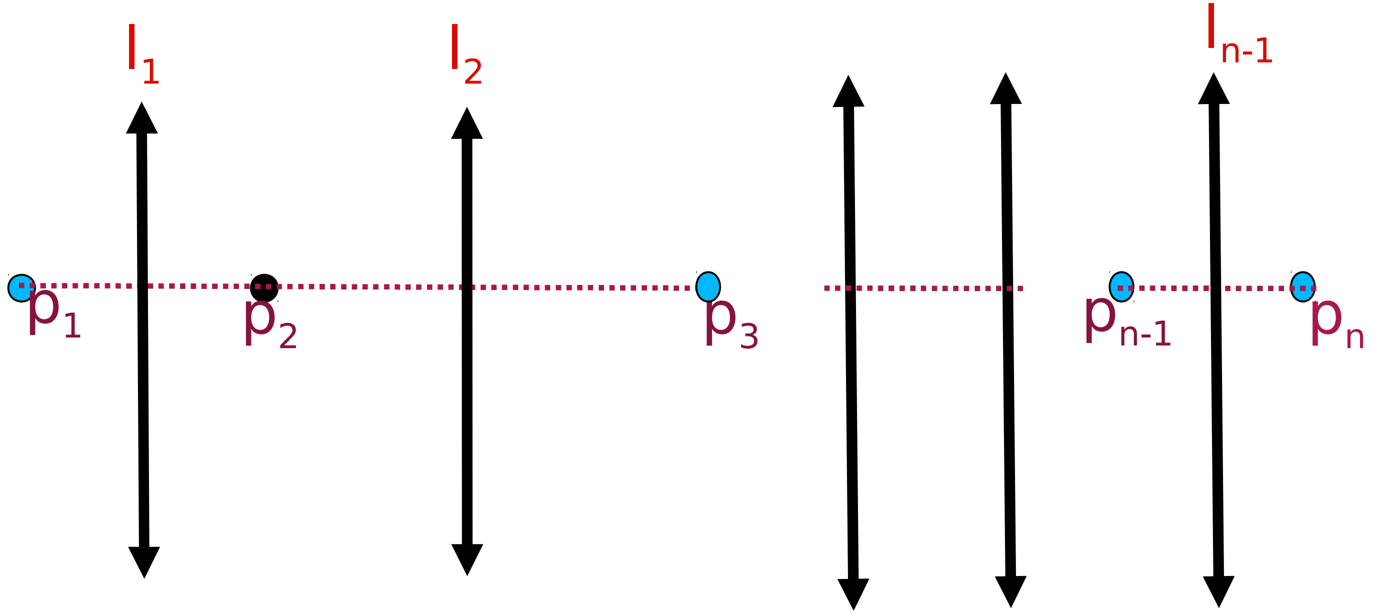

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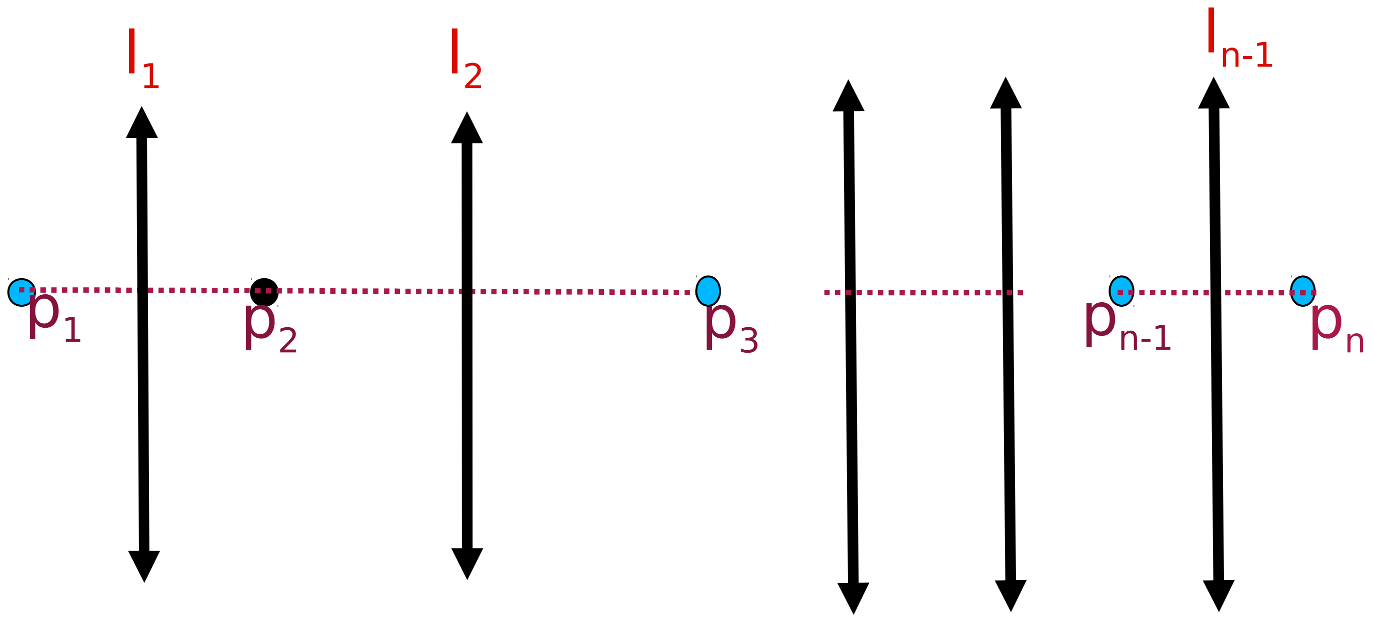

Find Perpendicular bisector l_i of line segment $[p_i \, p_{i+1}]$

Let a_i be the intersection point of l_i and $[p_i \, p_{i+1}]$

Computing the Voronoi Diagram

Input: A set of points $P=(p_1, p_2, \ldots, p_n)$ on a line (special case)

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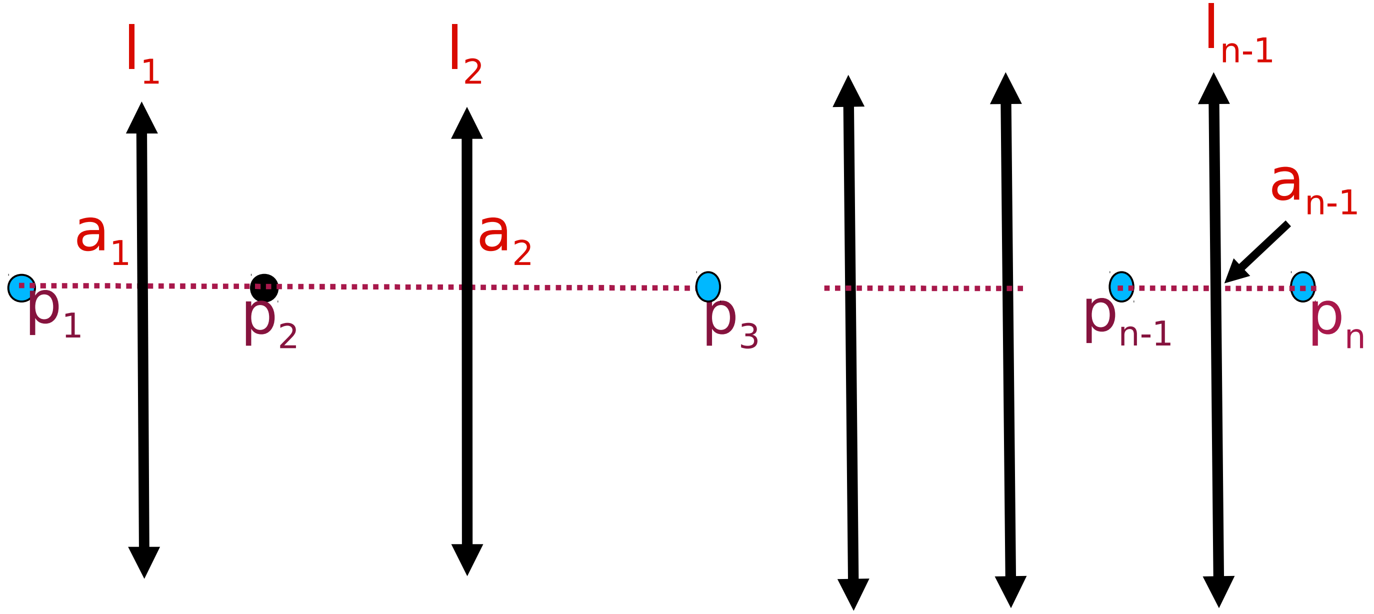

Find Perpendicular bisector l_i of line segment $[p_i\ p_{i+1}]$

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Computing the Voronoi Diagram

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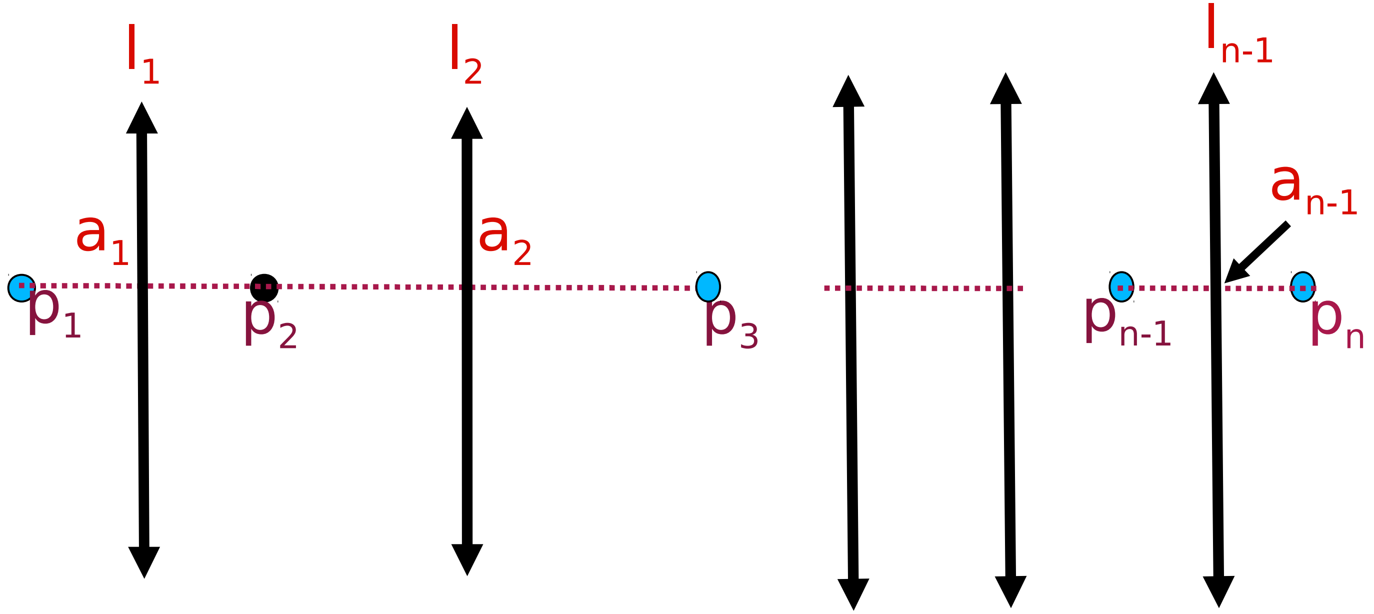

Find Perpendicular bisector l_i of line segment $[p_i \, p_{i+1}]$

Let a_i be the intersection point of l_i and $[p_i \, p_{i+1}]$

Sort a_i in increasing x-coordinate

Computing the Voronoi Diagram

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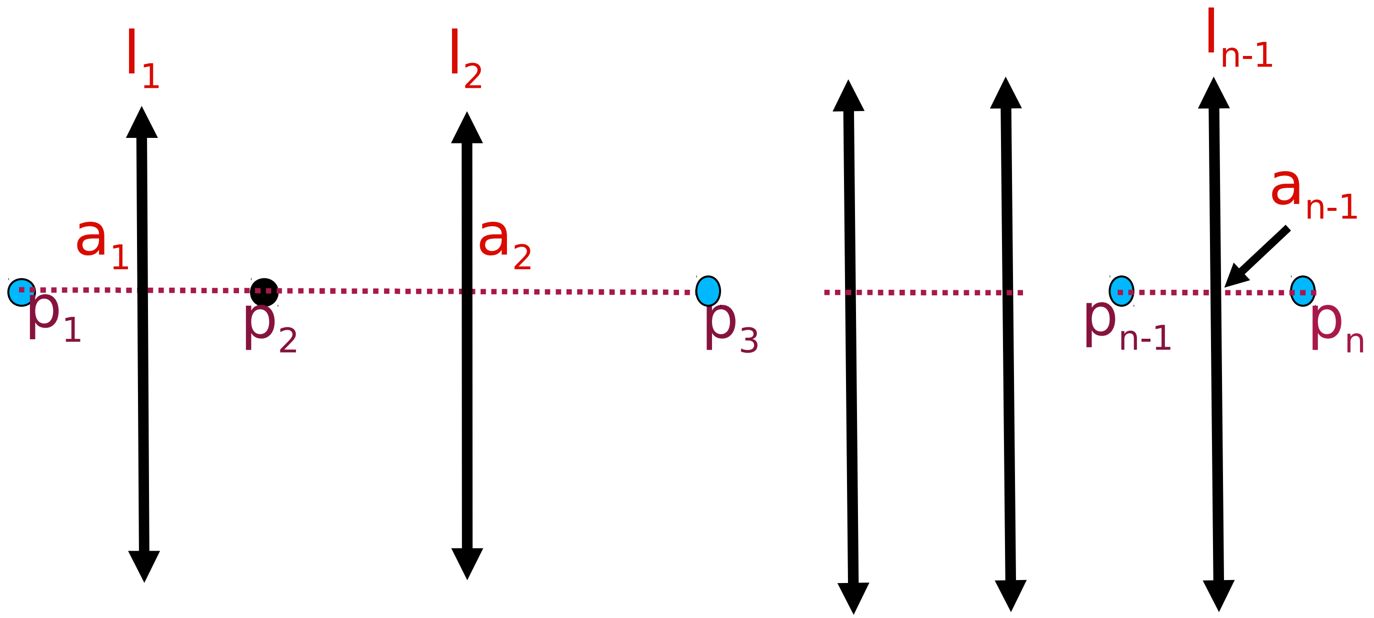

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This gives us Voronoi Diagram $V(P)$

Computing the Voronoi Diagram

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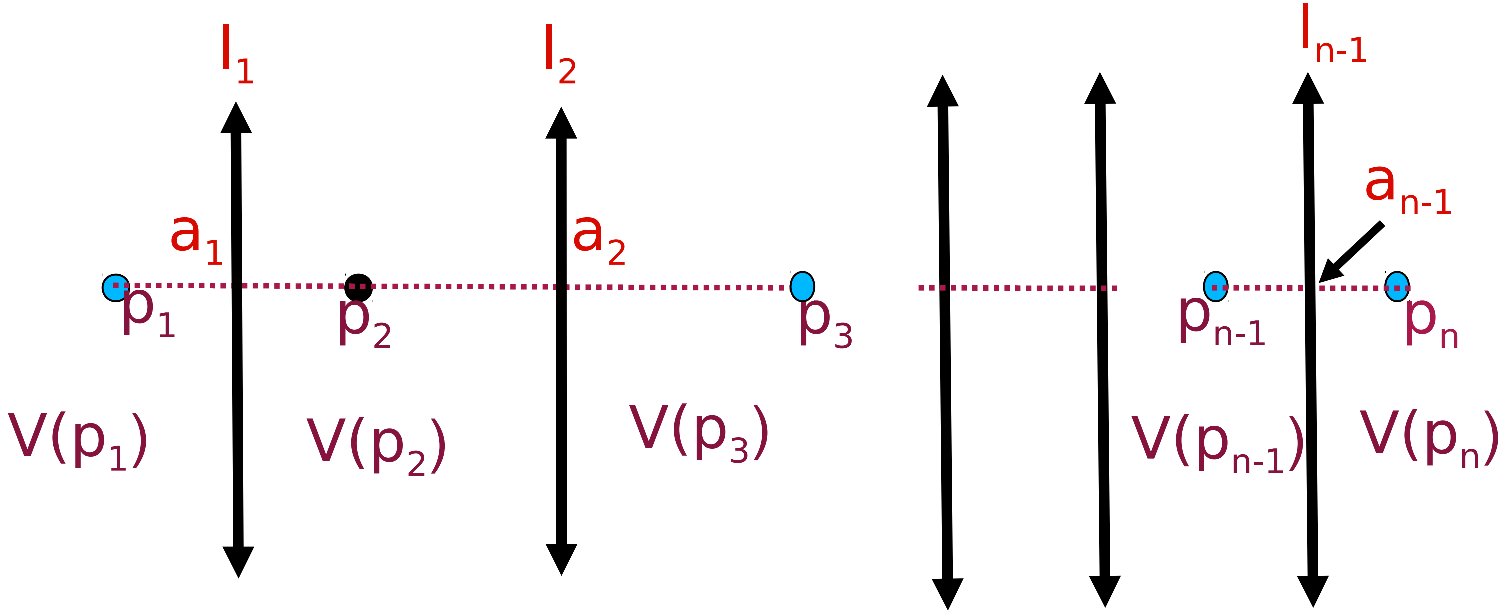
Output: A partitioning of the plane into regions of nearest neighbors



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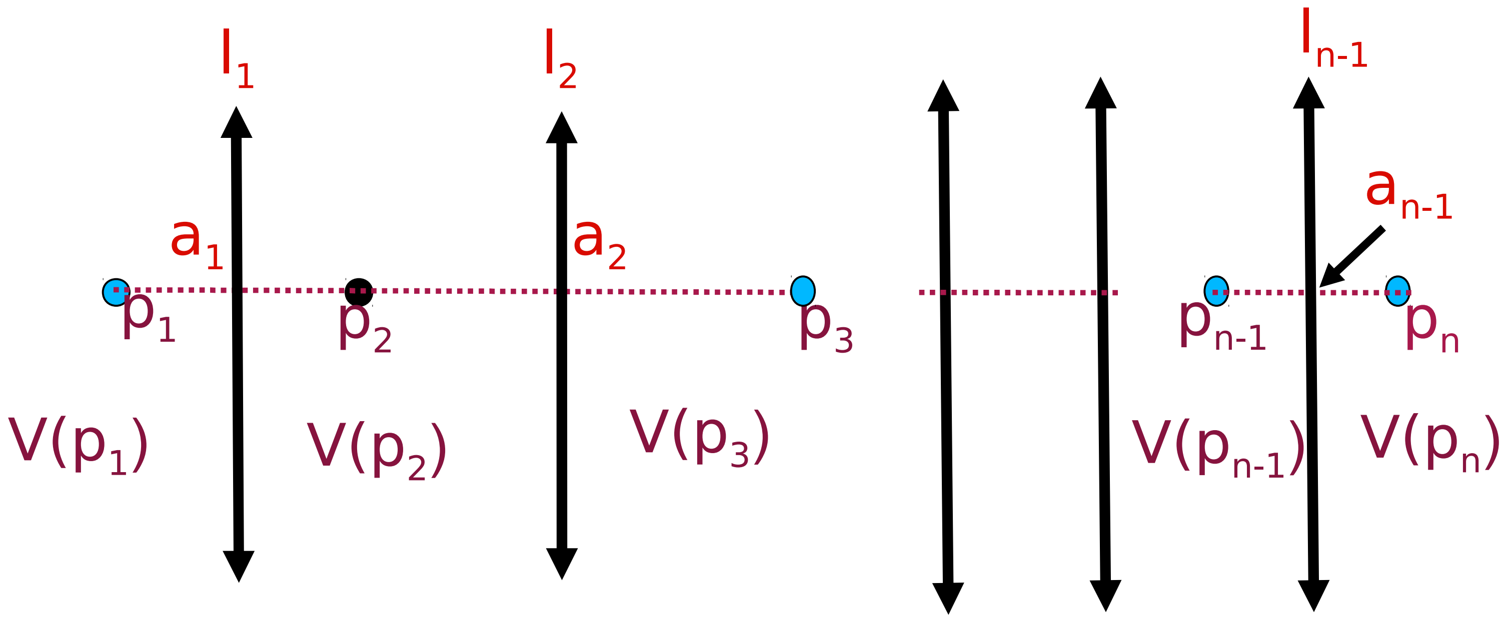
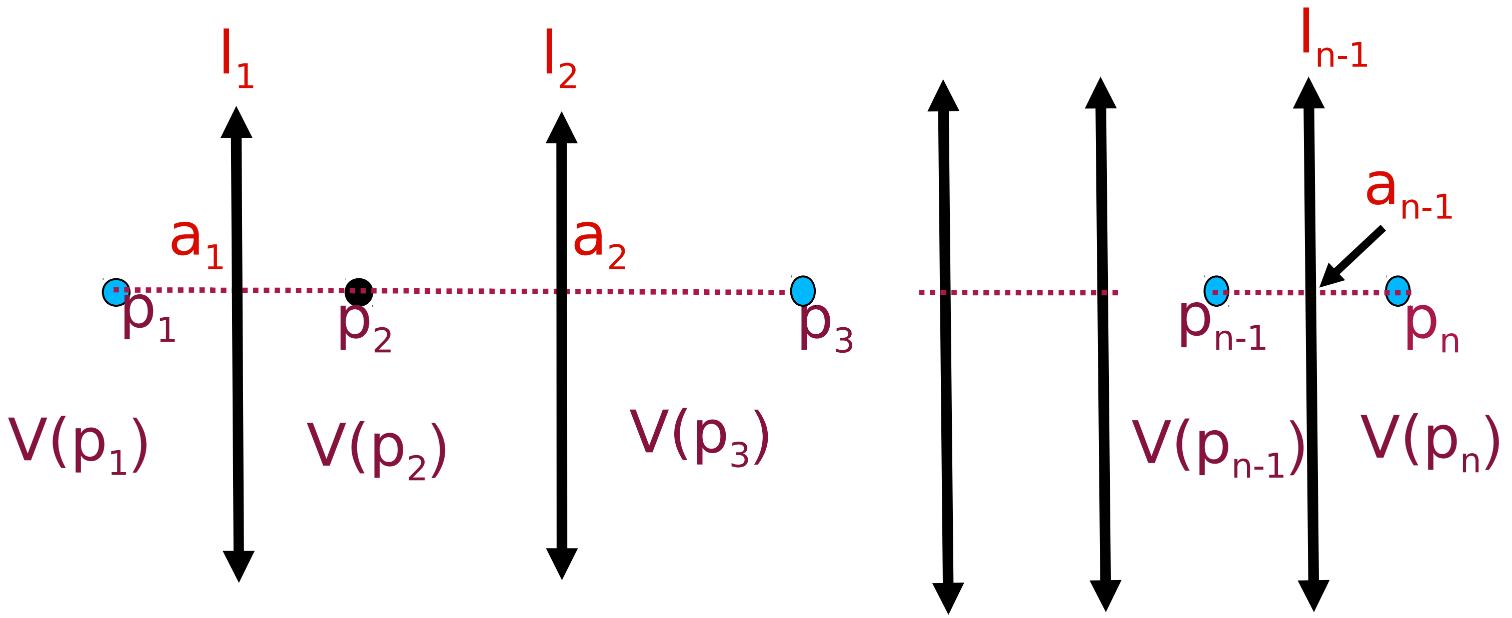
Query Answering



Query Answering

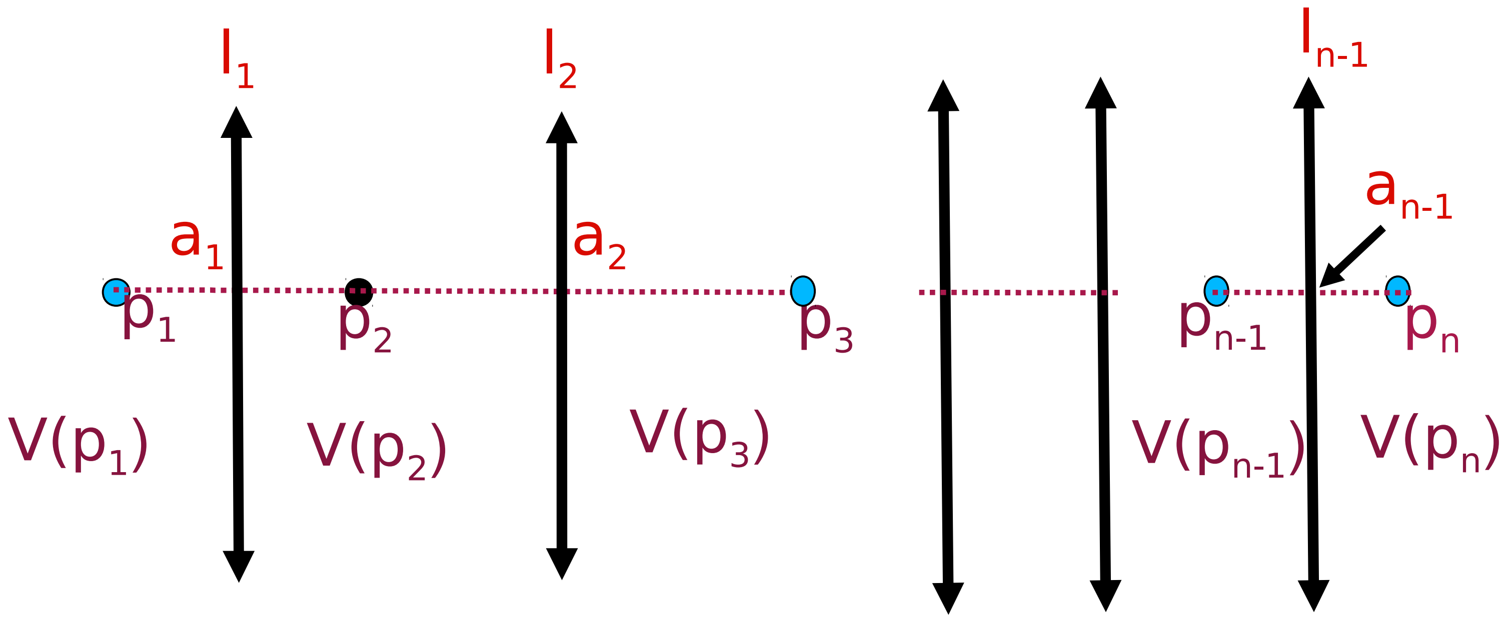
We have a_i's sorted in increasing x-coordinate



Query Answering

We have a_i's sorted in increasing x-coordinate

Given a query point p[x,y]



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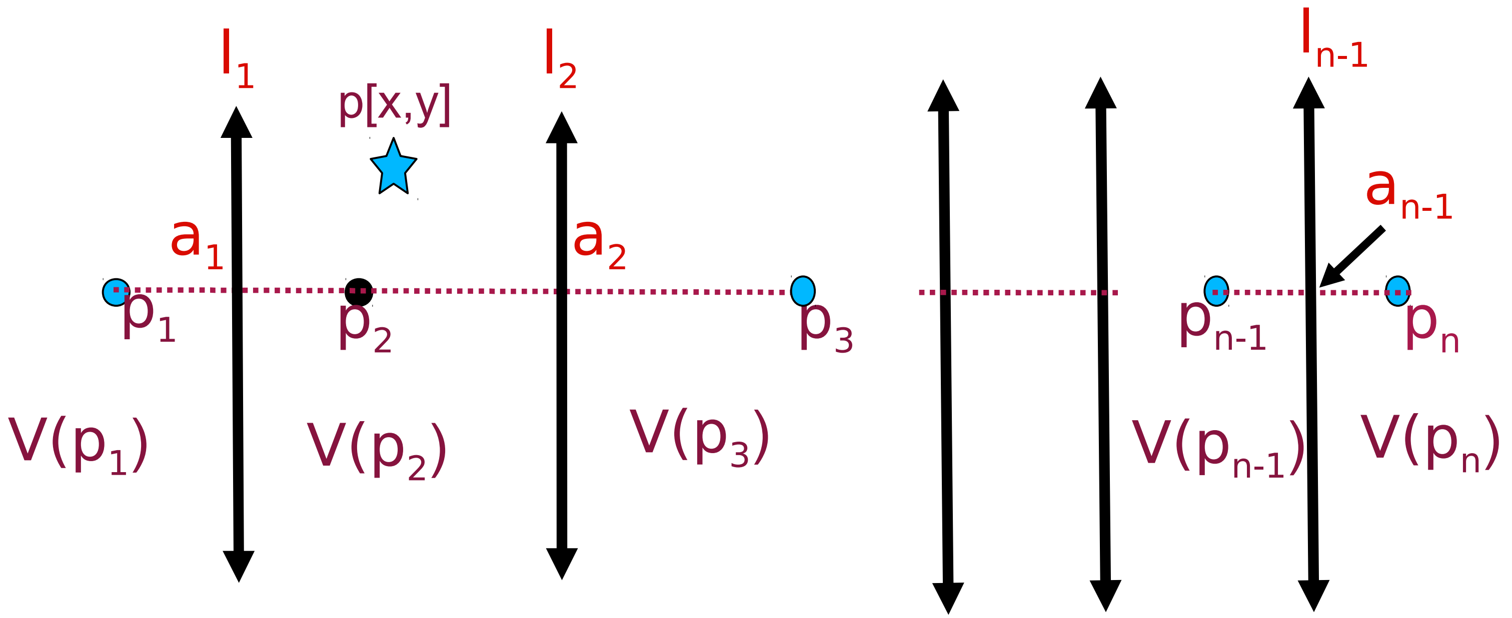

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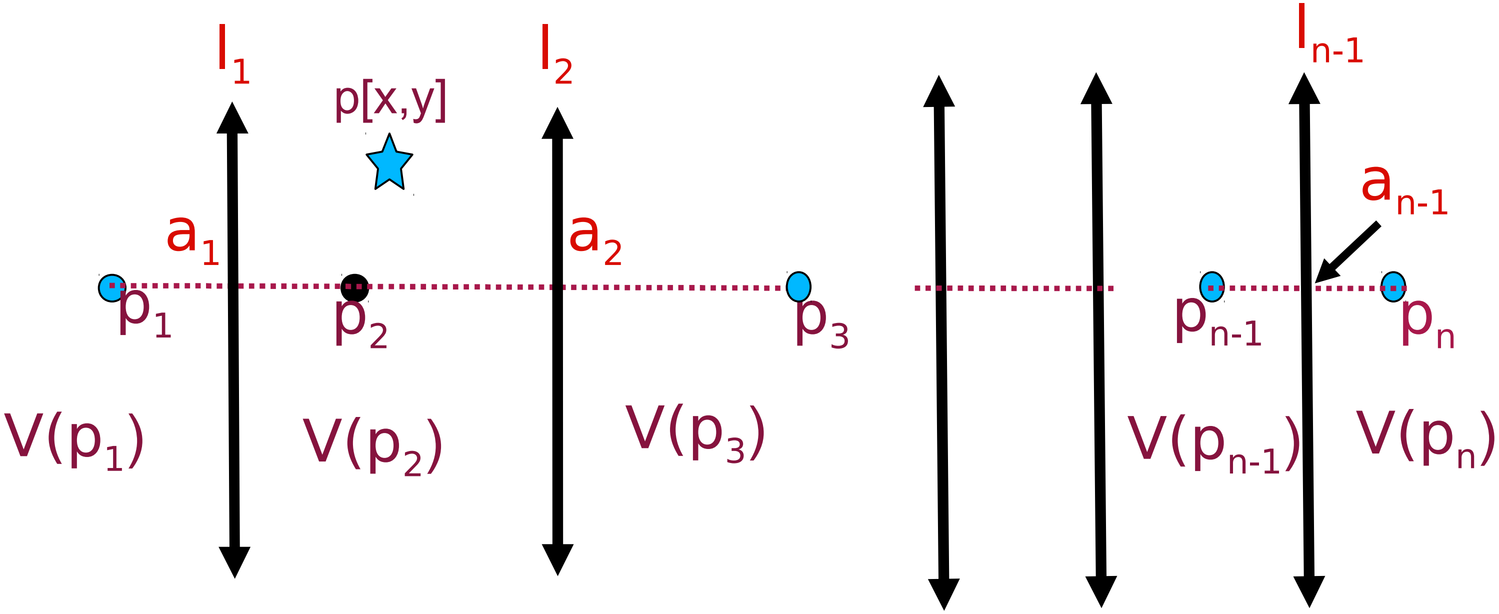

What we have to do?

Query Answering

We have a_i's sorted in increasing x-coordinate

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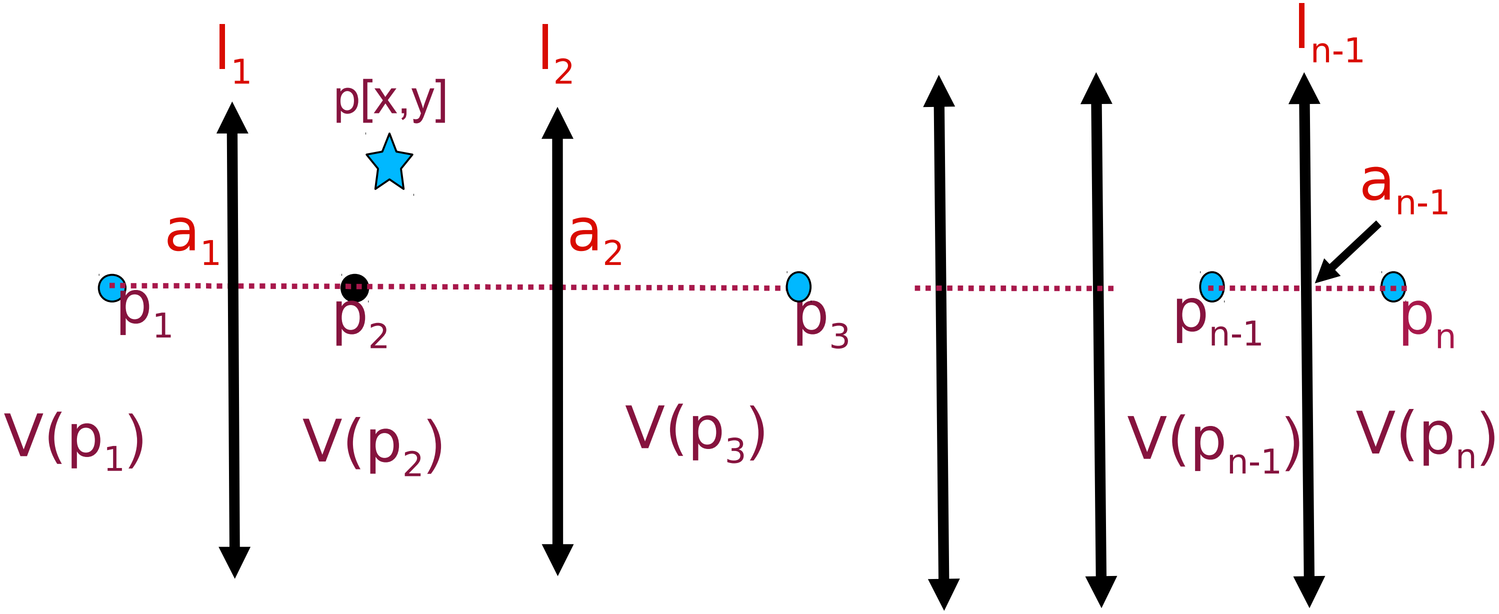


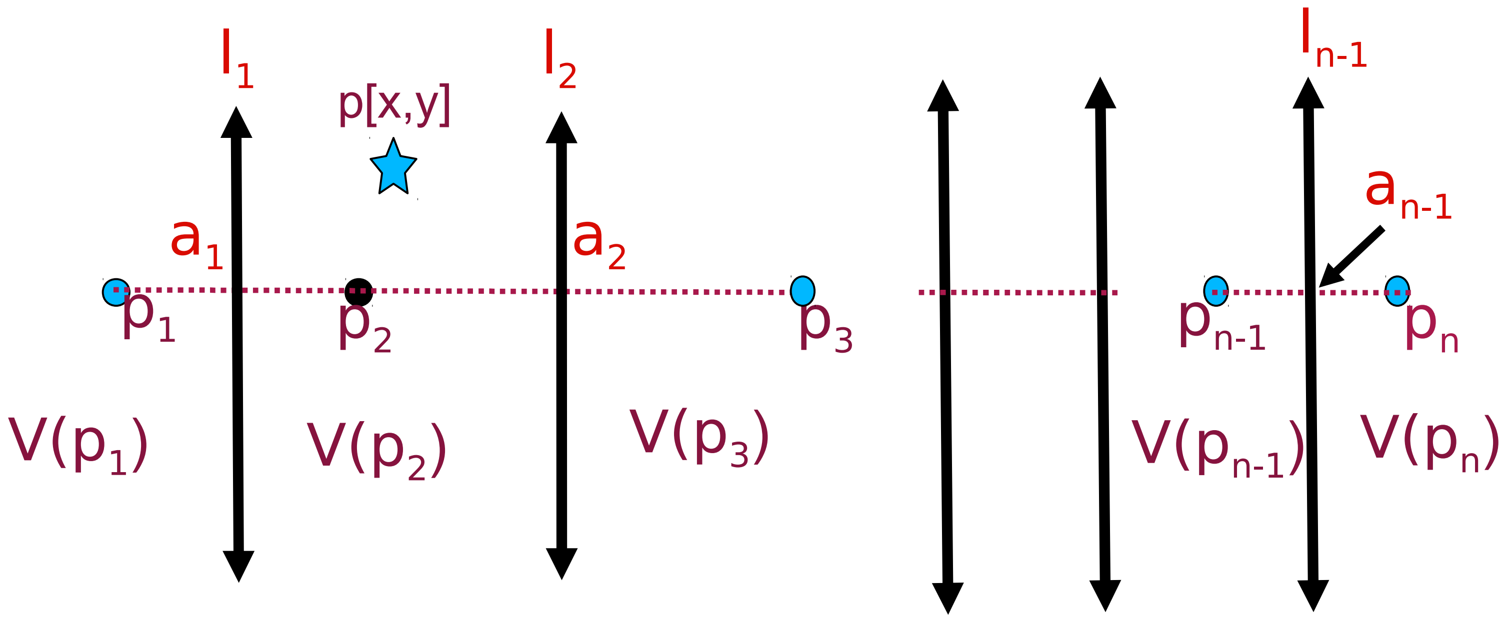
What we have to do?

Locate x correctly between a_i and a_{i+1}

Query Answering

We have a_i's sorted in increasing x-coordinate

Given a query point p[x,y]



What we have to do? Locate x correctly between a_i and a_{i+1}

We can forget about y coordinate

Time Complexity analysis

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Preprocessing Time =O(n log n)

Time Complexity analysis

Preprocessing Time =O(n log n)

Query Time =O(log n)

Computing the Voronoi Diagram

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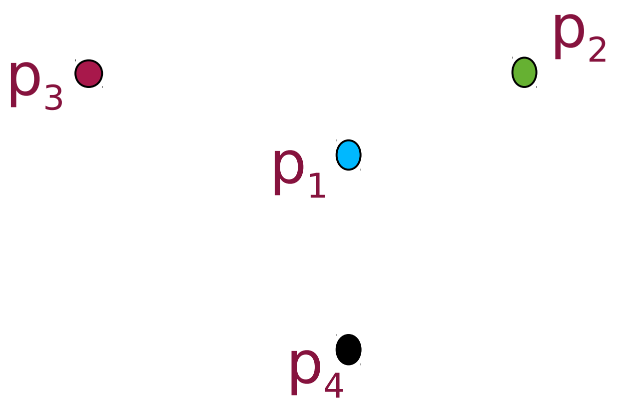
Input: A set of points $P=(p_1, p_2, \ldots, p_n)$ on 2D



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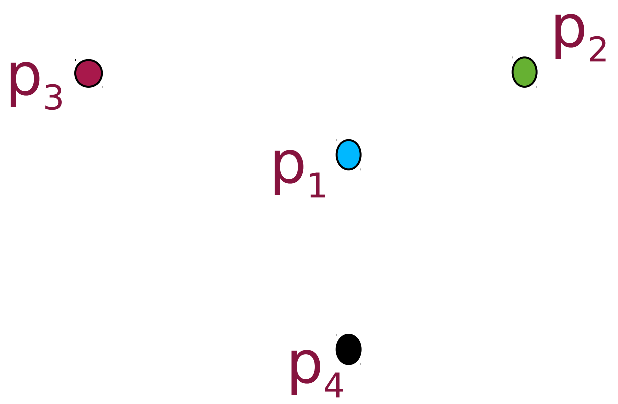

Computing the Voronoi Diagram

Input: A set of points $P=(p_1, p_2, ..., p_n)$ on 2D

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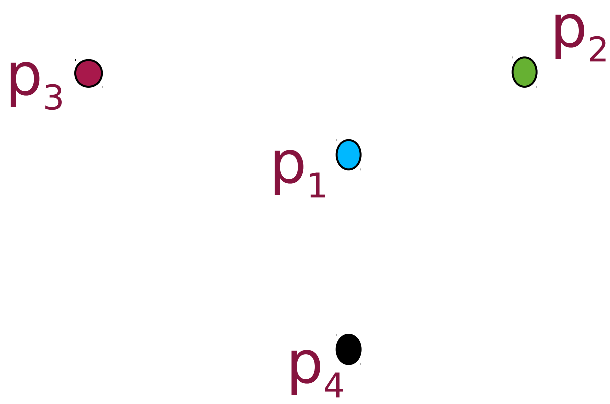
Find cell for each point one by one?



Computing the Voronoi Diagram

Input: A set of points $P=(p_1, p_2, \ldots, p_n)$ on 2D

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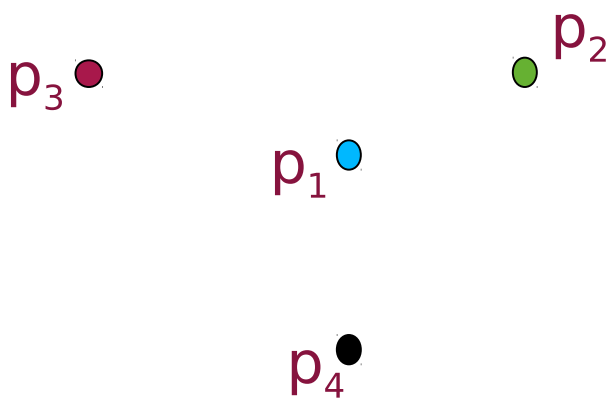
Find cell for each point one by one? use perpendicular bisector argument



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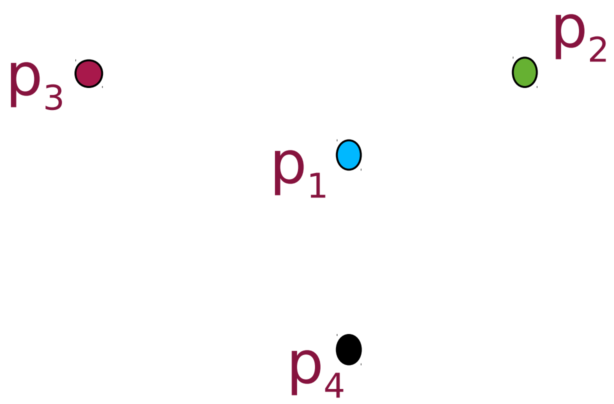
Find region for p_1



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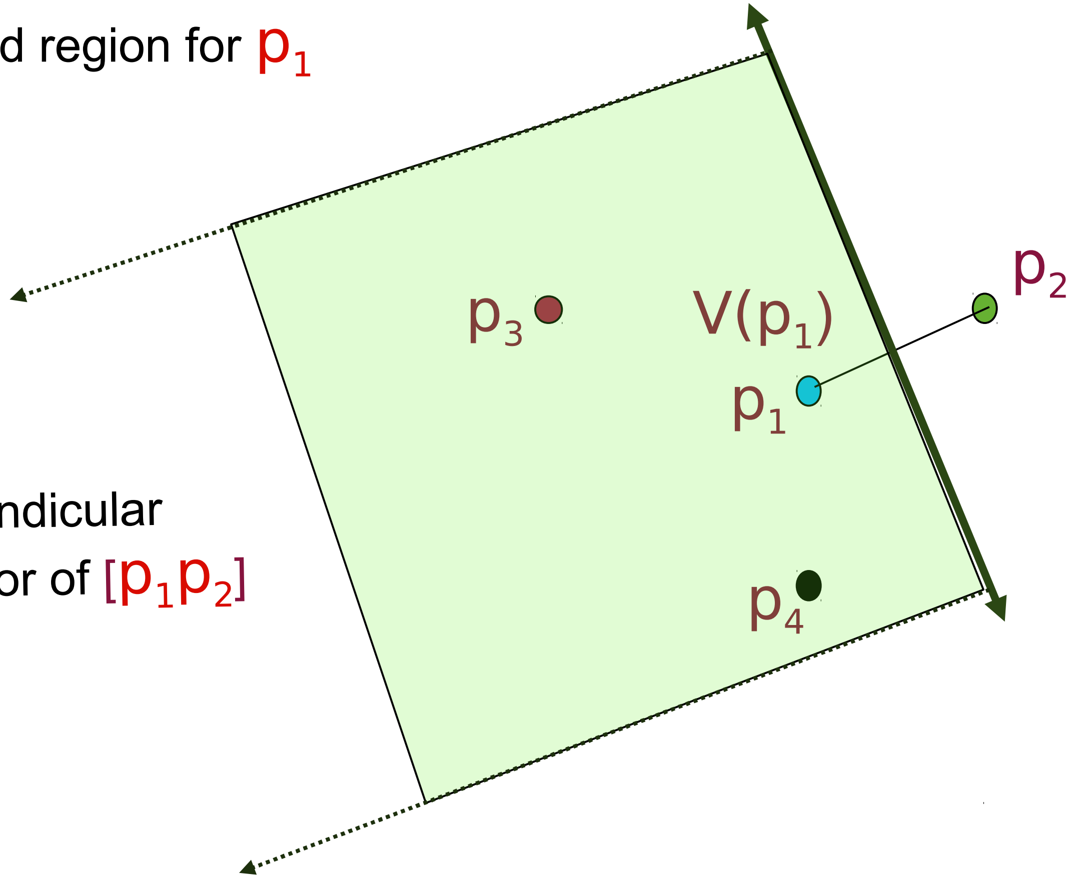

Perpendicular bisector of $[p_1p_2]$

Computing the Voronoi Diagram

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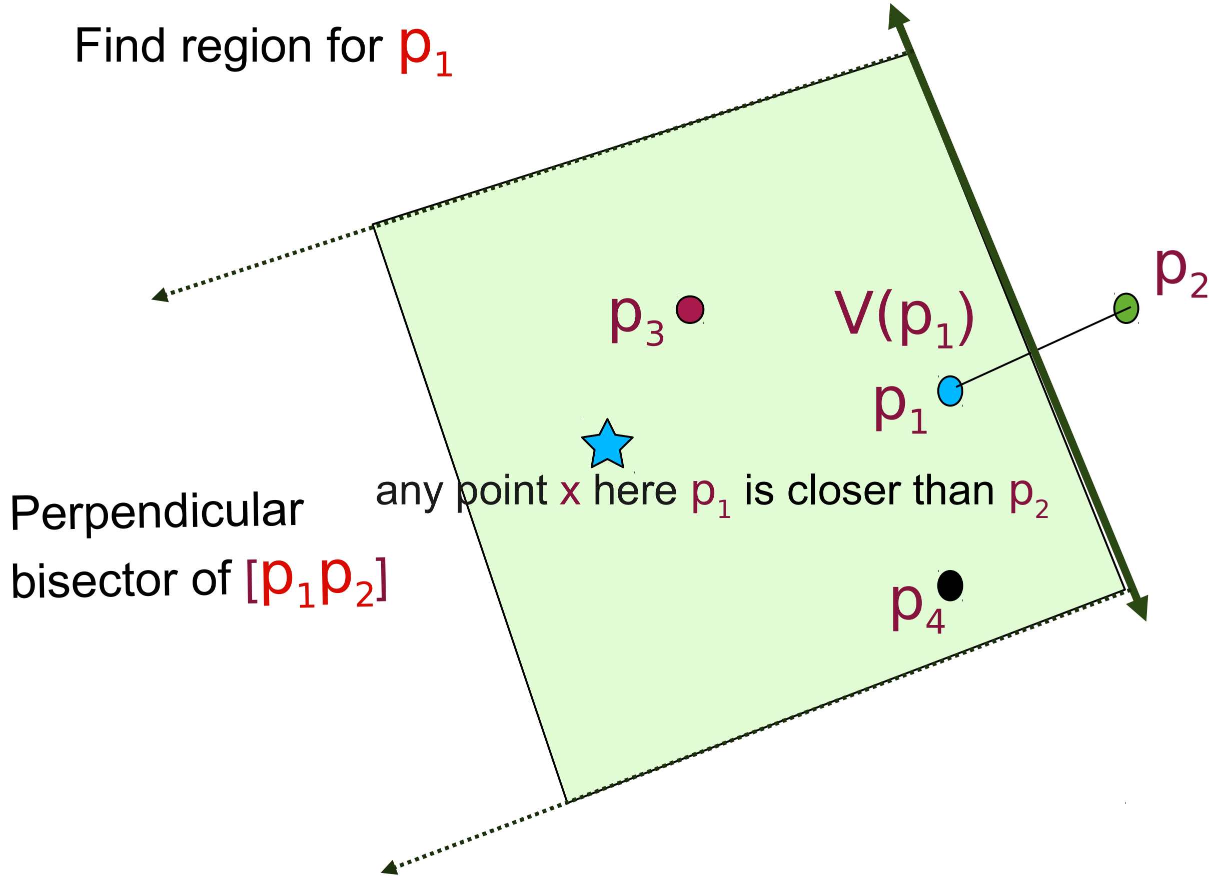

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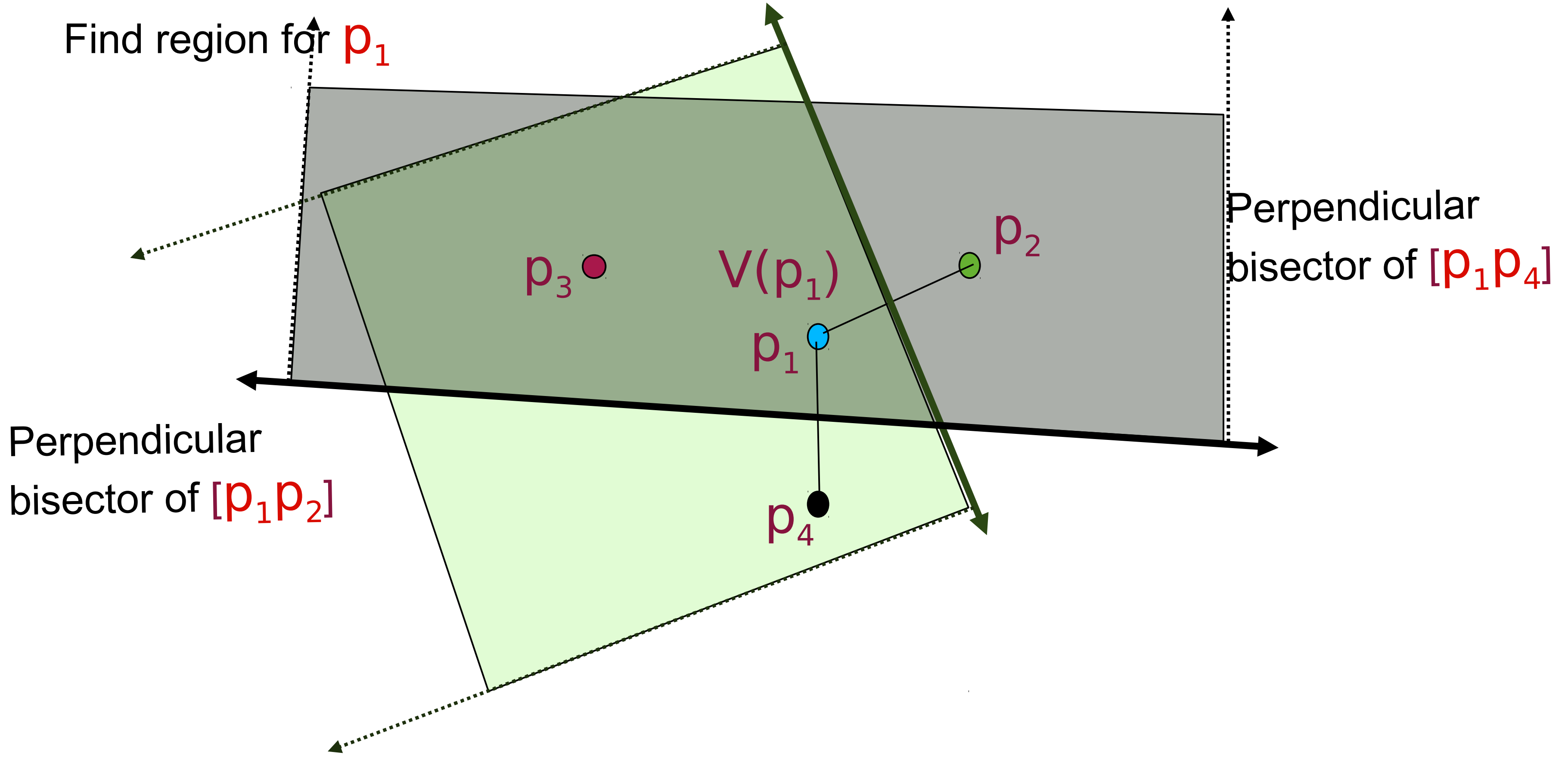

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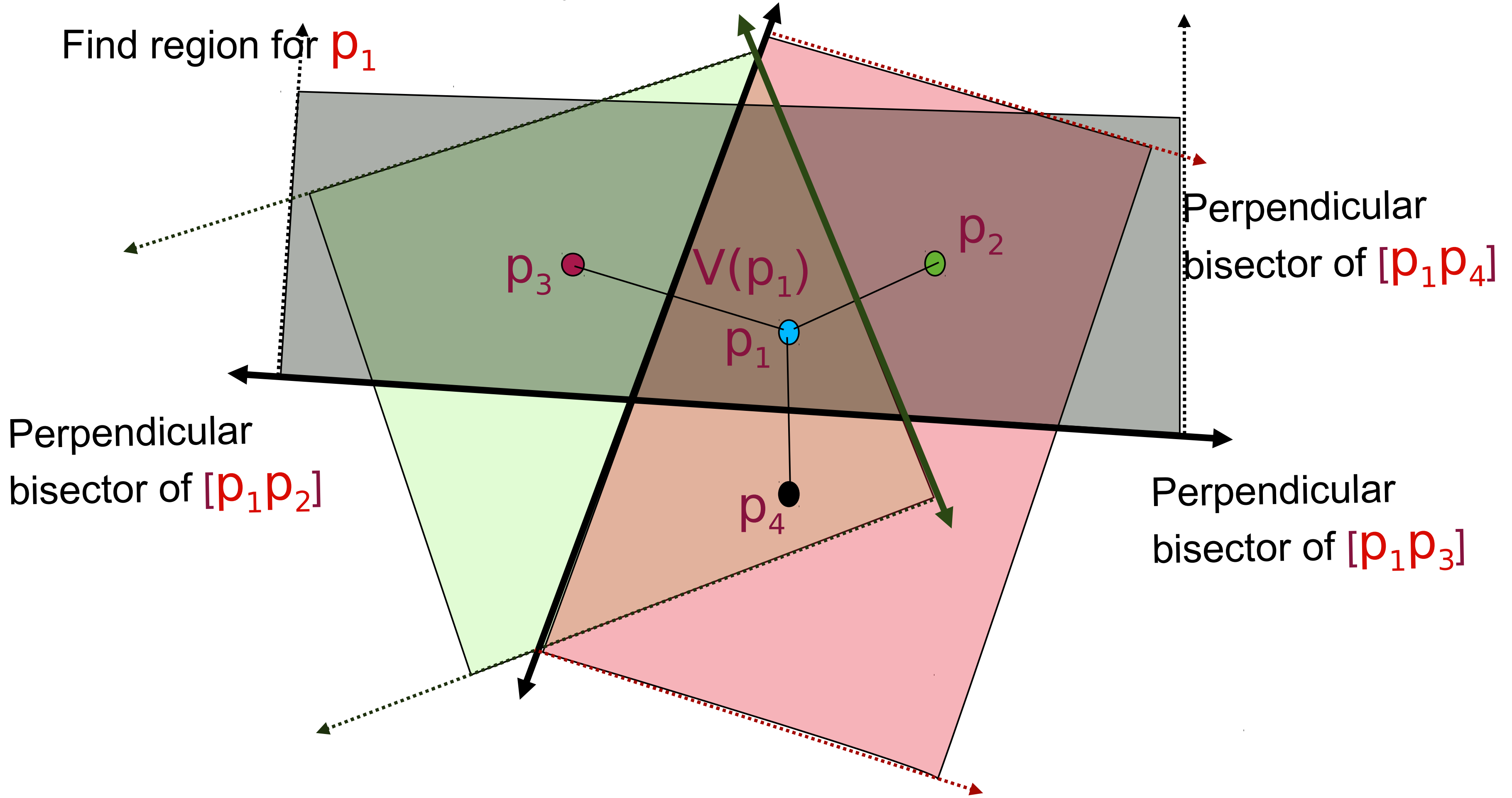

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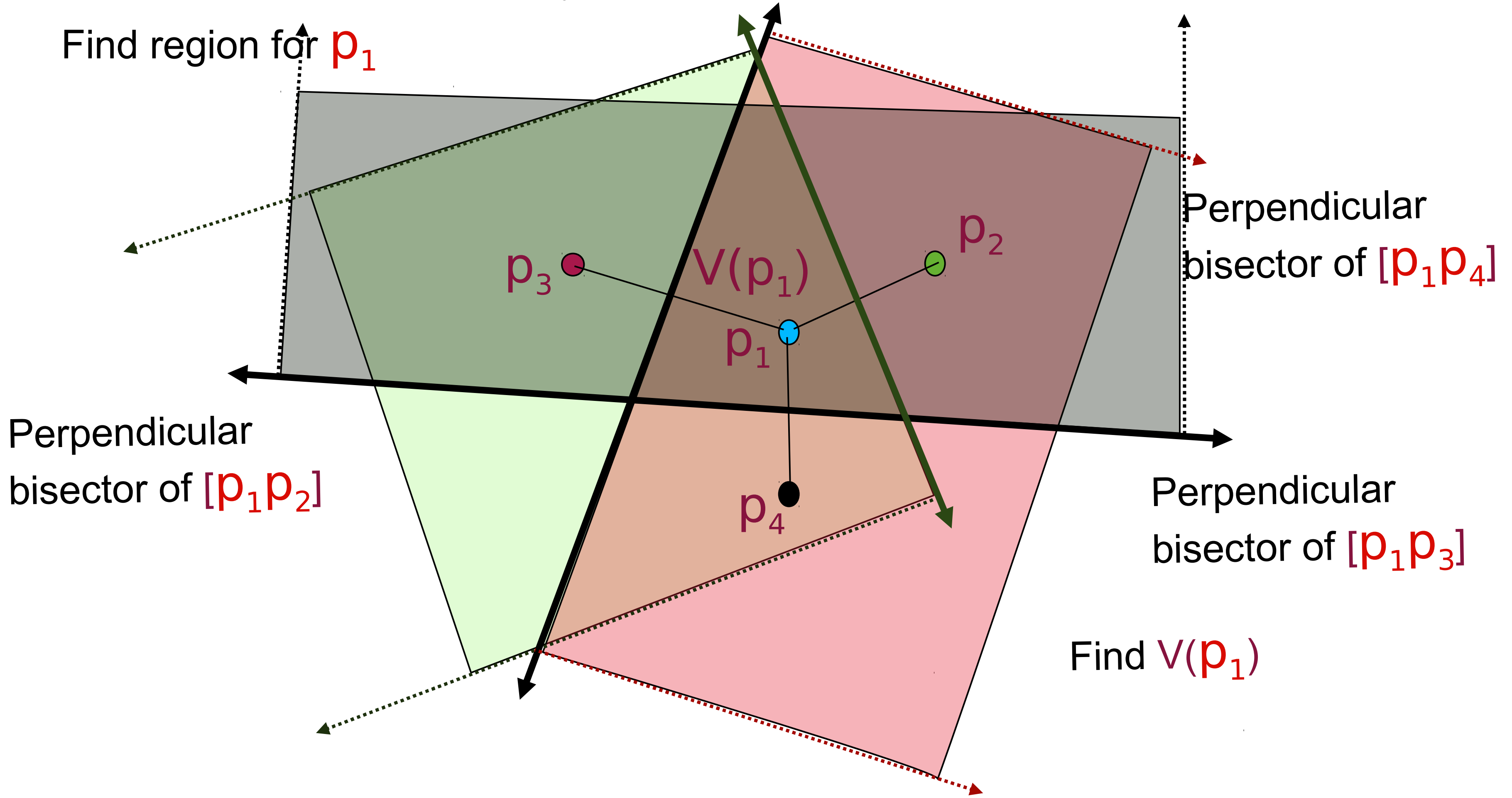

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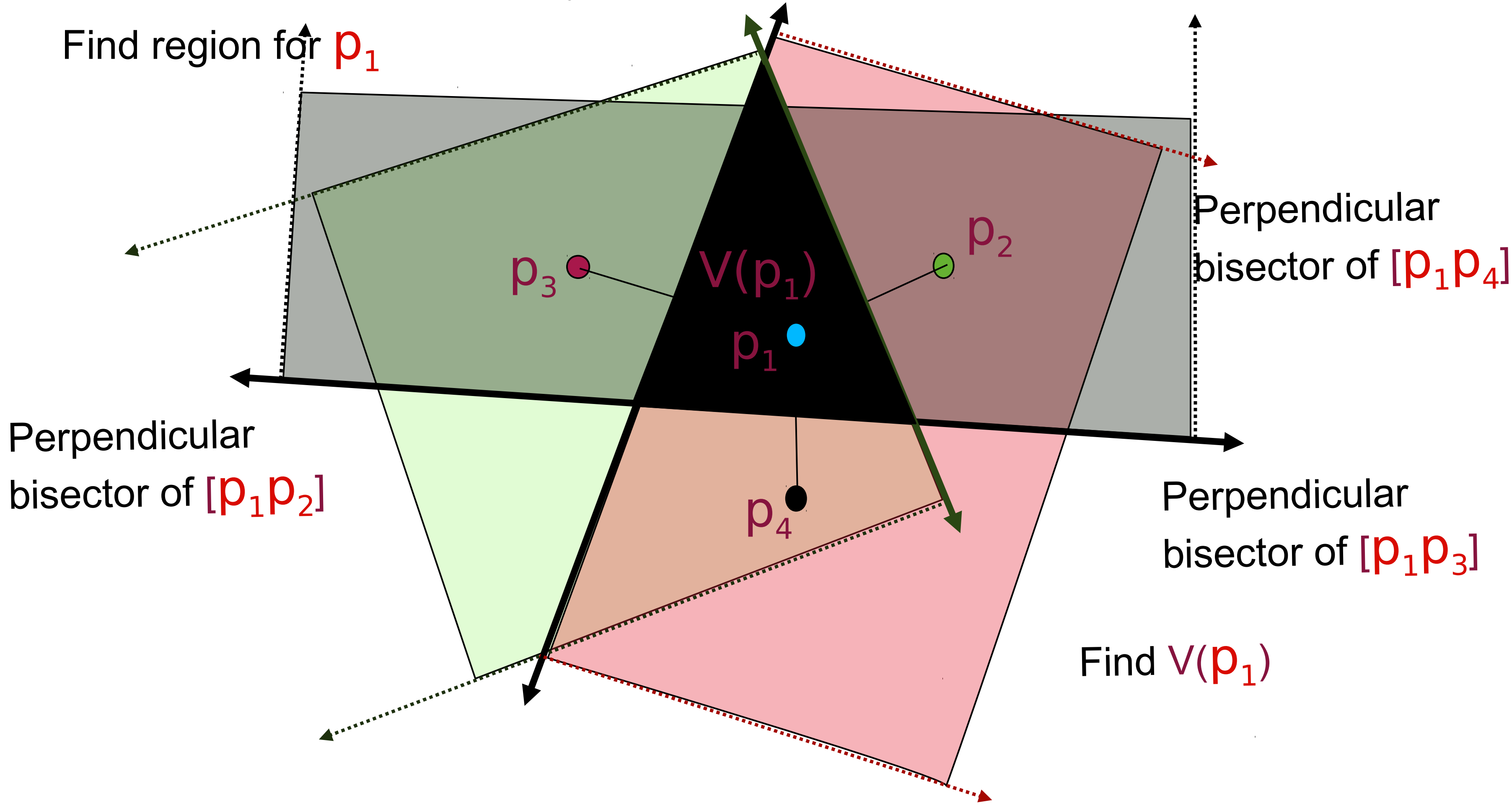
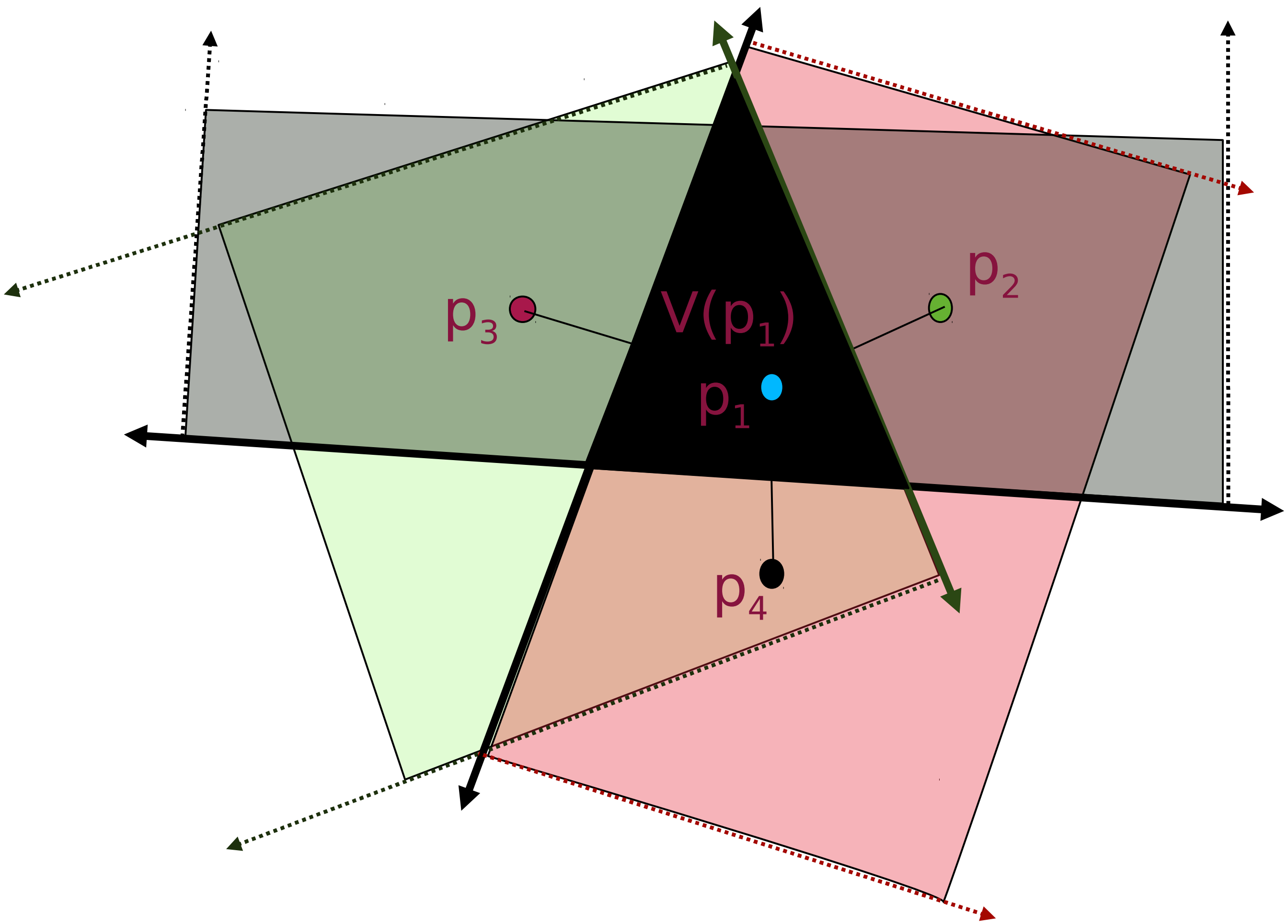


Computing the Voronoi Diagram

How do we find $V(p_1)$?



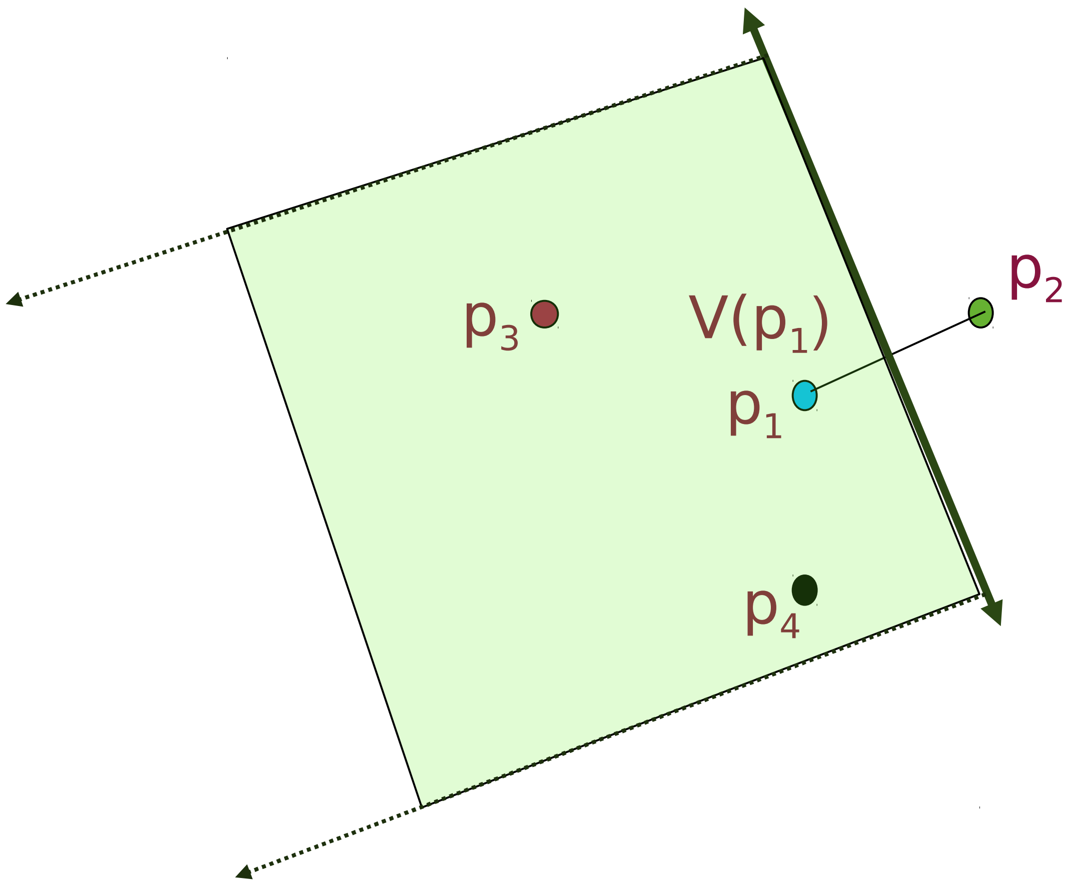
Computing the Voronoi Diagram

How do we find $V(p_1)$? Go back

Computing the Voronoi Diagram

How do we find $V(p_1)$? Go back

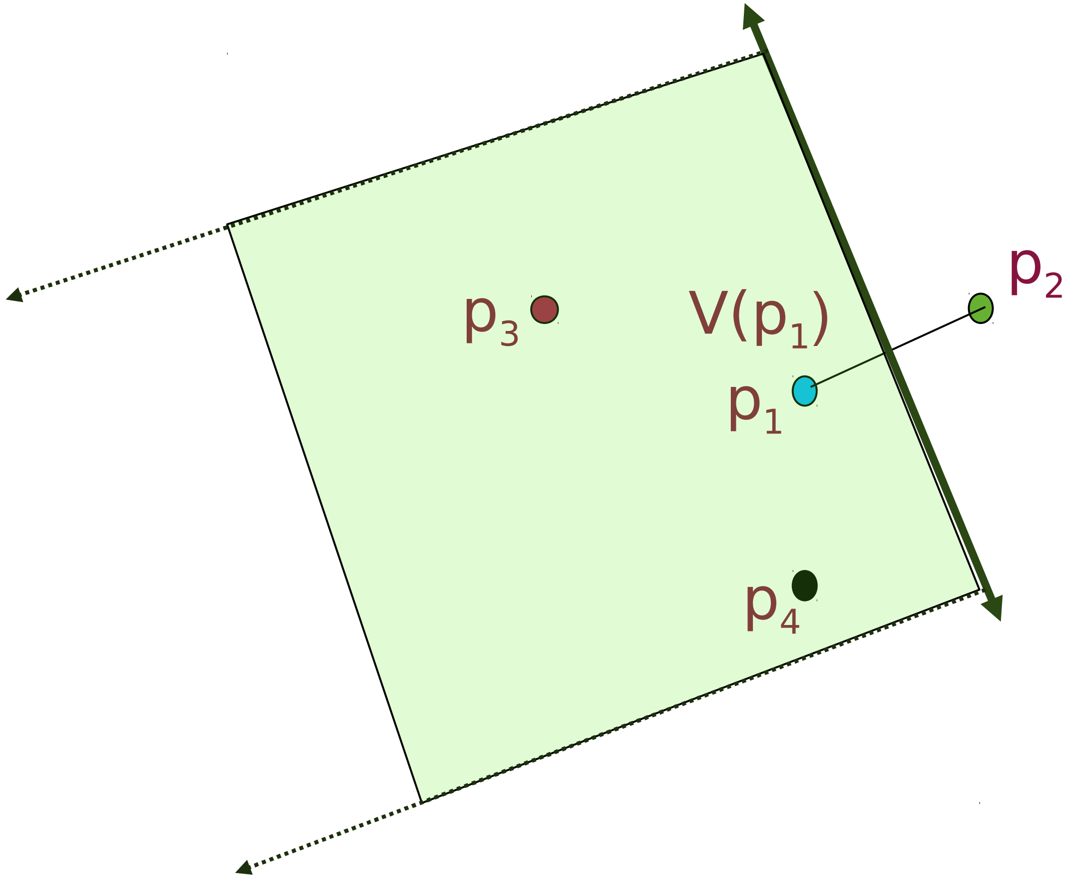
What is this region?



Computing the Voronoi Diagram

How do we find $V(p_1)$? Go back

What is this region? Half-plane, say H_1 , containing p_1



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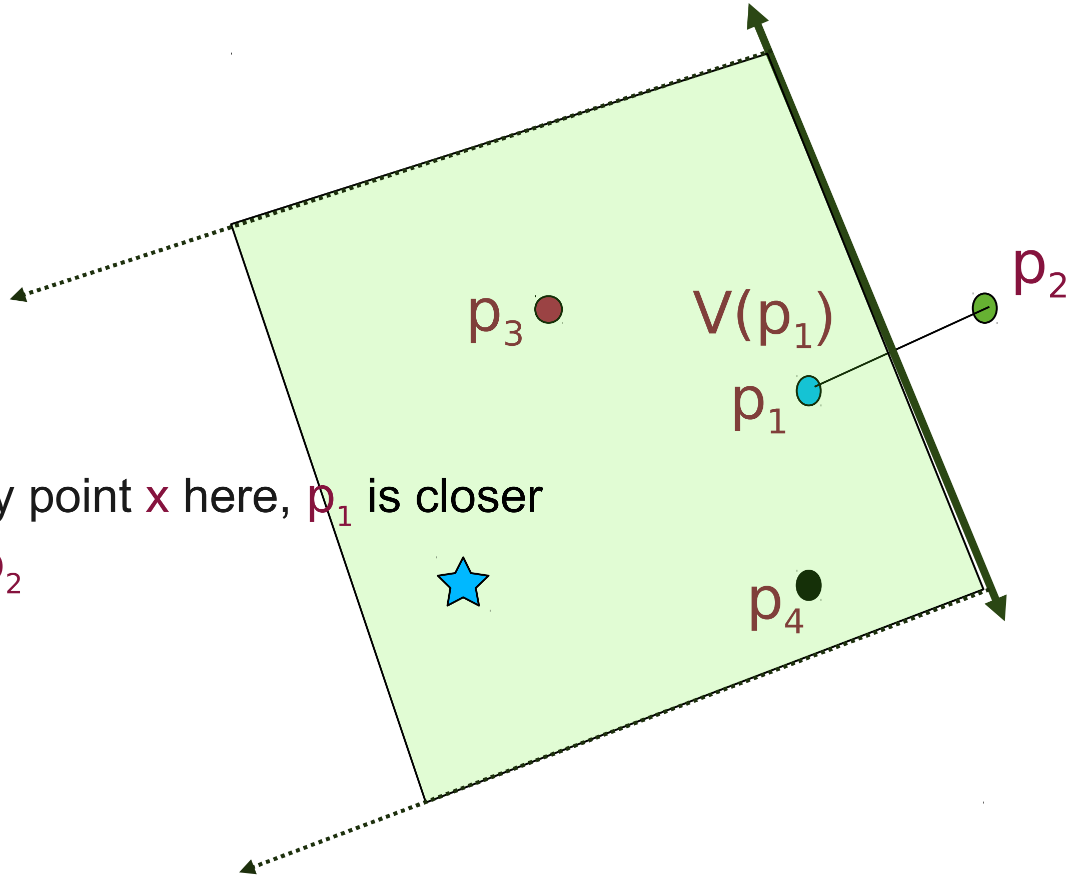
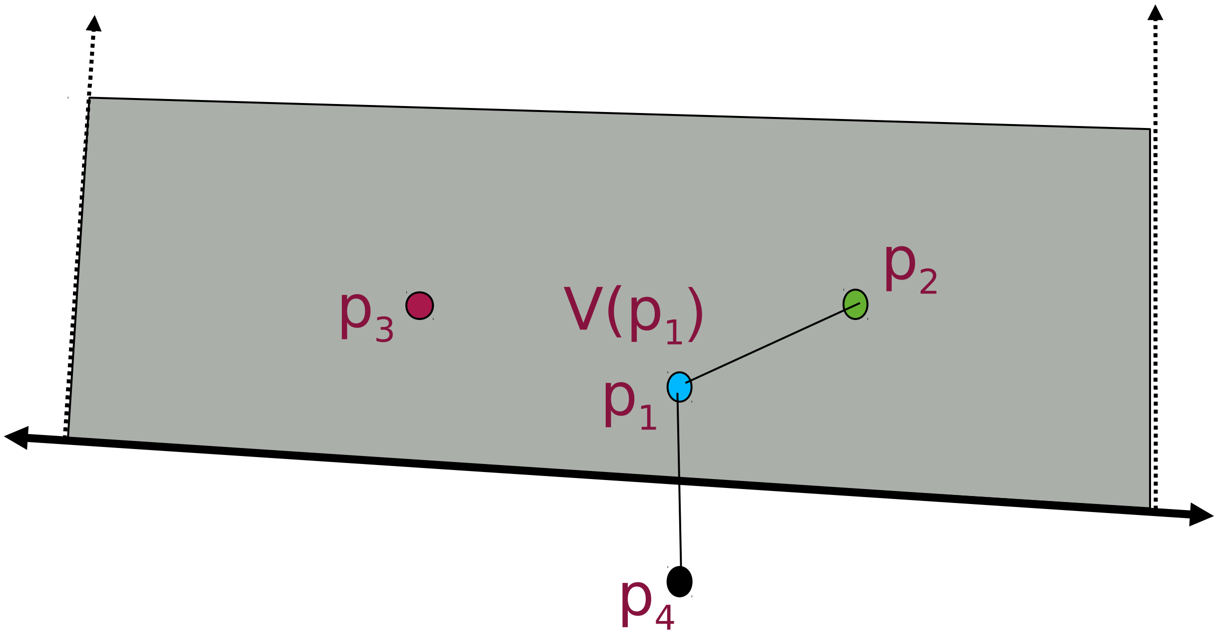


for any point x here, p_1 is closer than p_2

Computing the Voronoi Diagram

How do we find $V(p_1)$? Go back

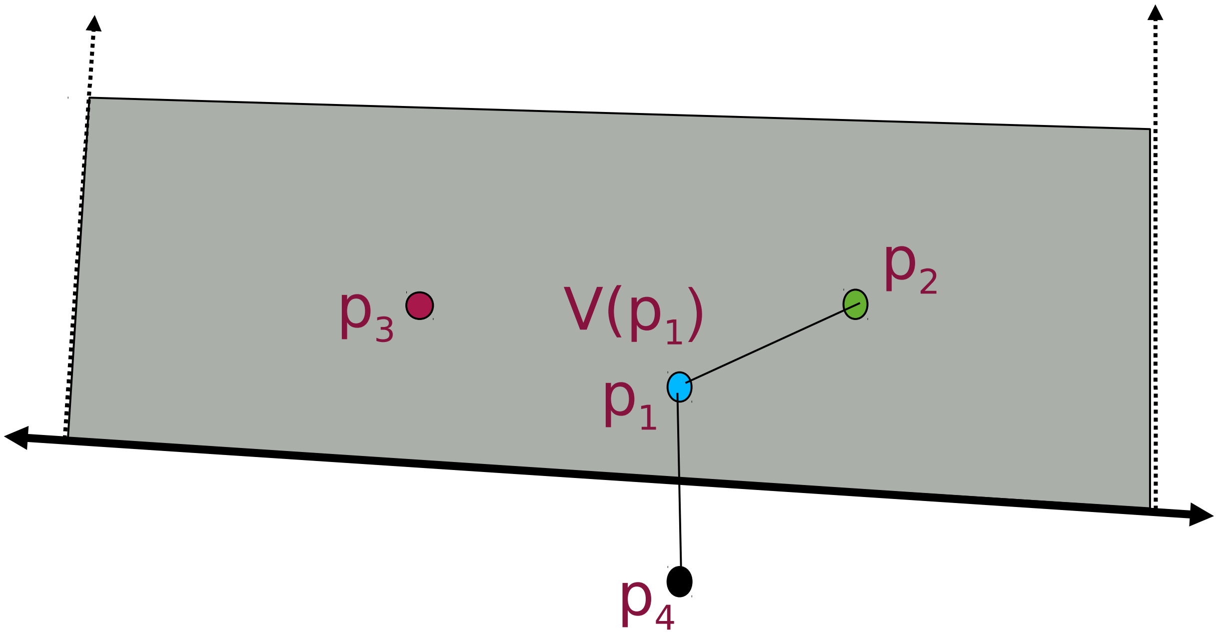
What is this region?



Computing the Voronoi Diagram

How do we find $V(p_1)$? Go back

What is this region? Half-plane, say H_2, containing p_1

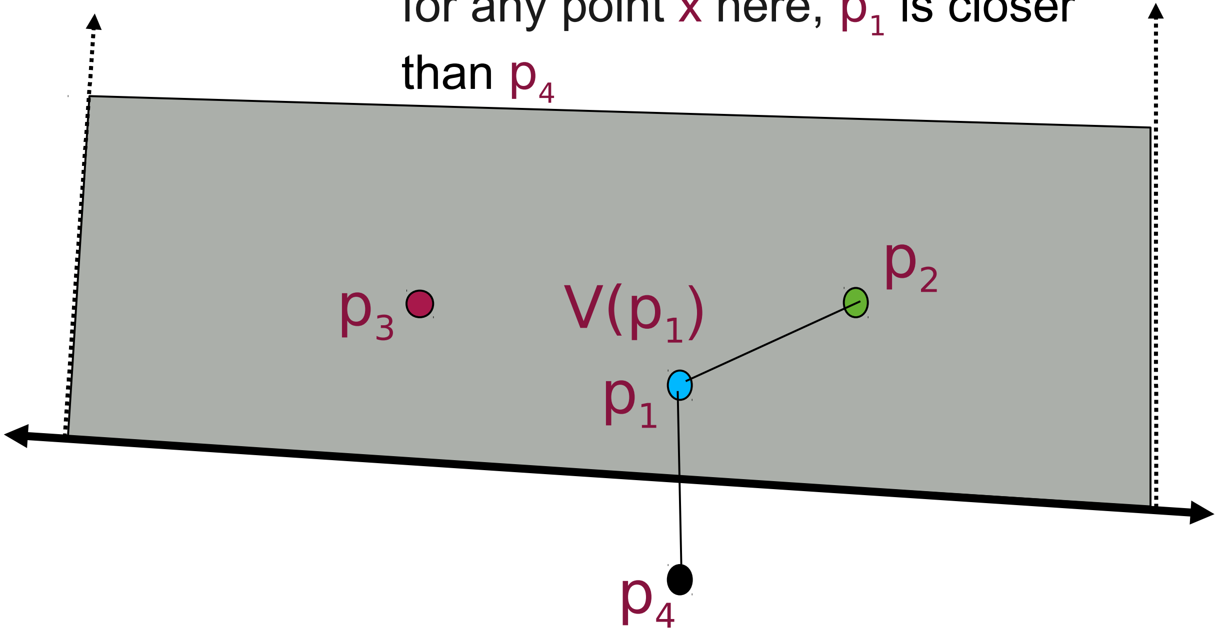


Computing the Voronoi Diagram

How do we find $V(p_1)$? Go back

What is this region? Half-plane, say H_2, containing p_1

for any point x here, p_1 is closer than p_4



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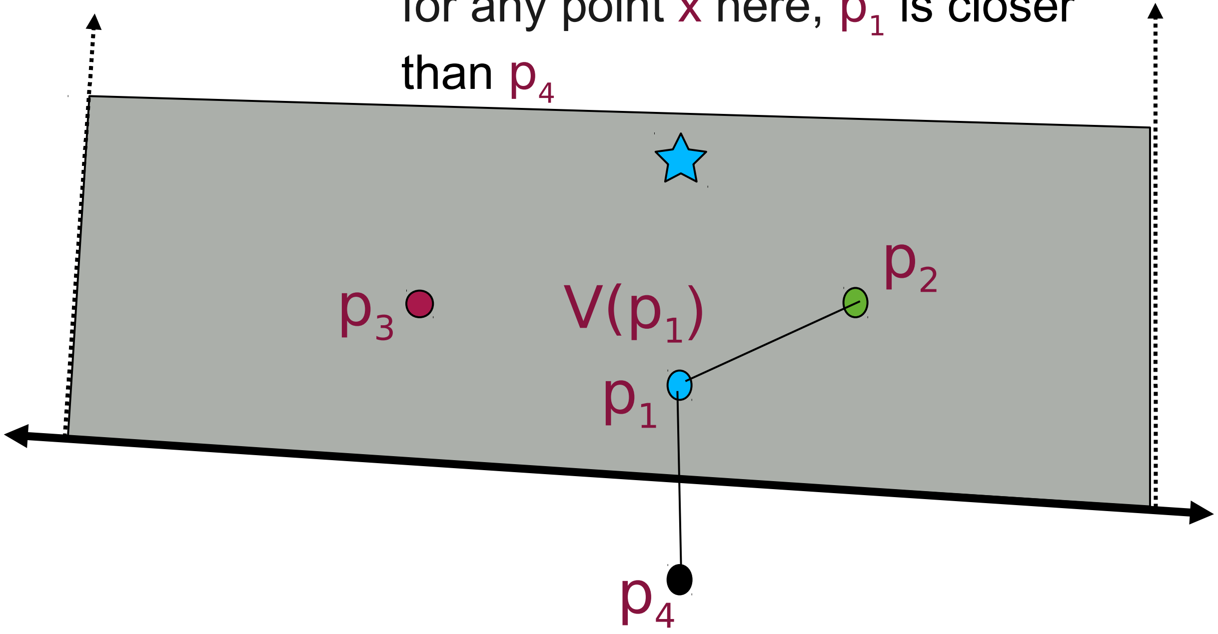

Computing the Voronoi Diagram

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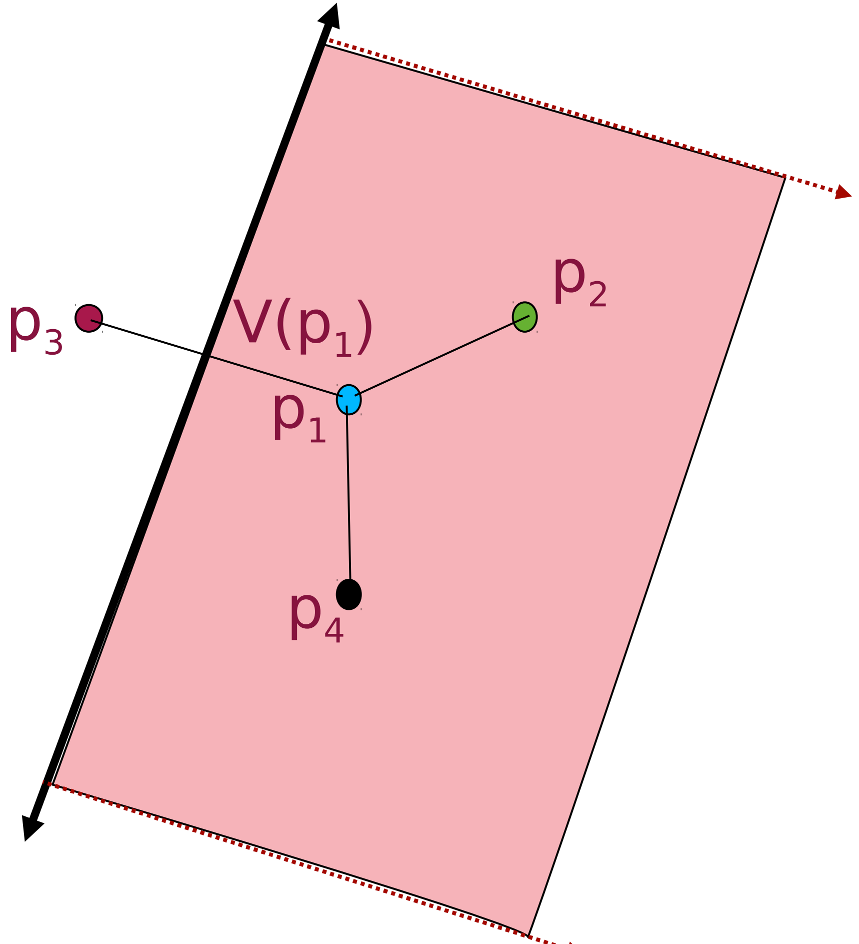
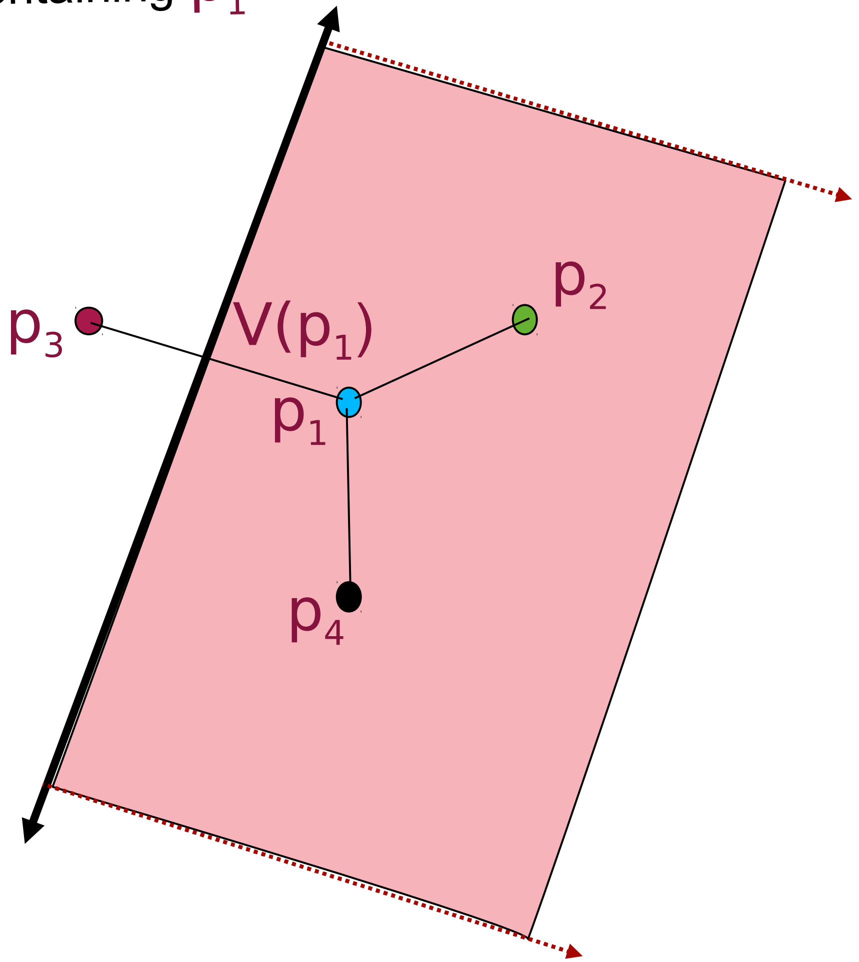


Computing the Voronoi Diagram

What is this region?

Half-plane, say H_3 , containing p_1



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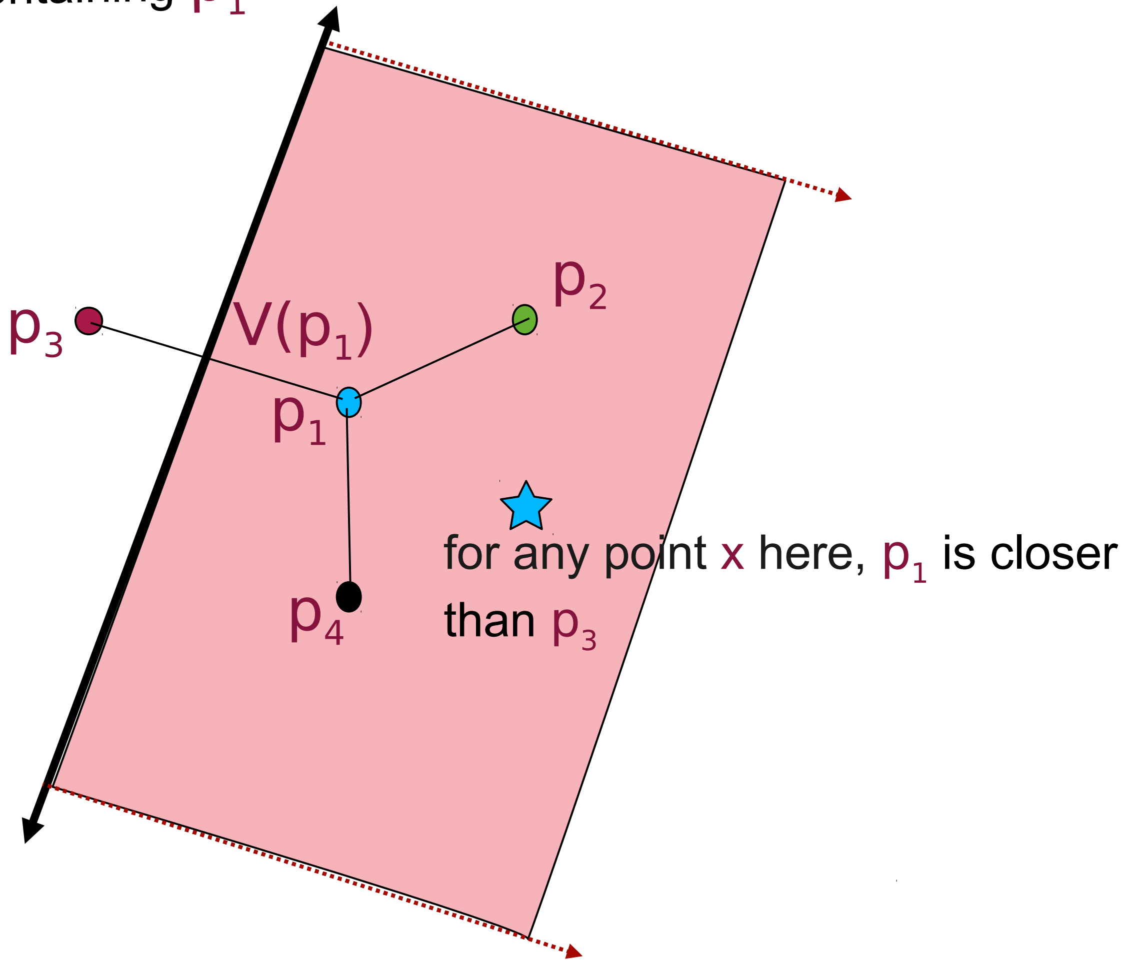

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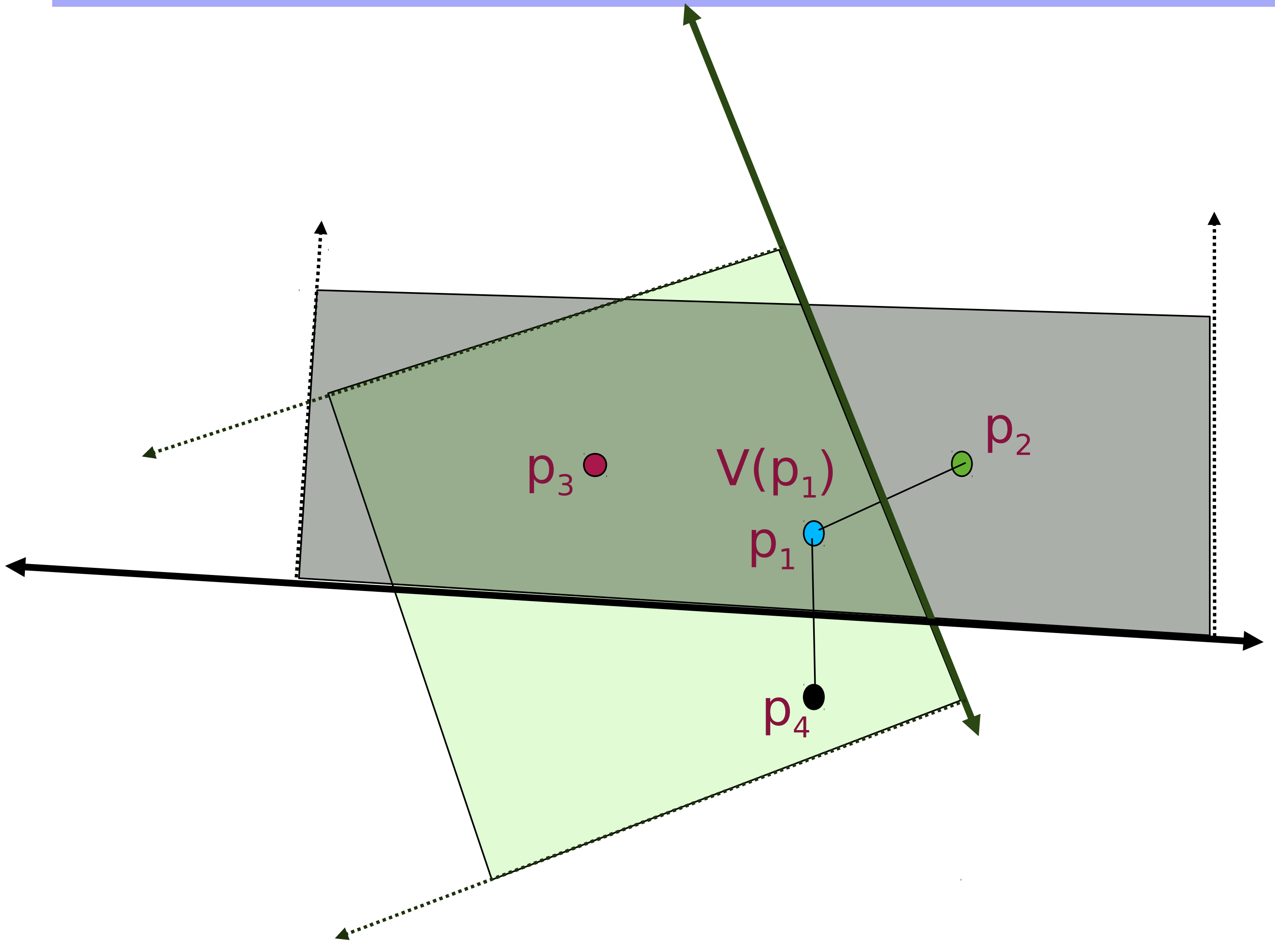

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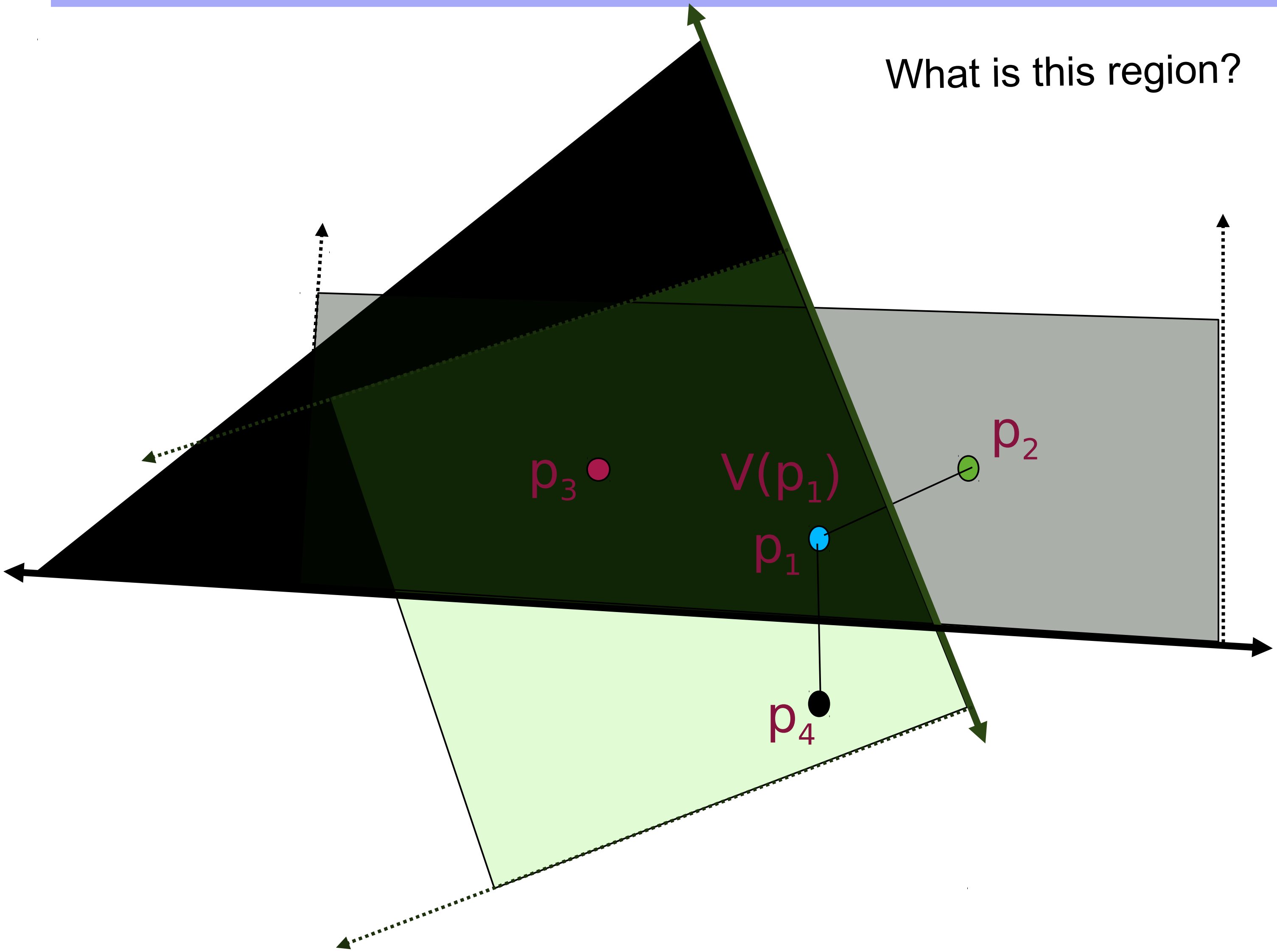

Computing the Voronoi Diagram

for any point x here, p_1 is closer than p_2 and p_4

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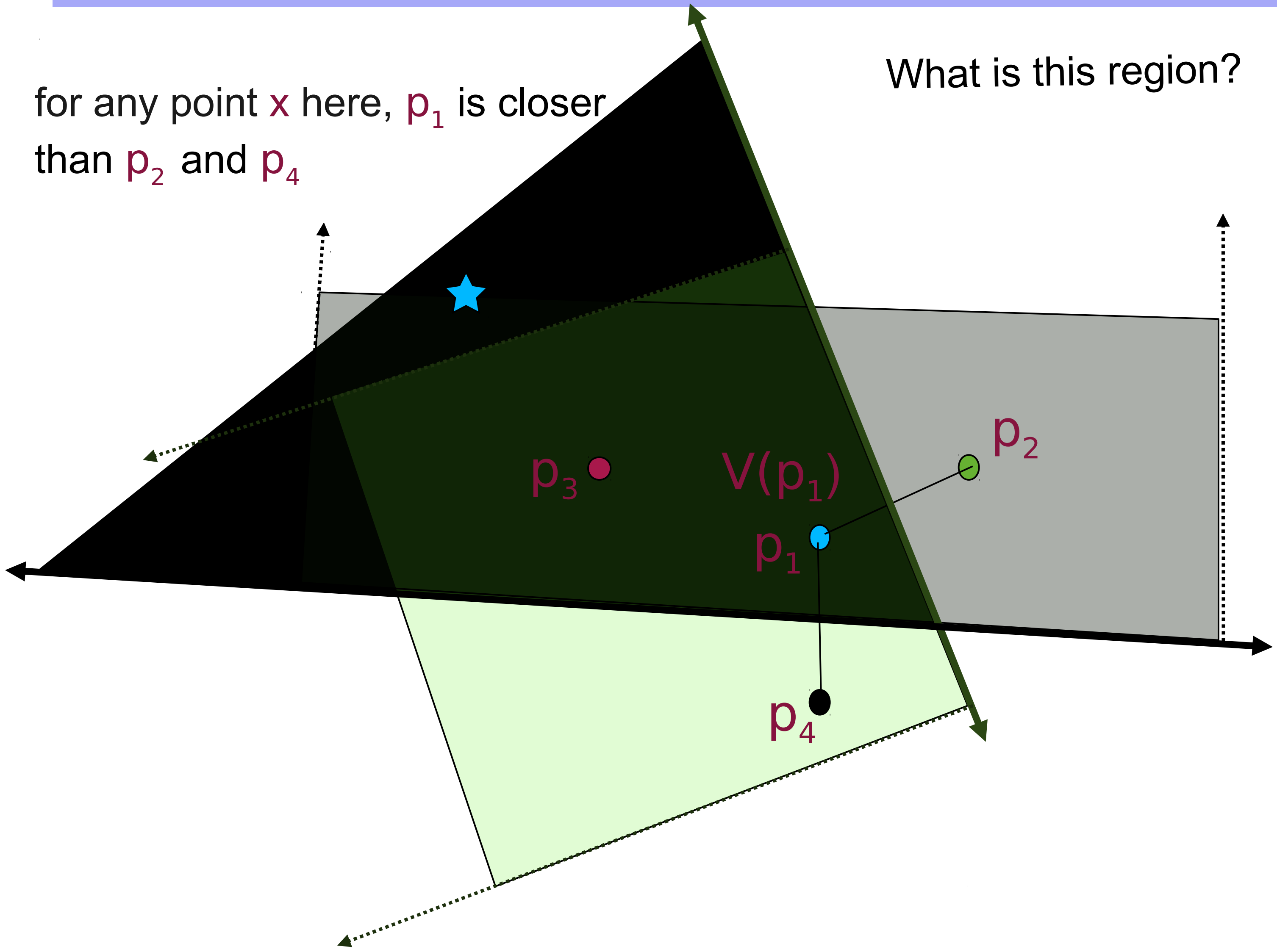
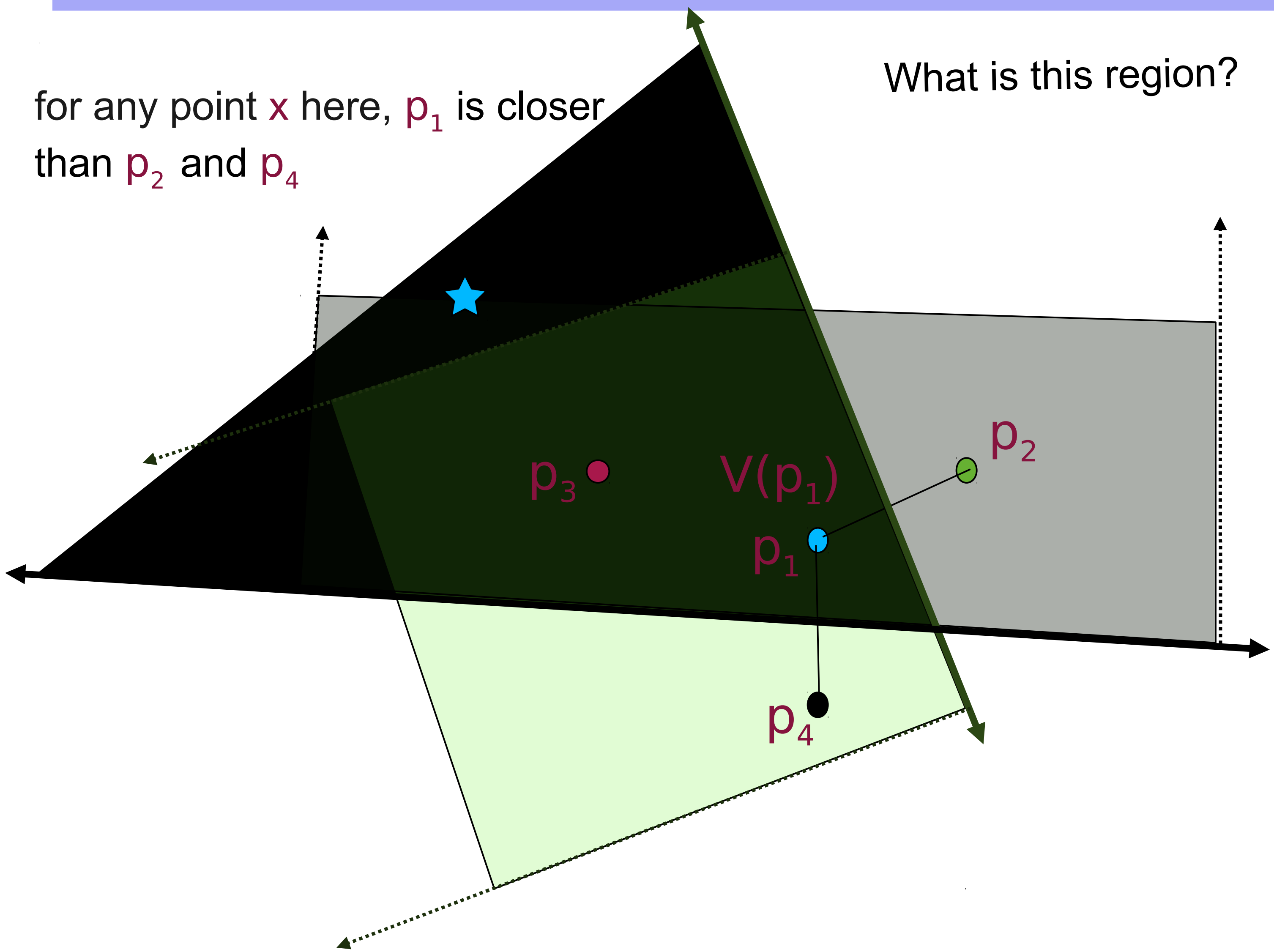


Computing the Voronoi Diagram

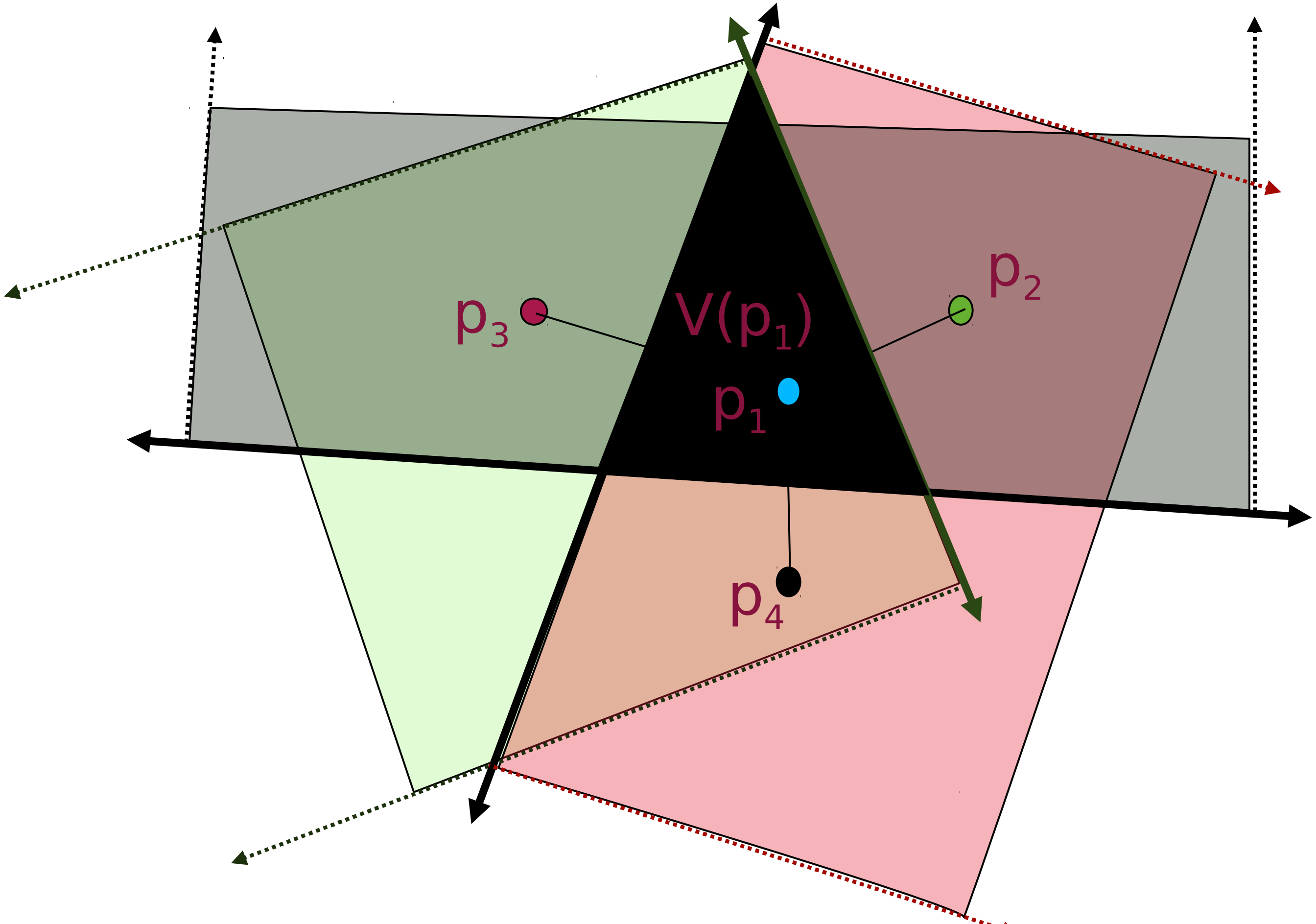
for any point x here, p_1 is closer than p_2 and p_4

What is this region? $H_1 \cap H_2$



Computing the Voronoi Diagram

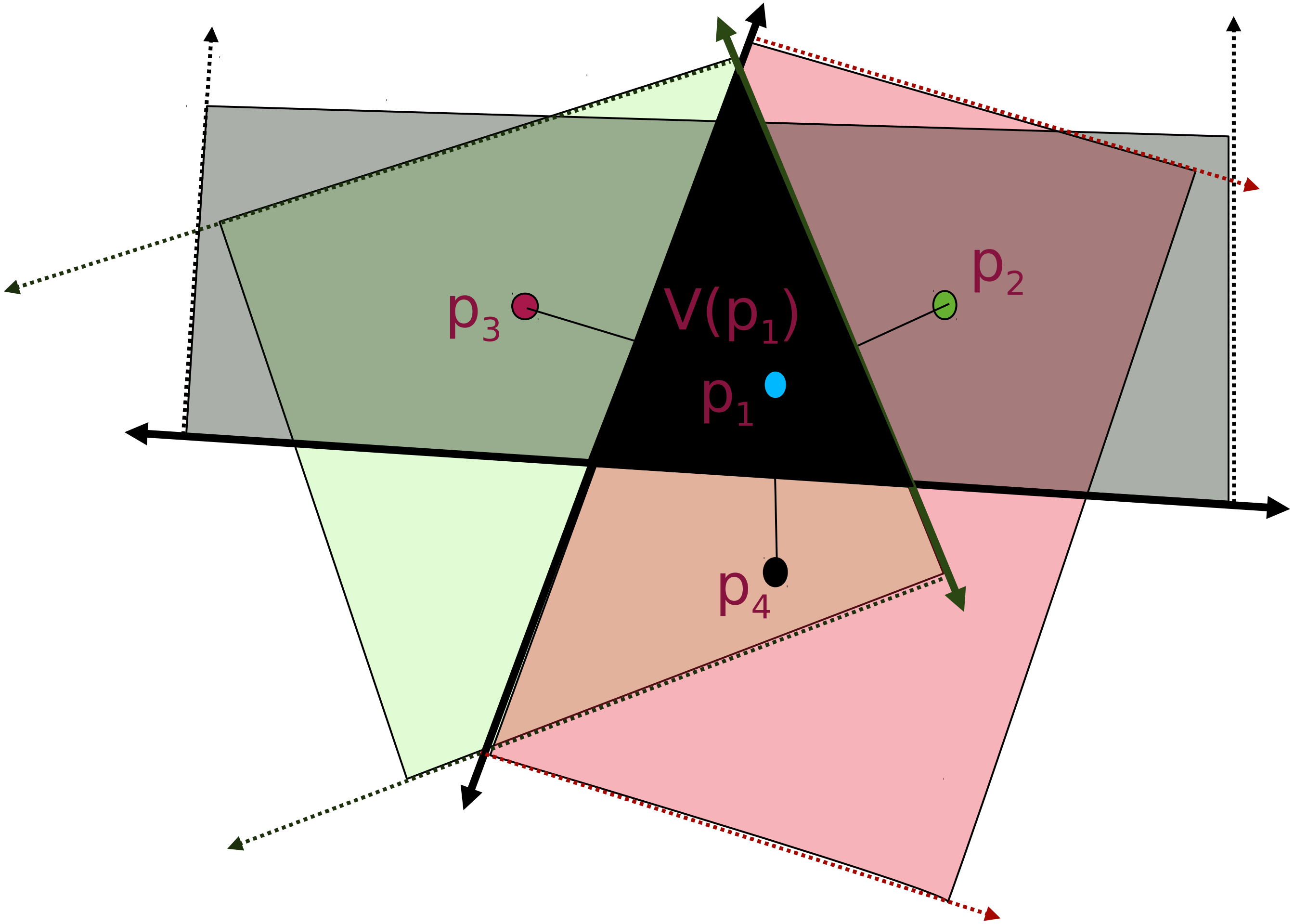
What is $V(p_1)$?



Computing the Voronoi Diagram

What is $V(p_1)$?

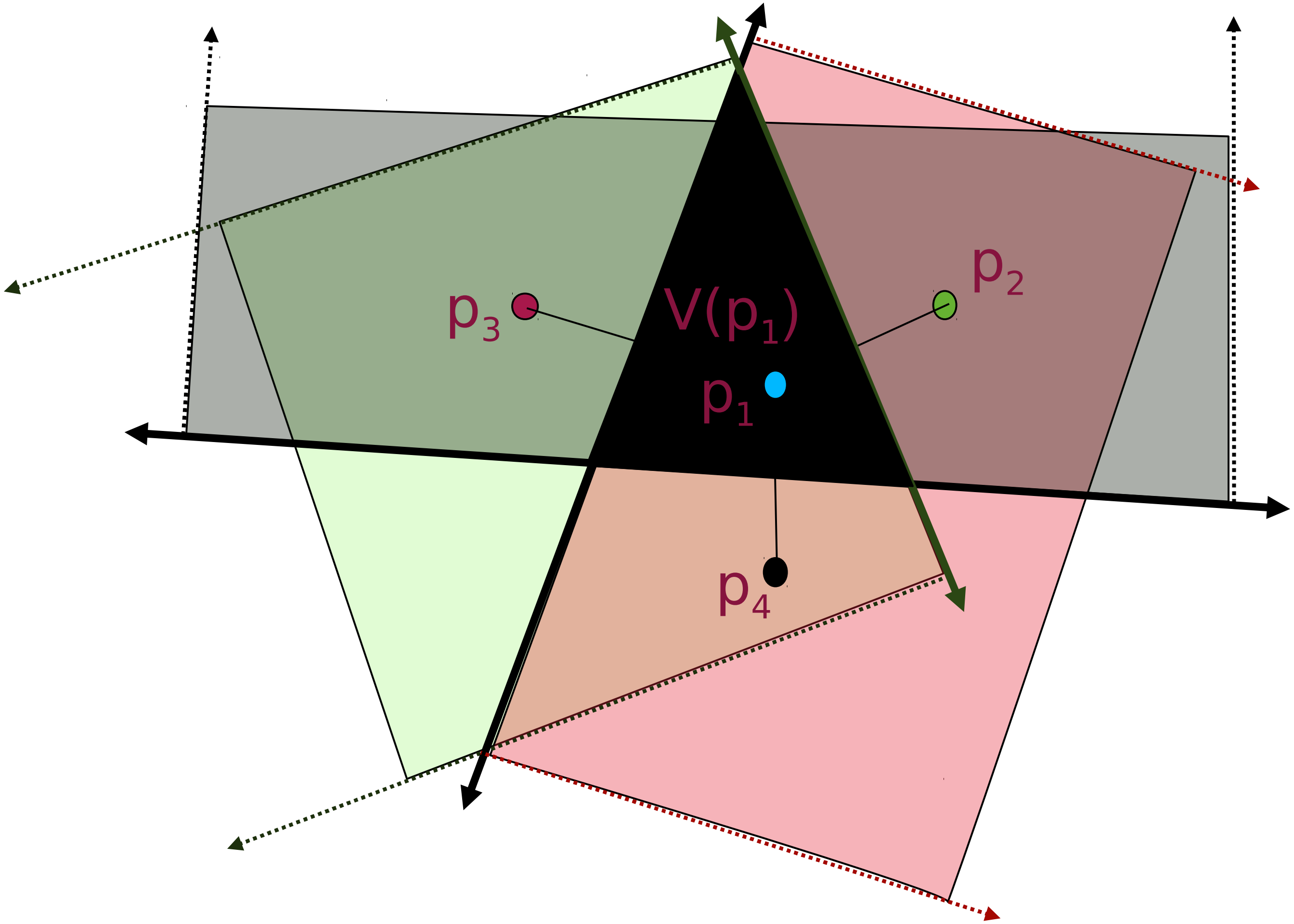
$H_1 \cap H_2 \cap H_3$



Computing the Voronoi Diagram

What is $V(p_1)$? $H_1 \cap H_2 \cap H_3$

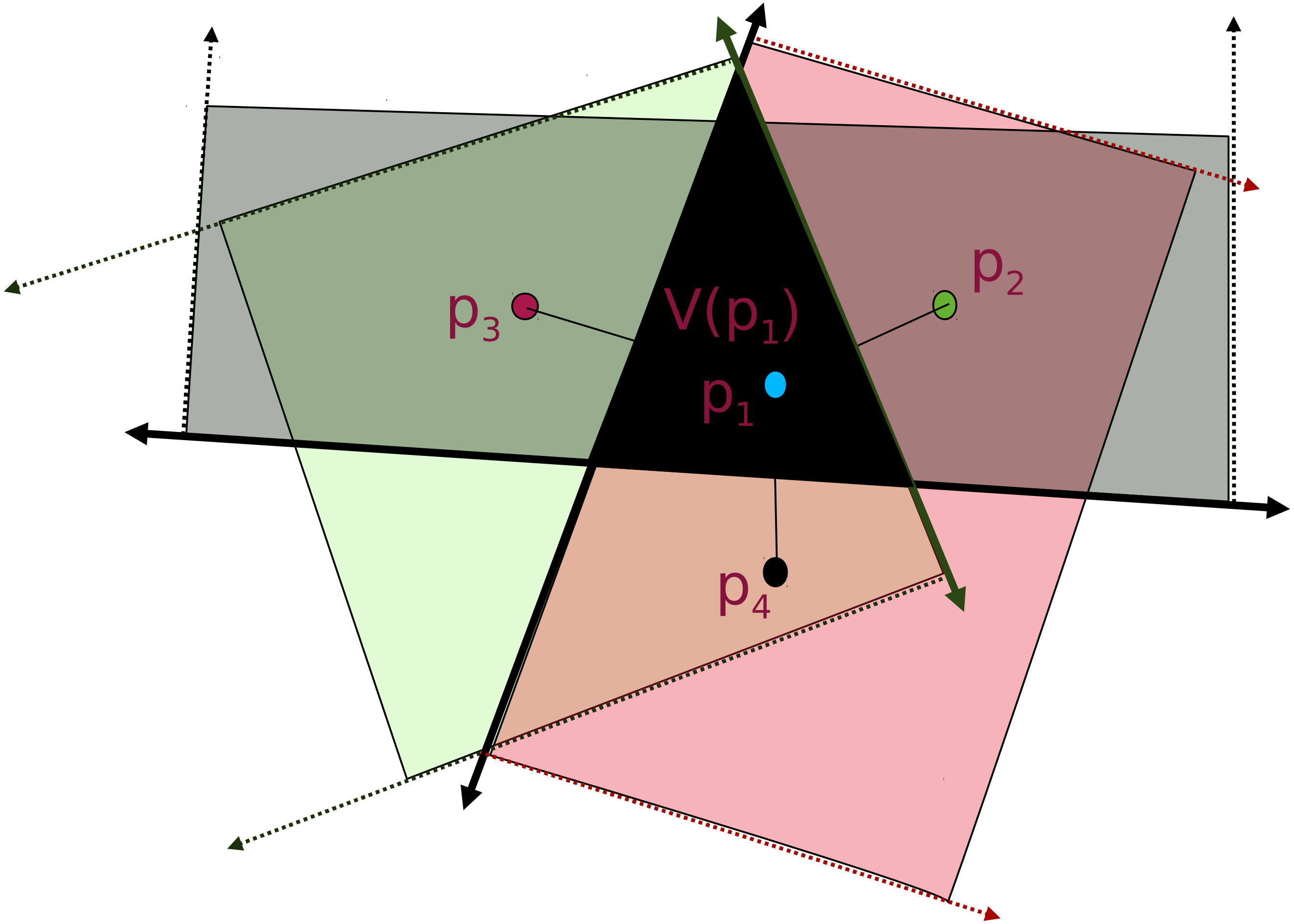
In general, what would be $V(p_1)$?



Computing the Voronoi Diagram

What is $V(p_1)$? $H_1 \cap H_2 \cap H_3$

In general, what would be $V(p_1)$? Intersection of (n-1) hyperplanes



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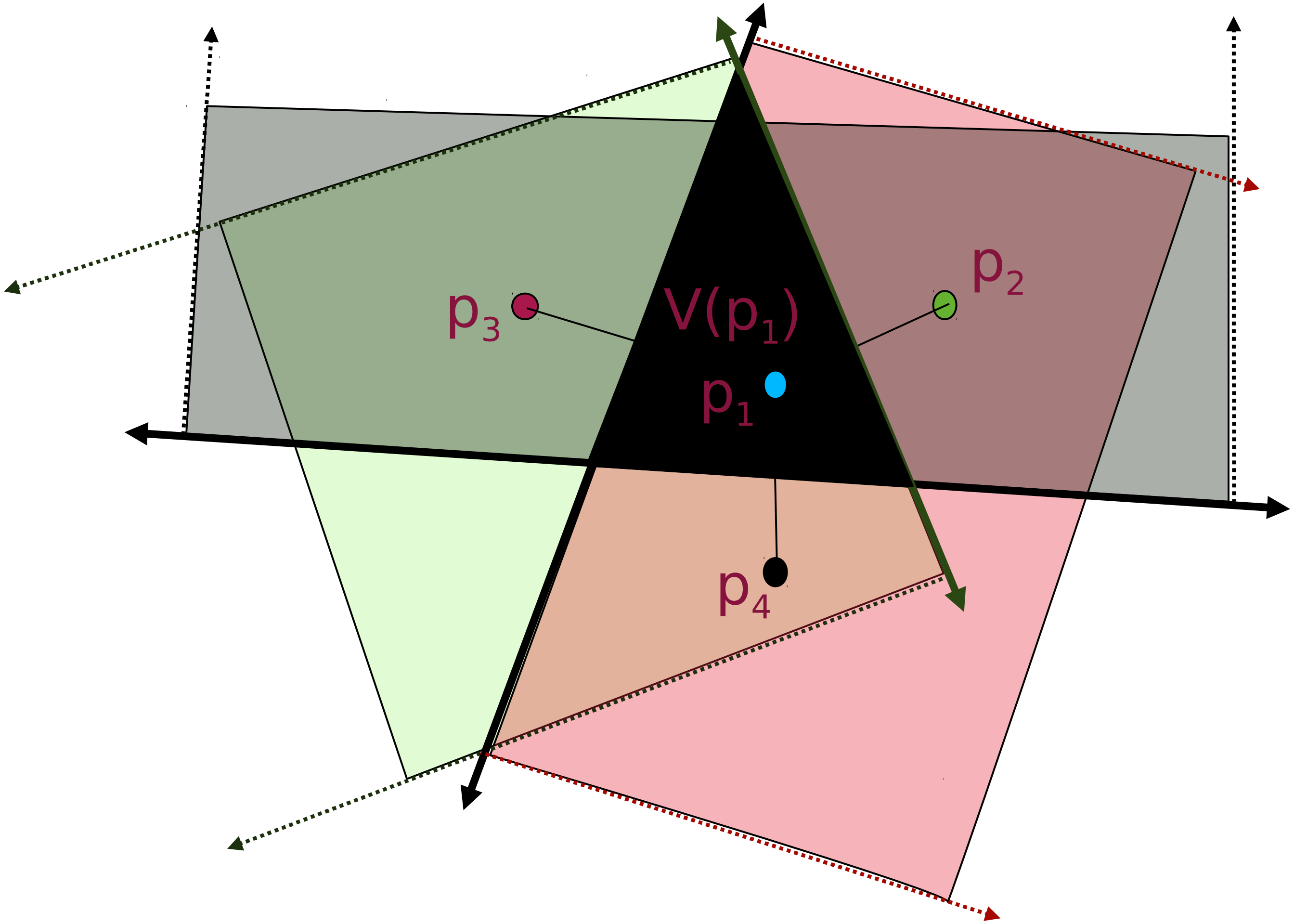
What is $V(p_1)$? $H_1 \cap H_2 \cap H_3$

In general, what would be $V(p_1)$? Intersection of (n-1) hyperplanes

$H_1 \cap H_2 \cap \ldots \cap H_{n-1}$



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Intersection of (n-1) hyperplanes can be found in O(n log n) time

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Time Complexity of Best Algorithms for Voronoi Diagram

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Voronoi Diagram can be constructed in $O(n \log n)$ time

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Voronoi Diagram can be constructed in O(n log n) time

There are well-known algorithms like:

1. Fortune's Line Sweep
2. Divide and Conquer
3. Lifting points in 3D

Size of the Voronoi Diagram

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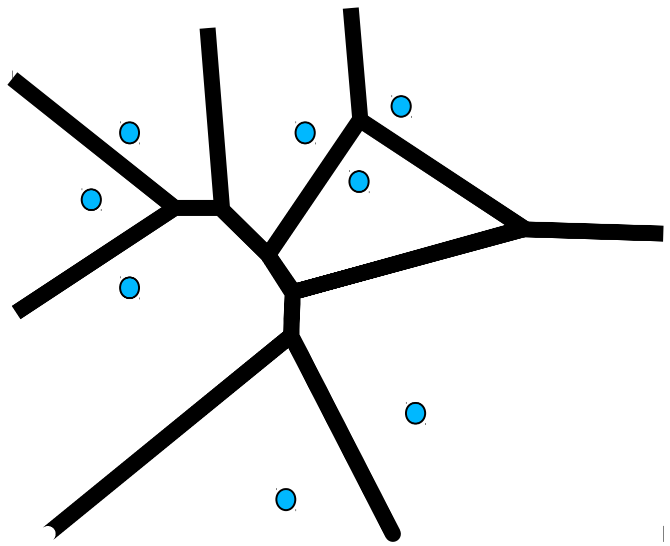
Size means: number of vertices, edges and faces



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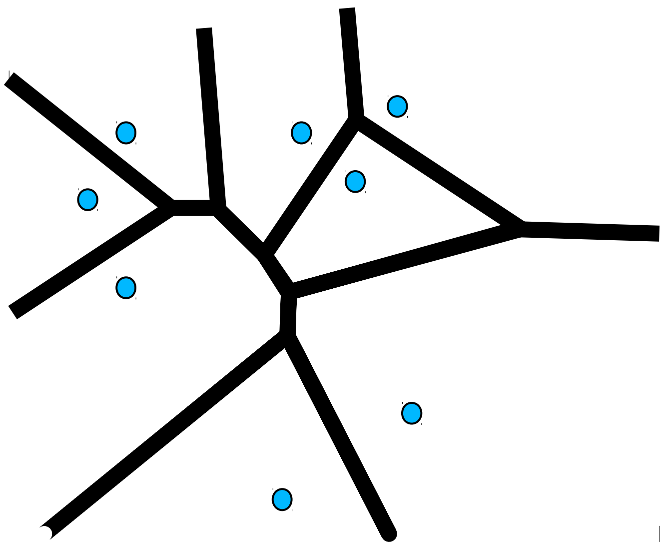

Lower bound (Smallest Size possible):

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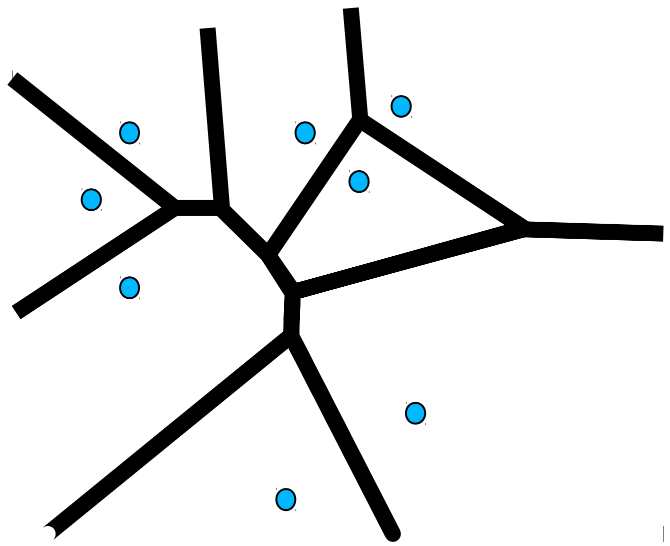

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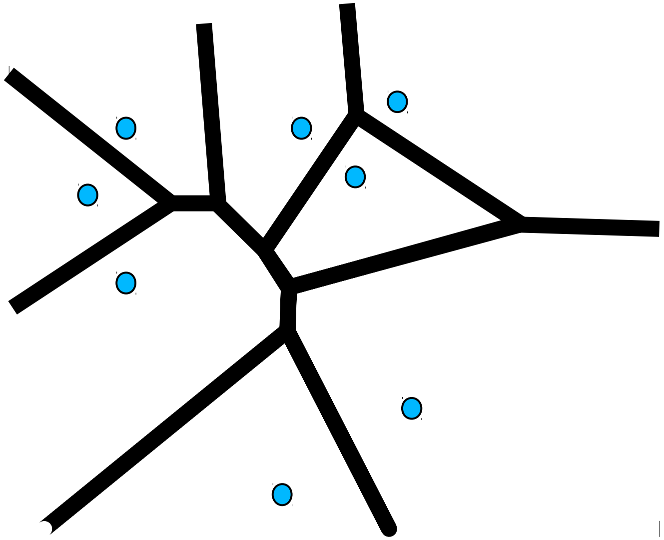

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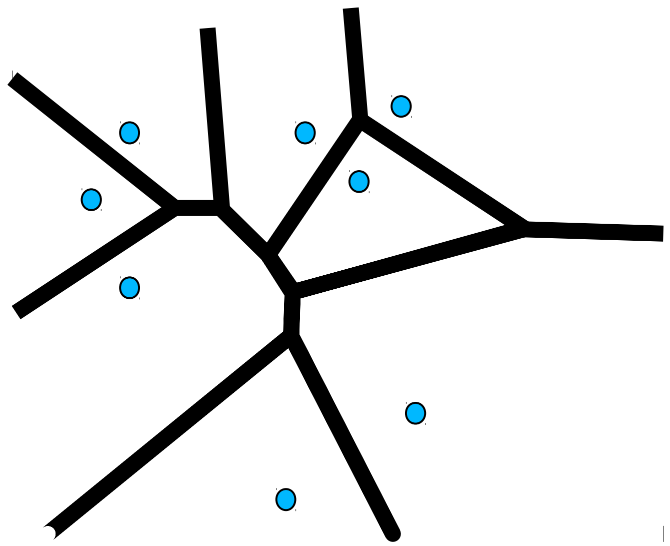

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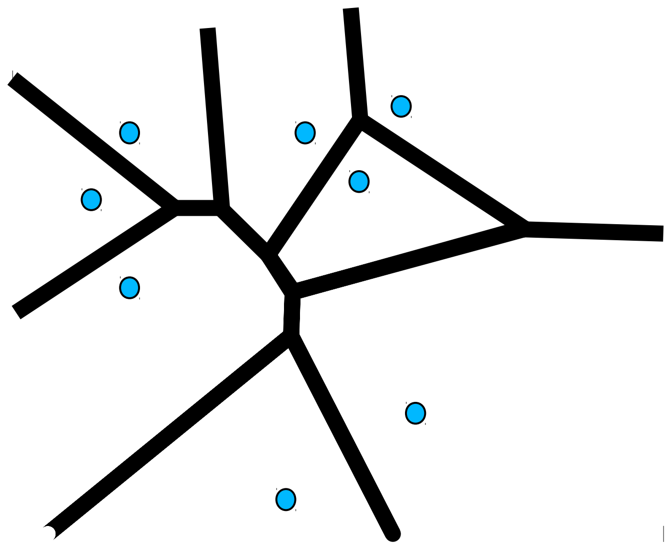

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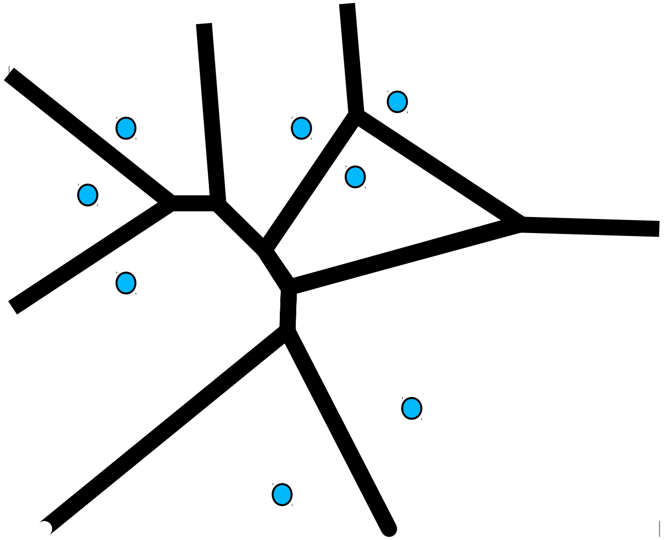

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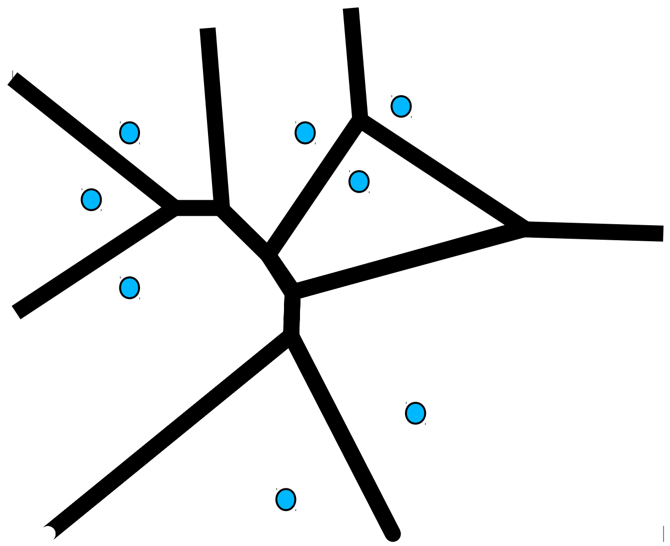

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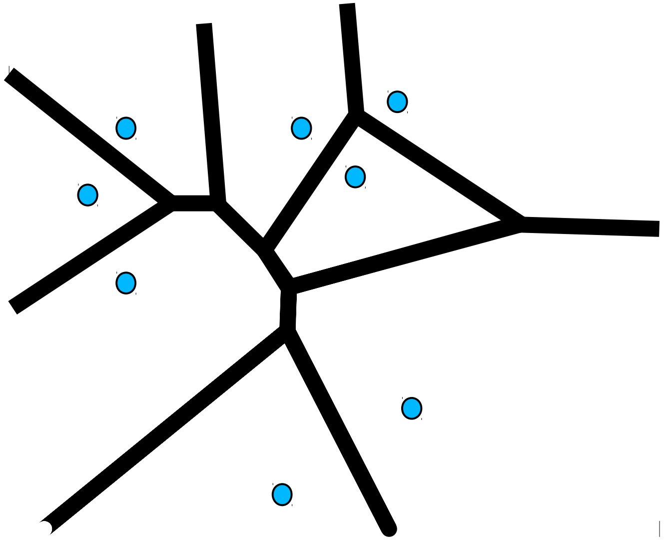
Voronoi Diagram is Planar Subdivision



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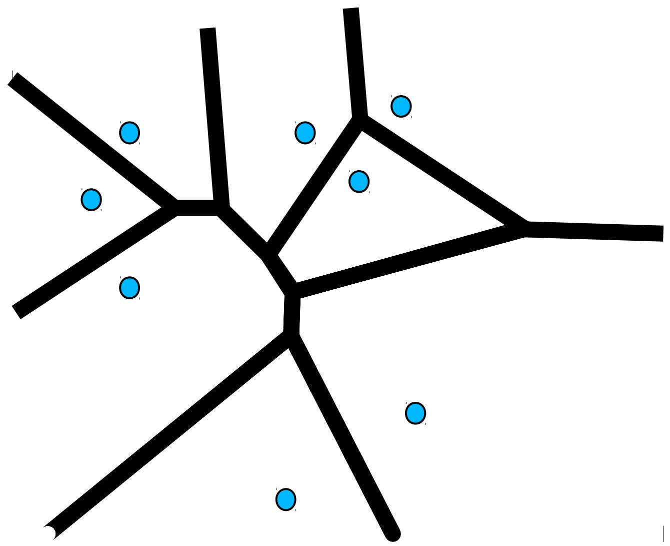

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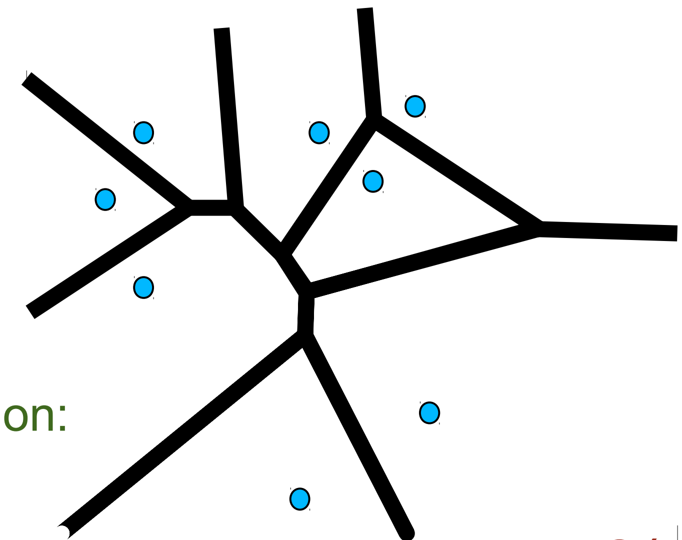

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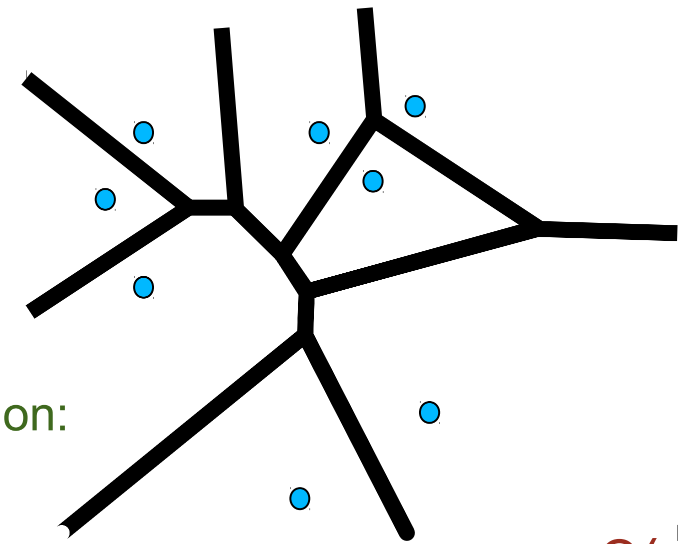

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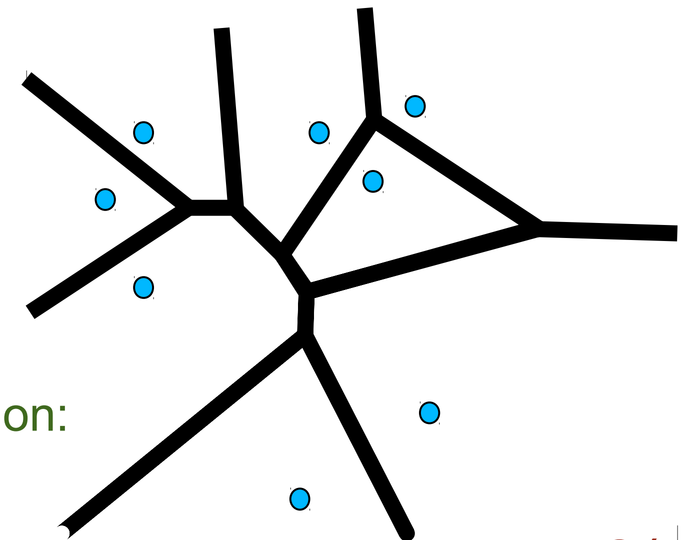

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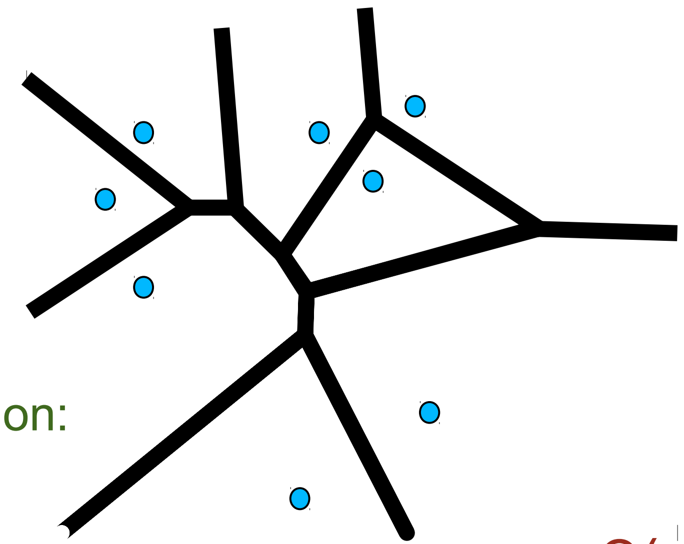

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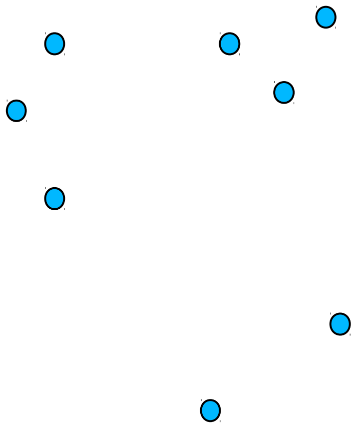
Summary

P → A set of n distinct points (Geometric Objects) in the plane.



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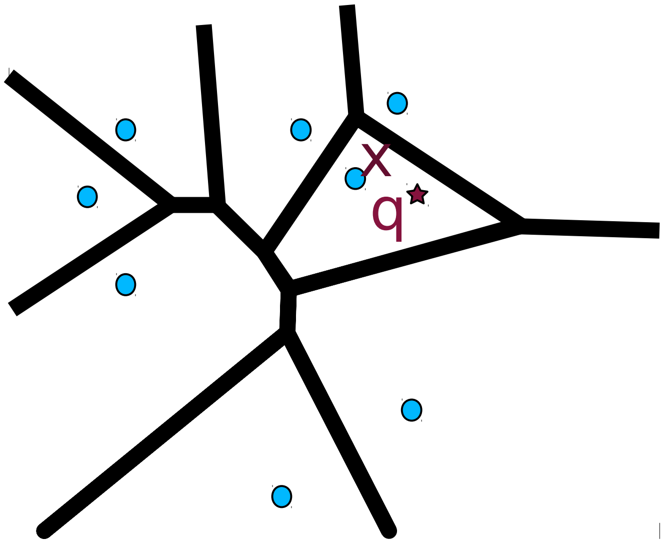

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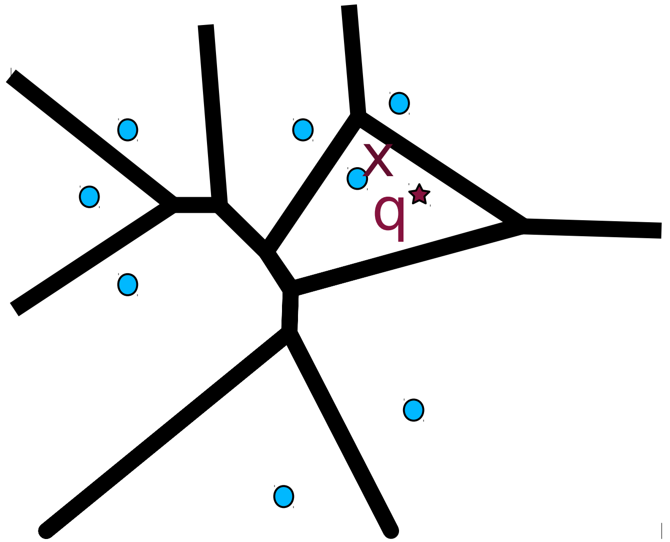

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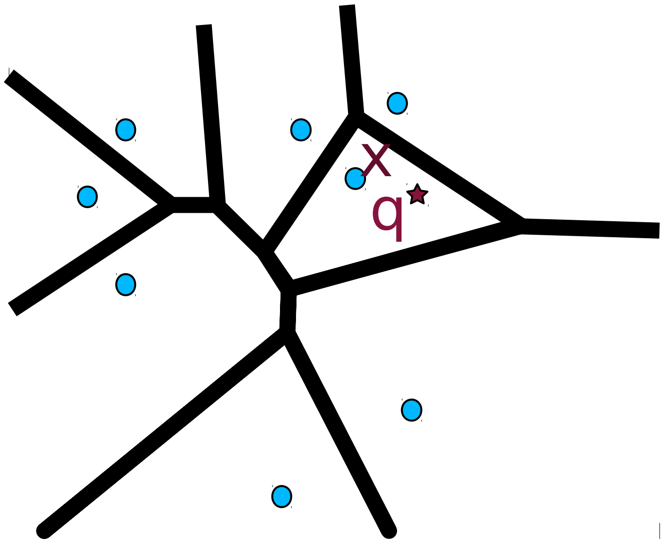
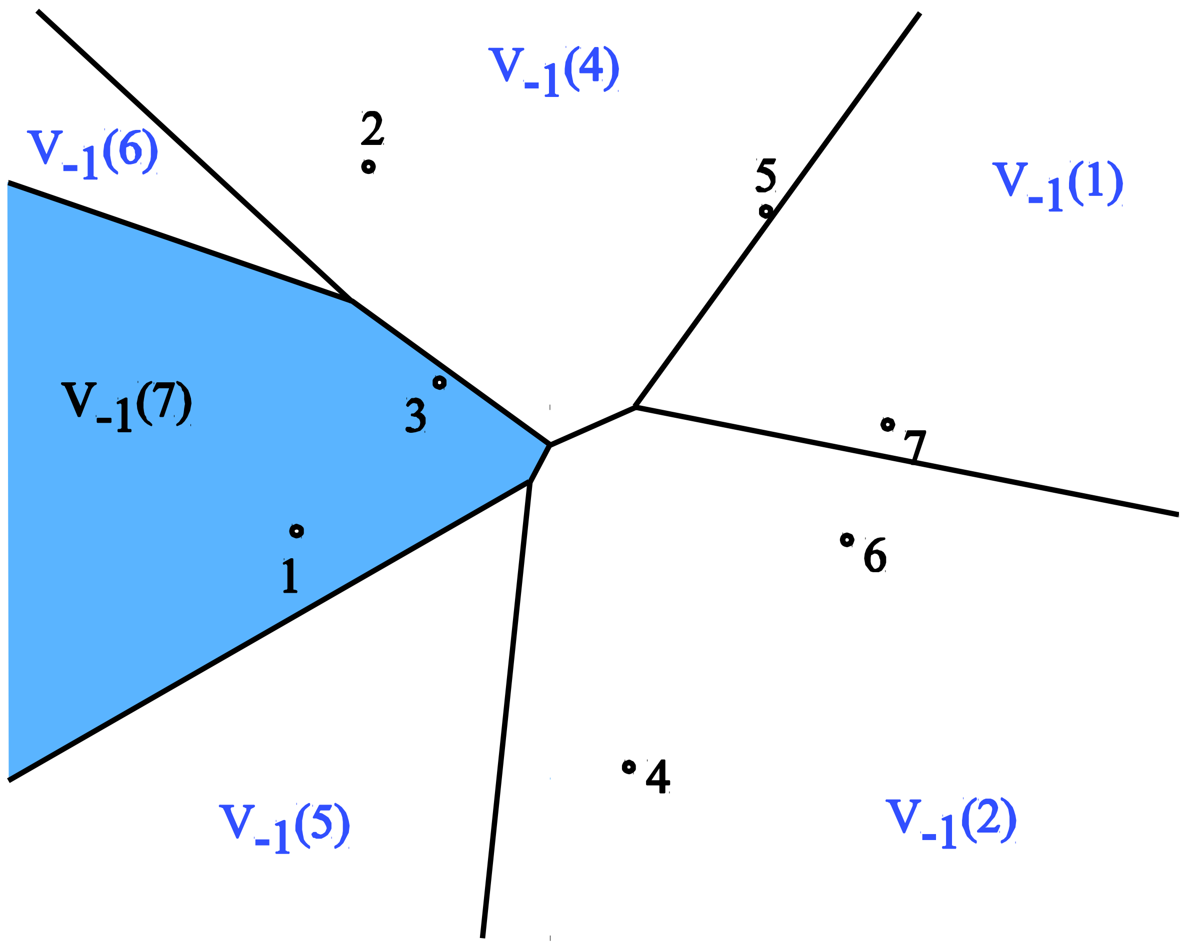


Preprocess structure is called Voronoi Diagram V(P)

V(P) can be constructed in O(n log n) time and can be stored in O(n) space

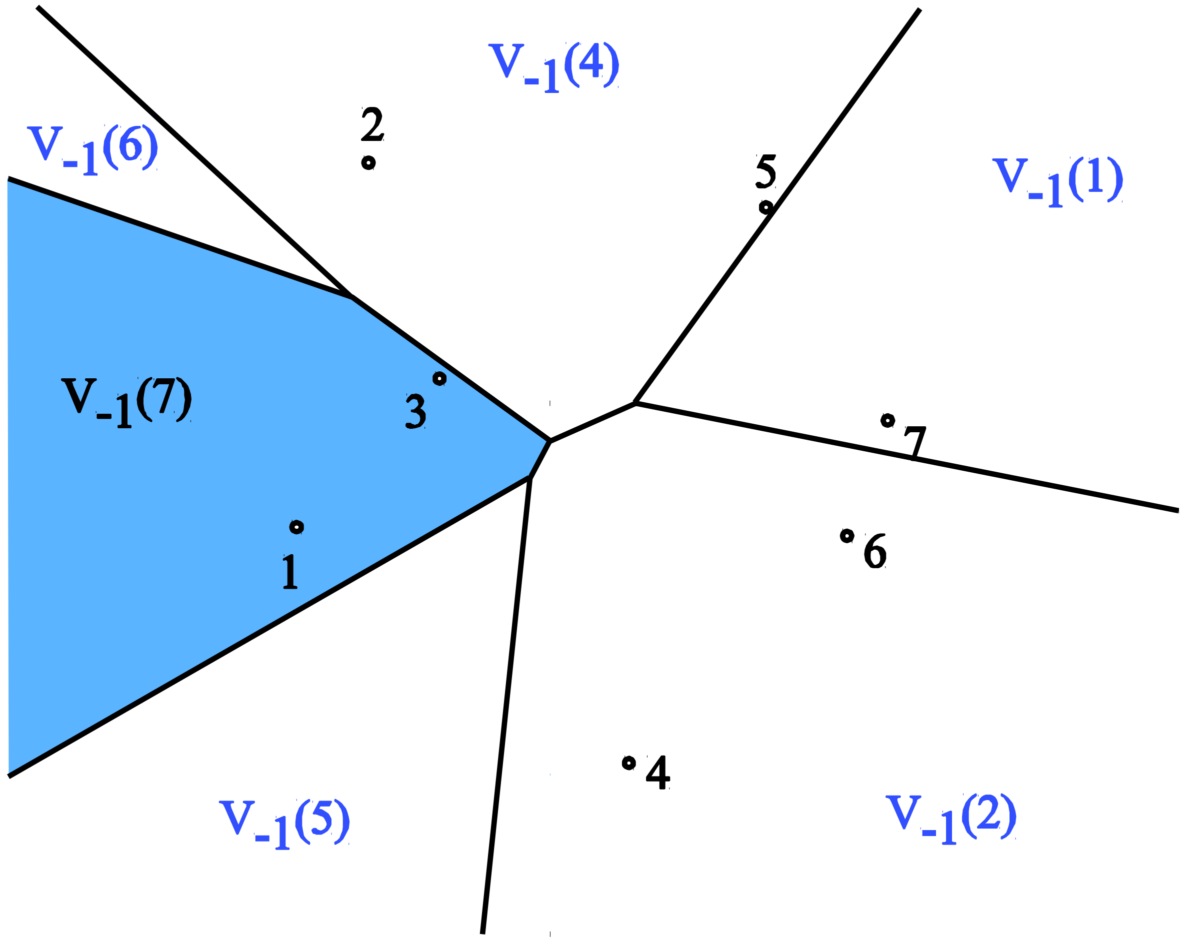
Other Kind of Voronoi Diagrams

Furthest Point Voronoi Diagram



Furthest Point Voronoi Diagram

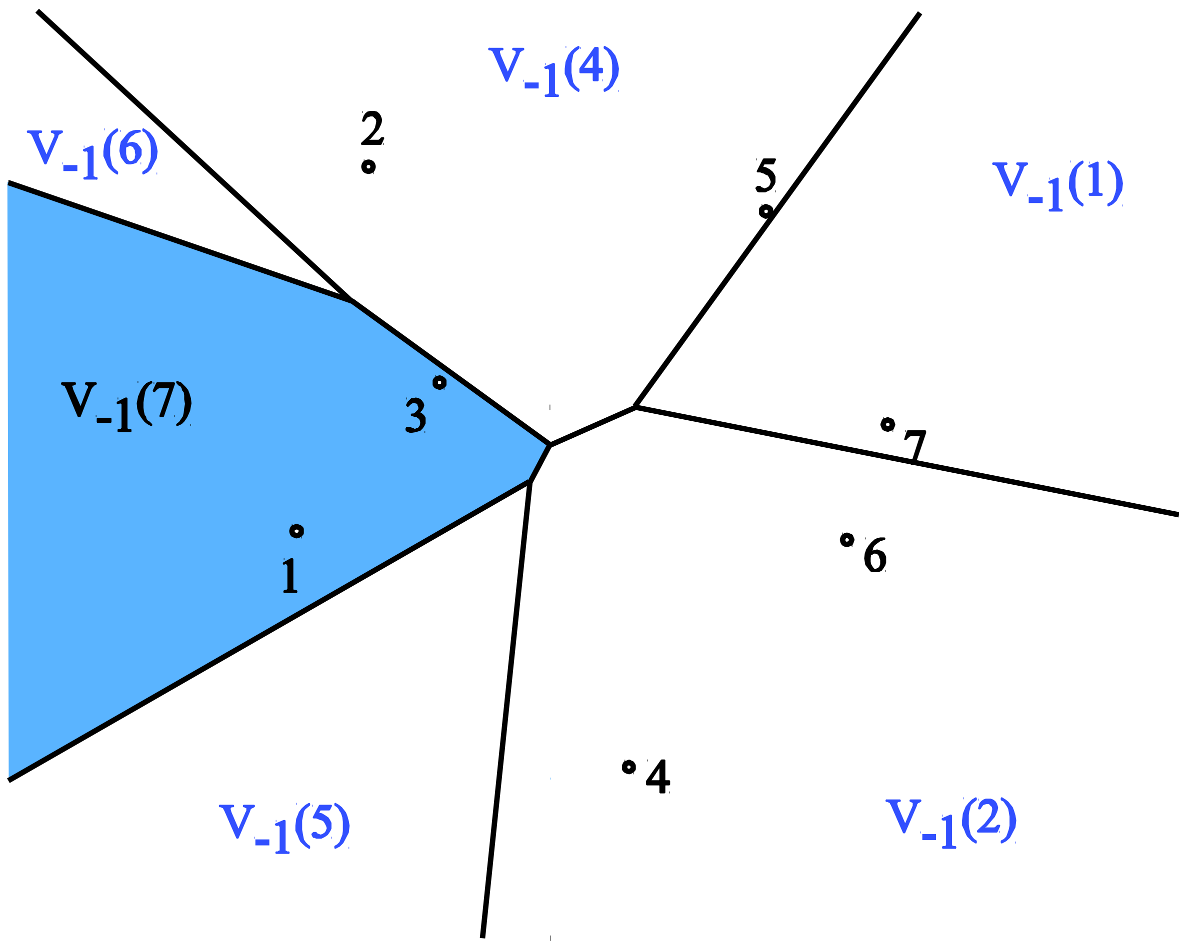
FV(P): the partition of the plane formed by the farthest point Voronoi regions, their edges, and vertices



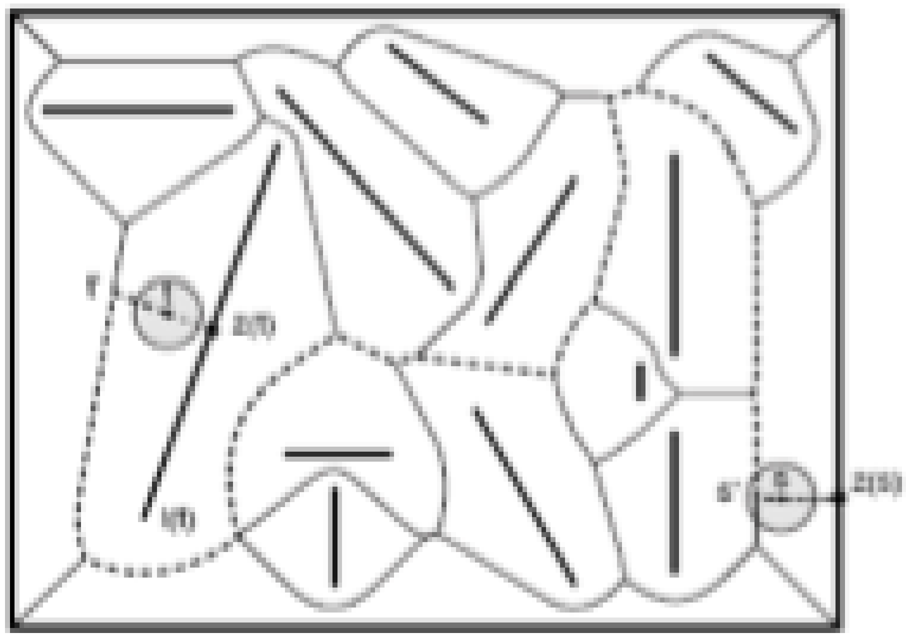
Furthest Point Voronoi Diagram

FV(P): the partition of the plane formed by the farthest point Voronoi regions, their edges, and vertices

$V_{-1}(p_i)$: the set of point of the plane farther from p_i than from any other site



Voronoi diagram for line segments



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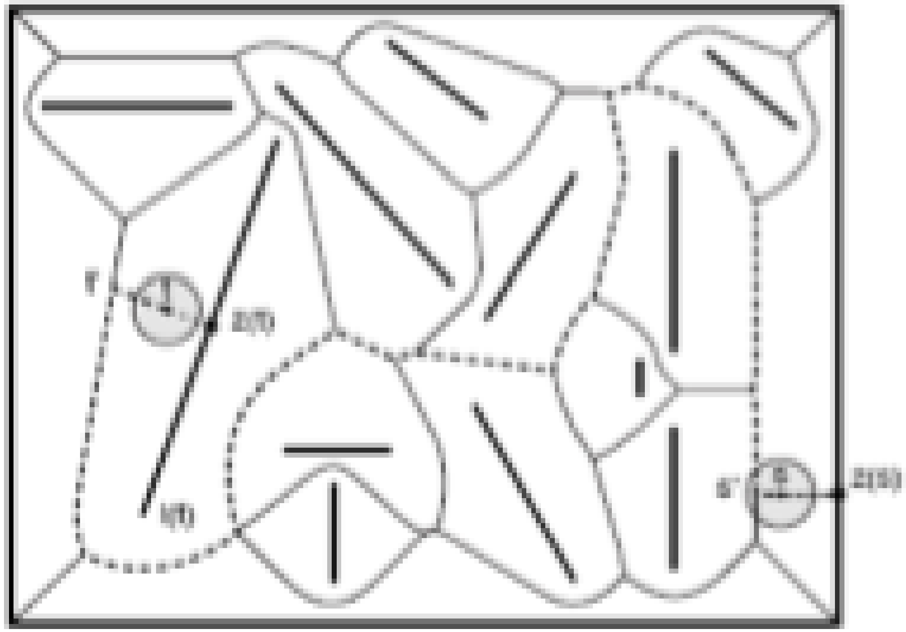

Moving a disk from s to t in the presence of barriers

Organization of the Talk

1. Preliminaries
2. Generic Definition
3. Some Technical Details
4. Conclusion

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There is dedicated Symposiums on Voronoi Diagram:

INTERNATIONAL SYMPOSIUM on VORONOI DIAGRAMS in science and engineering

Thank You