Motorcycles

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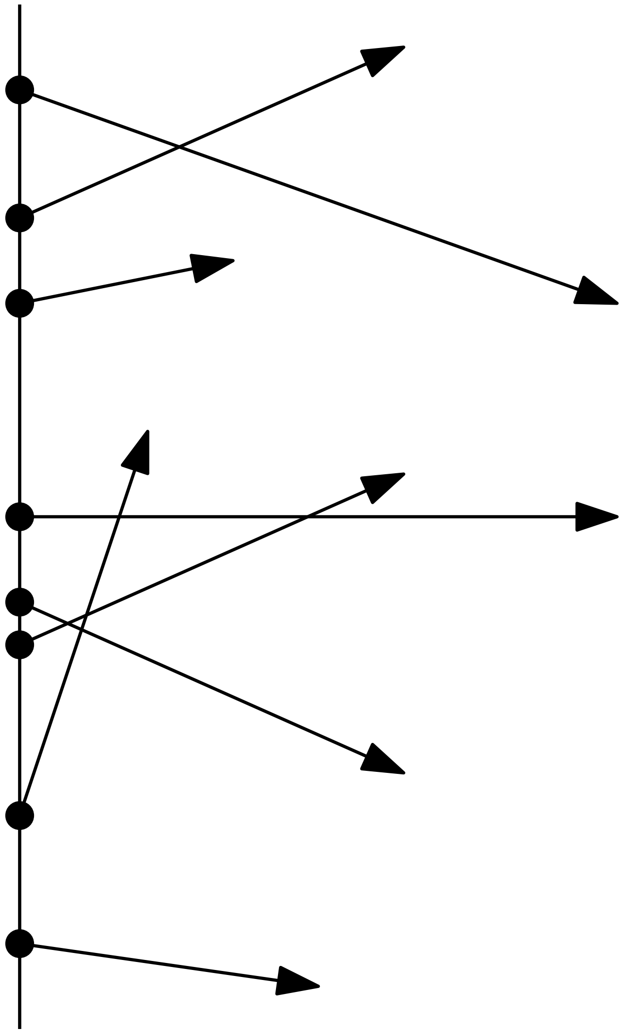

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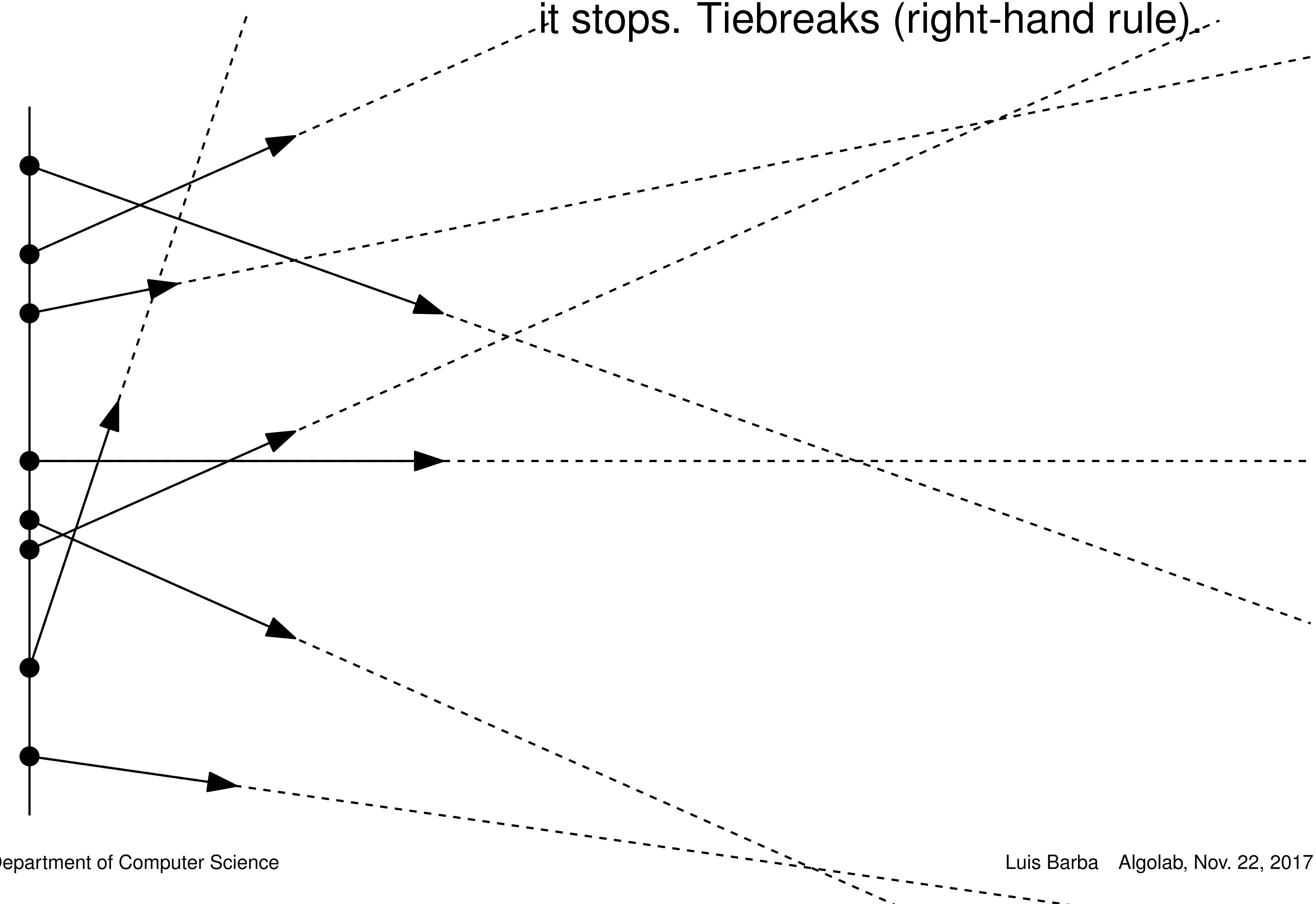

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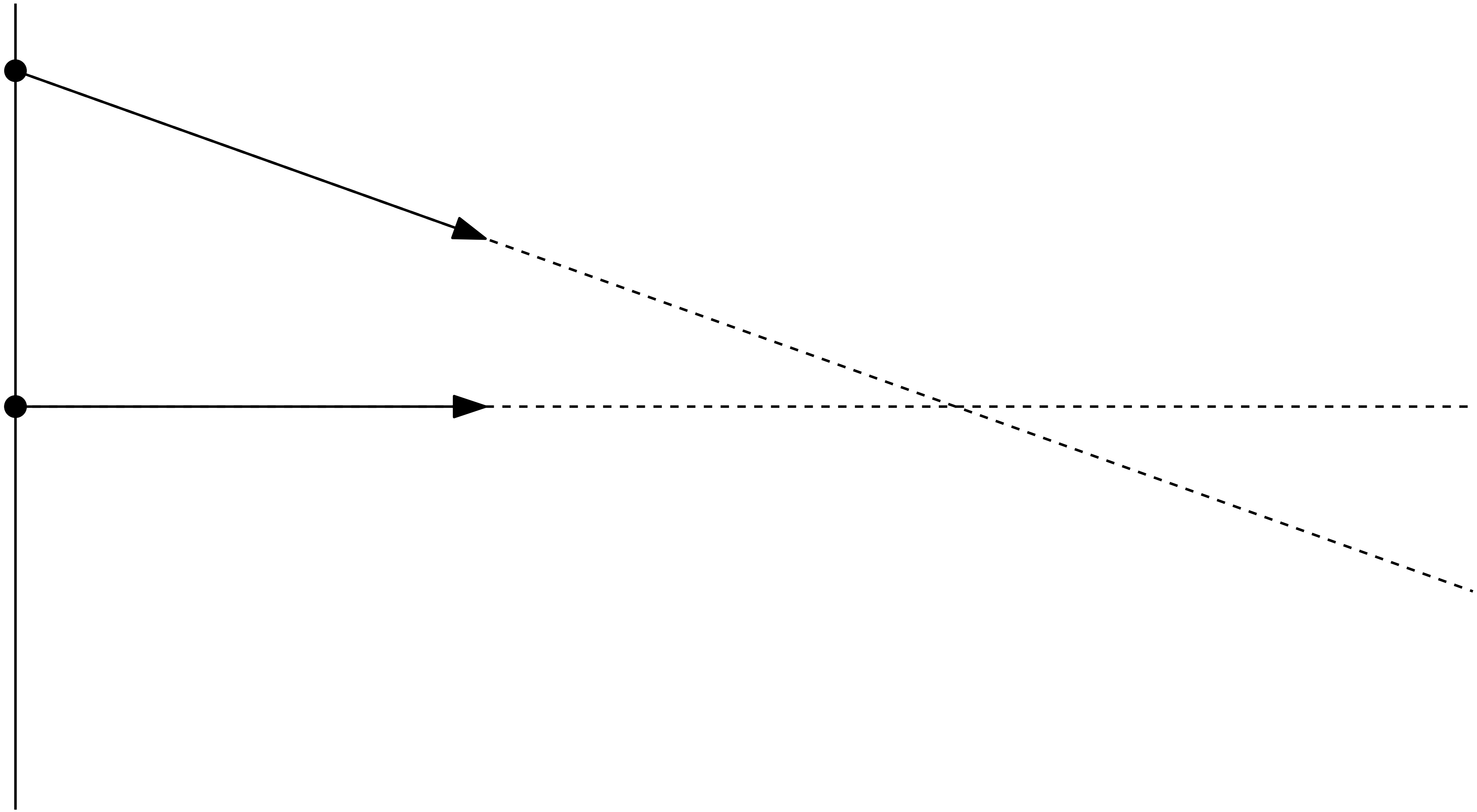

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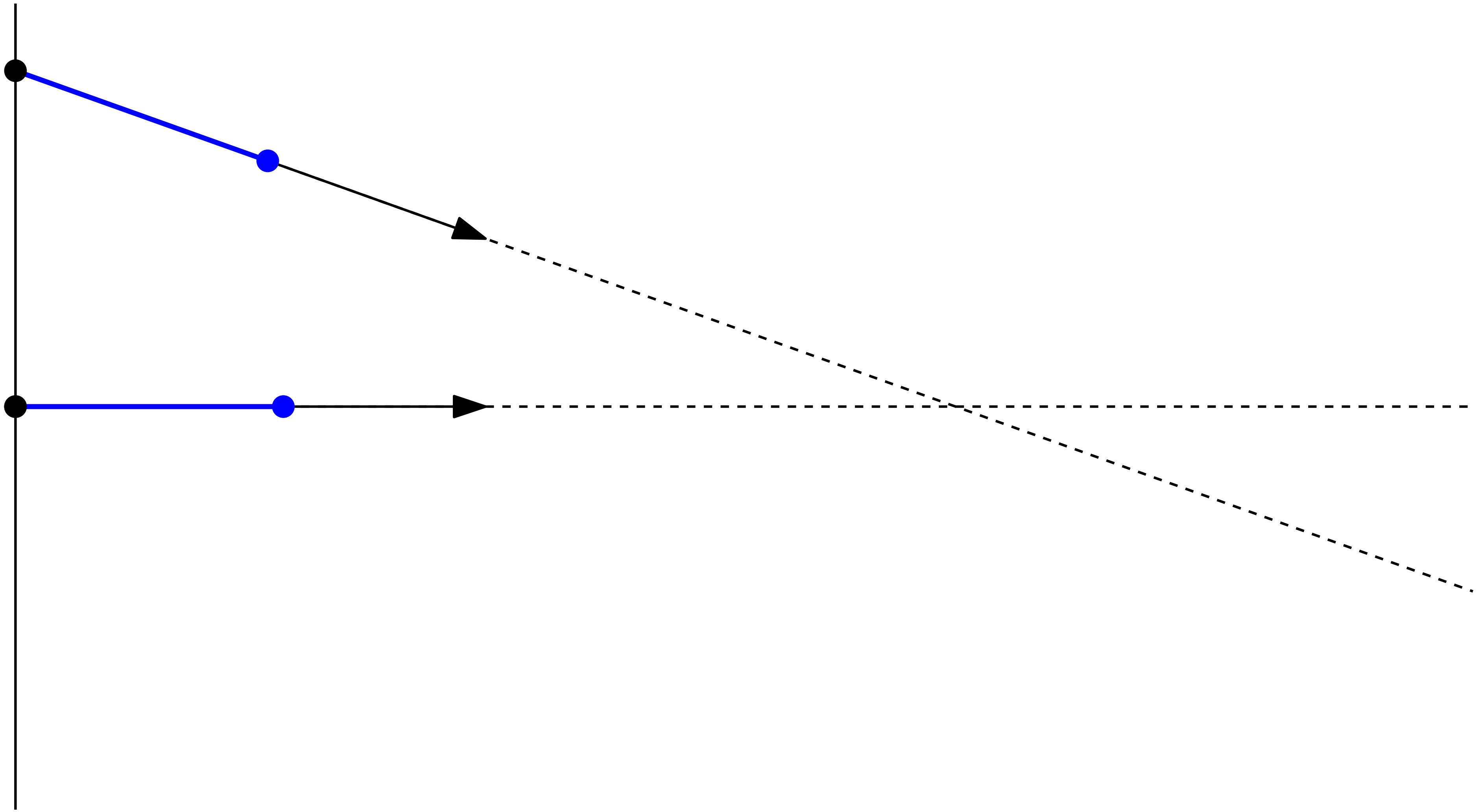

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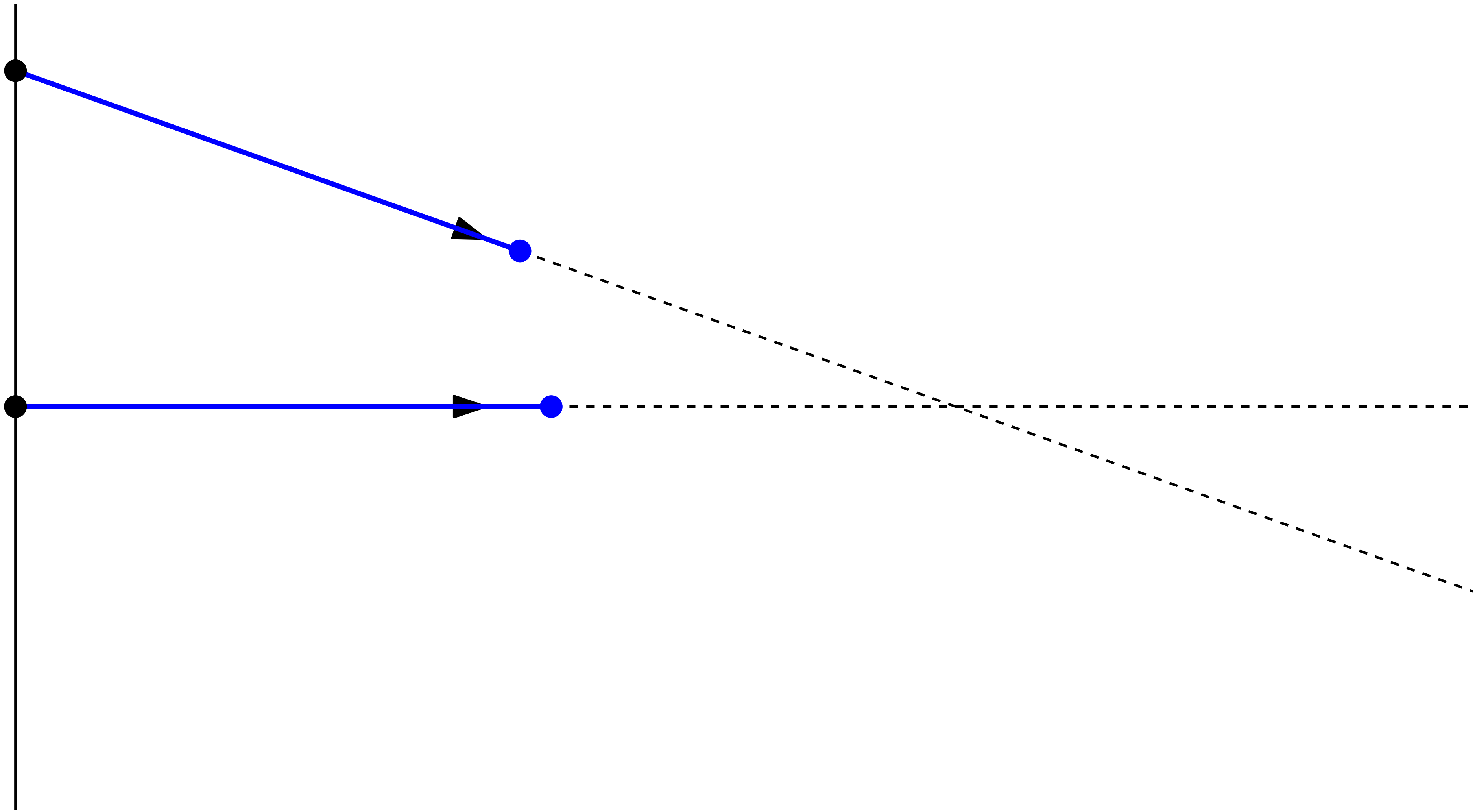

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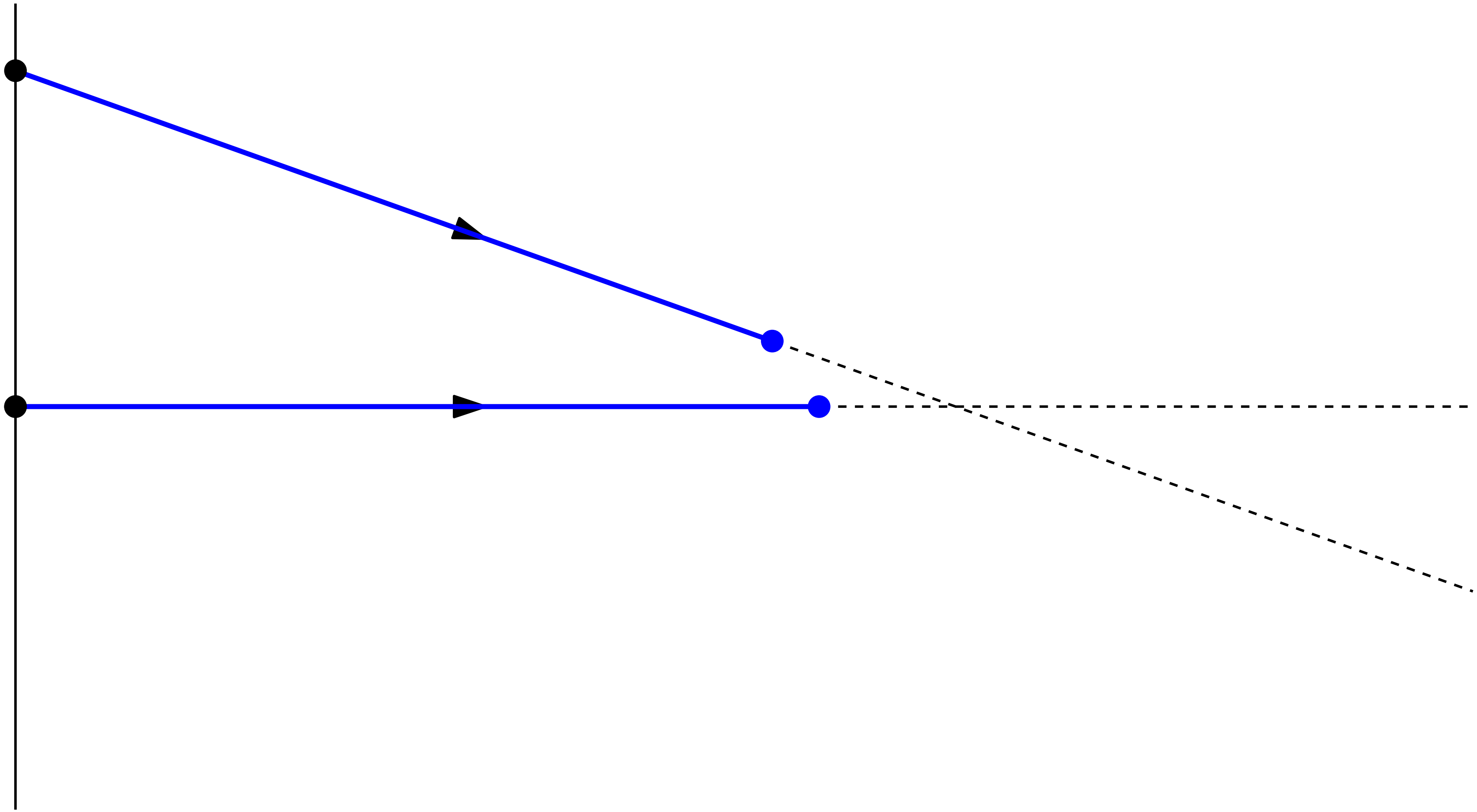

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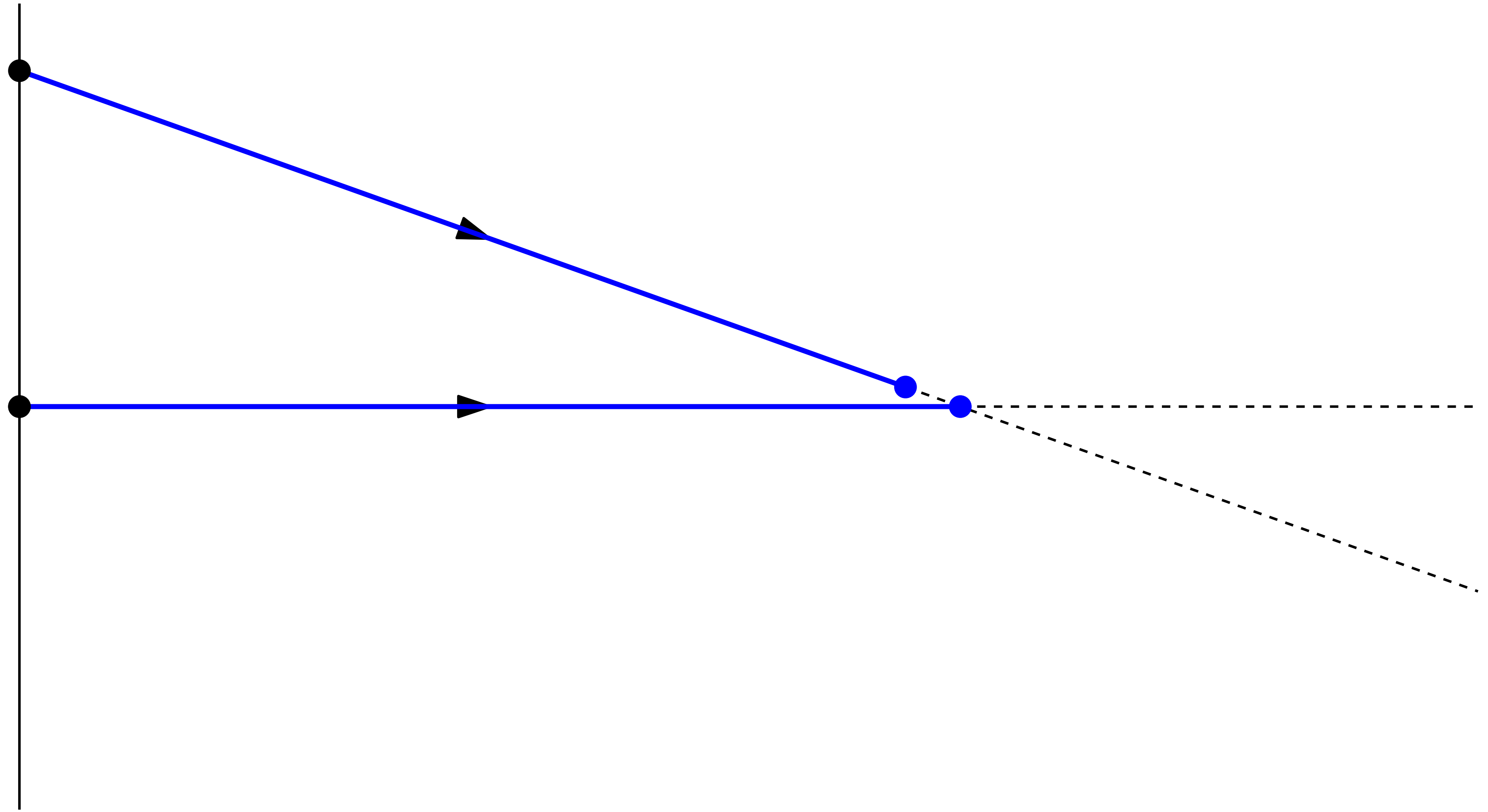

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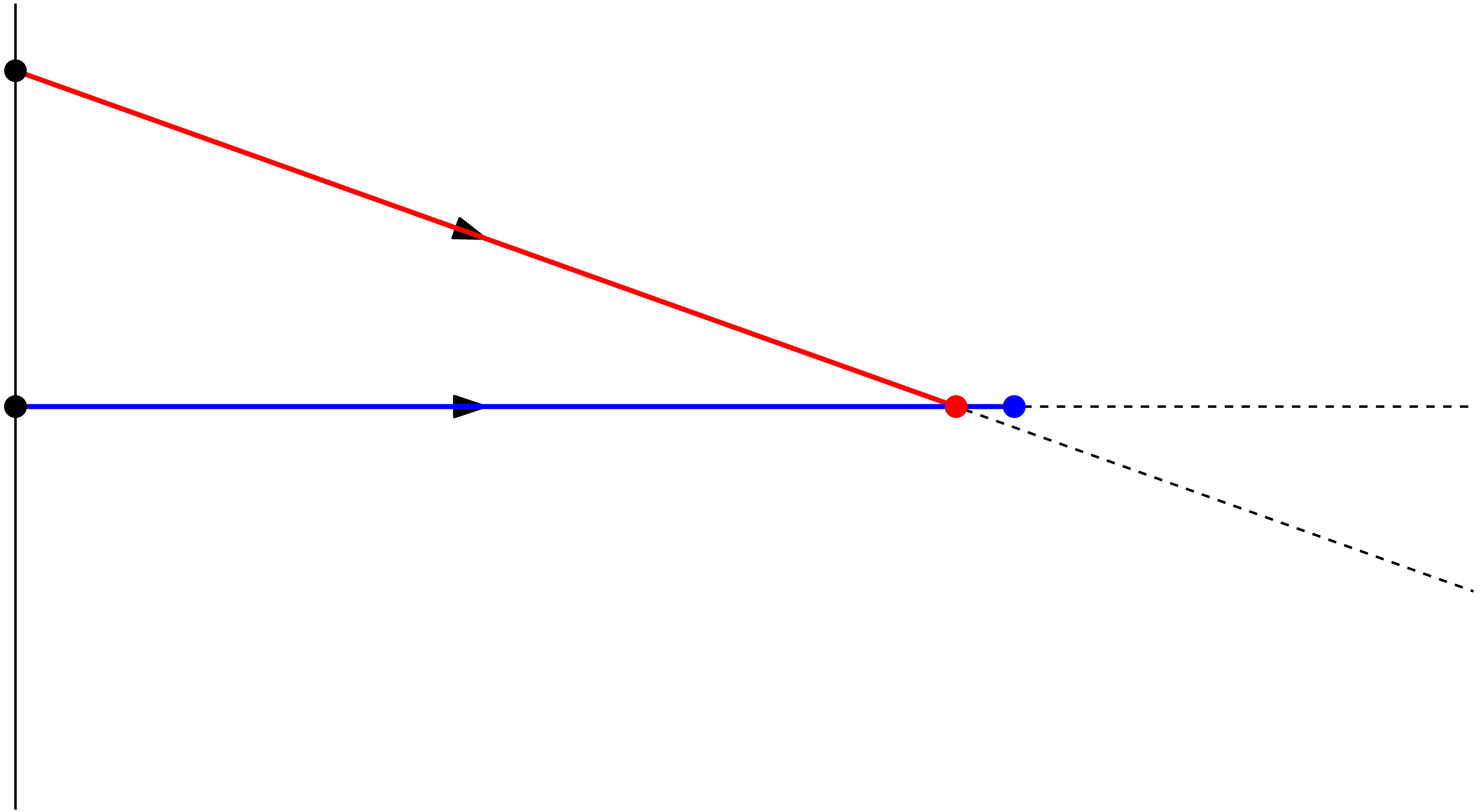

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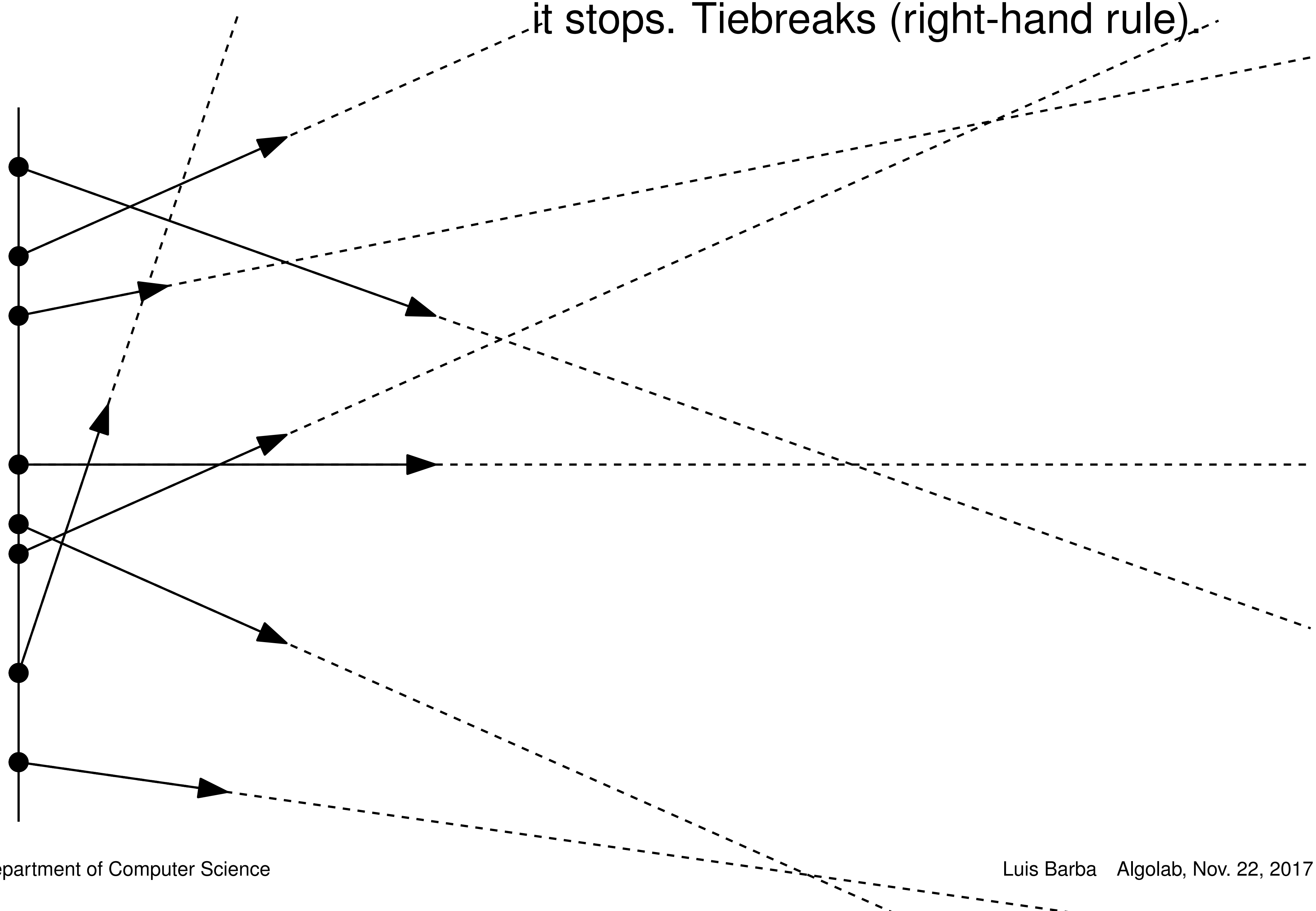

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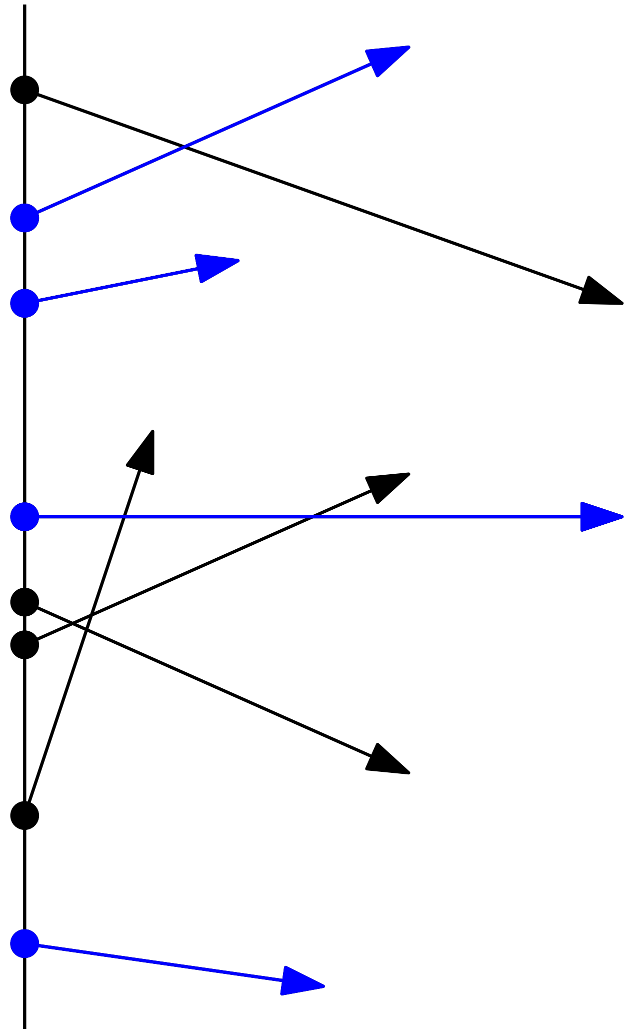
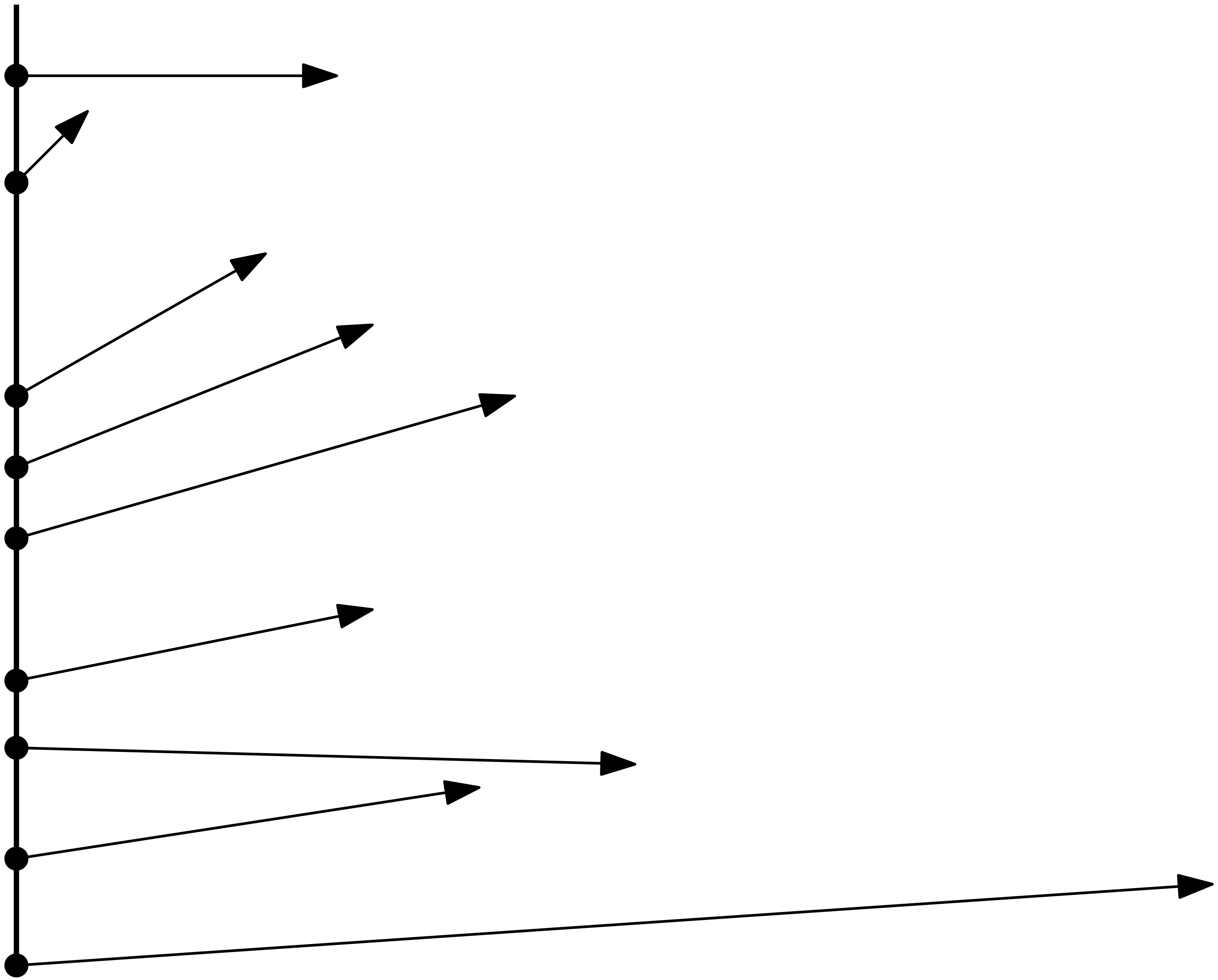


Find which riders get to ride forever.

Admission Control

Admission Control



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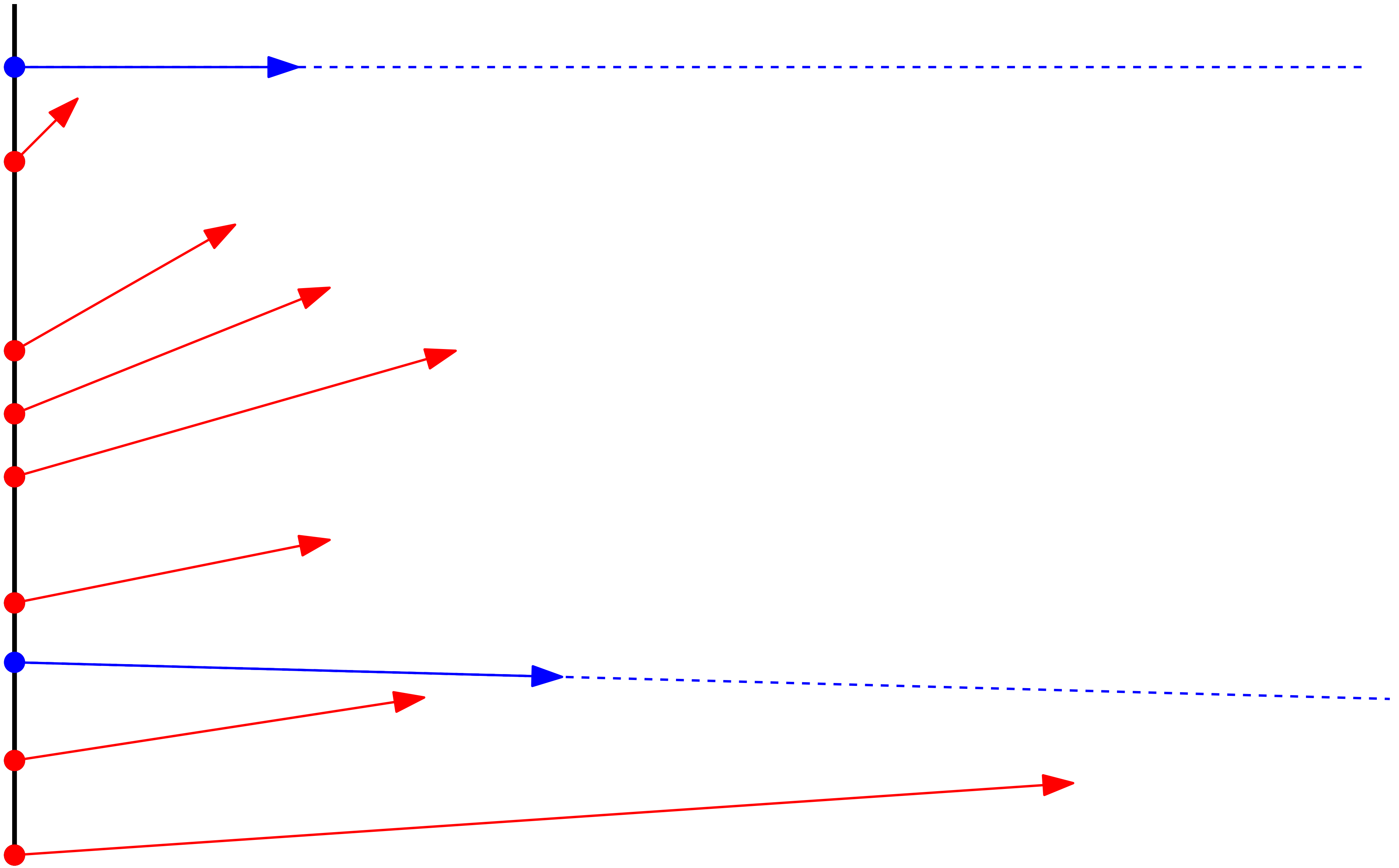

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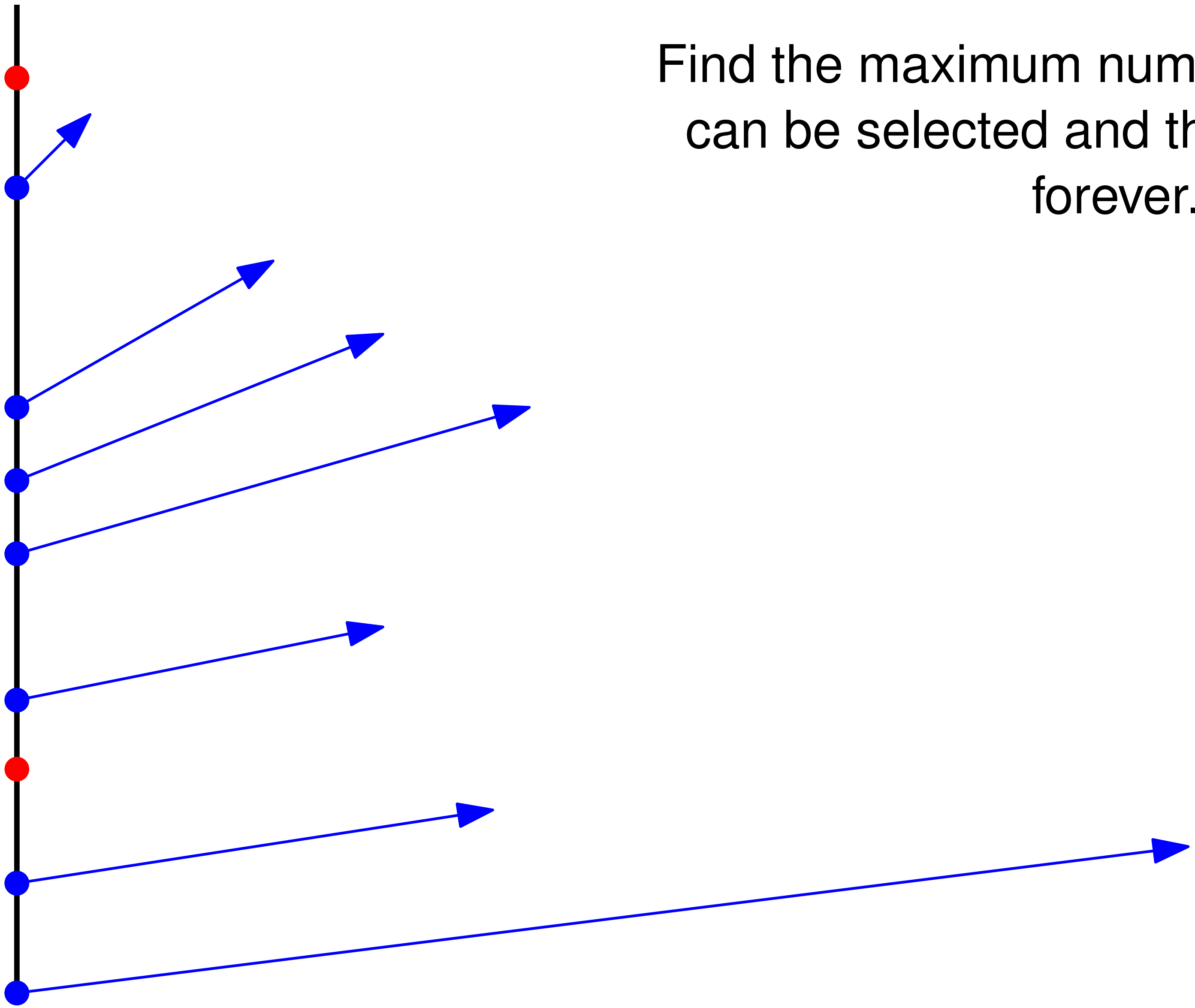
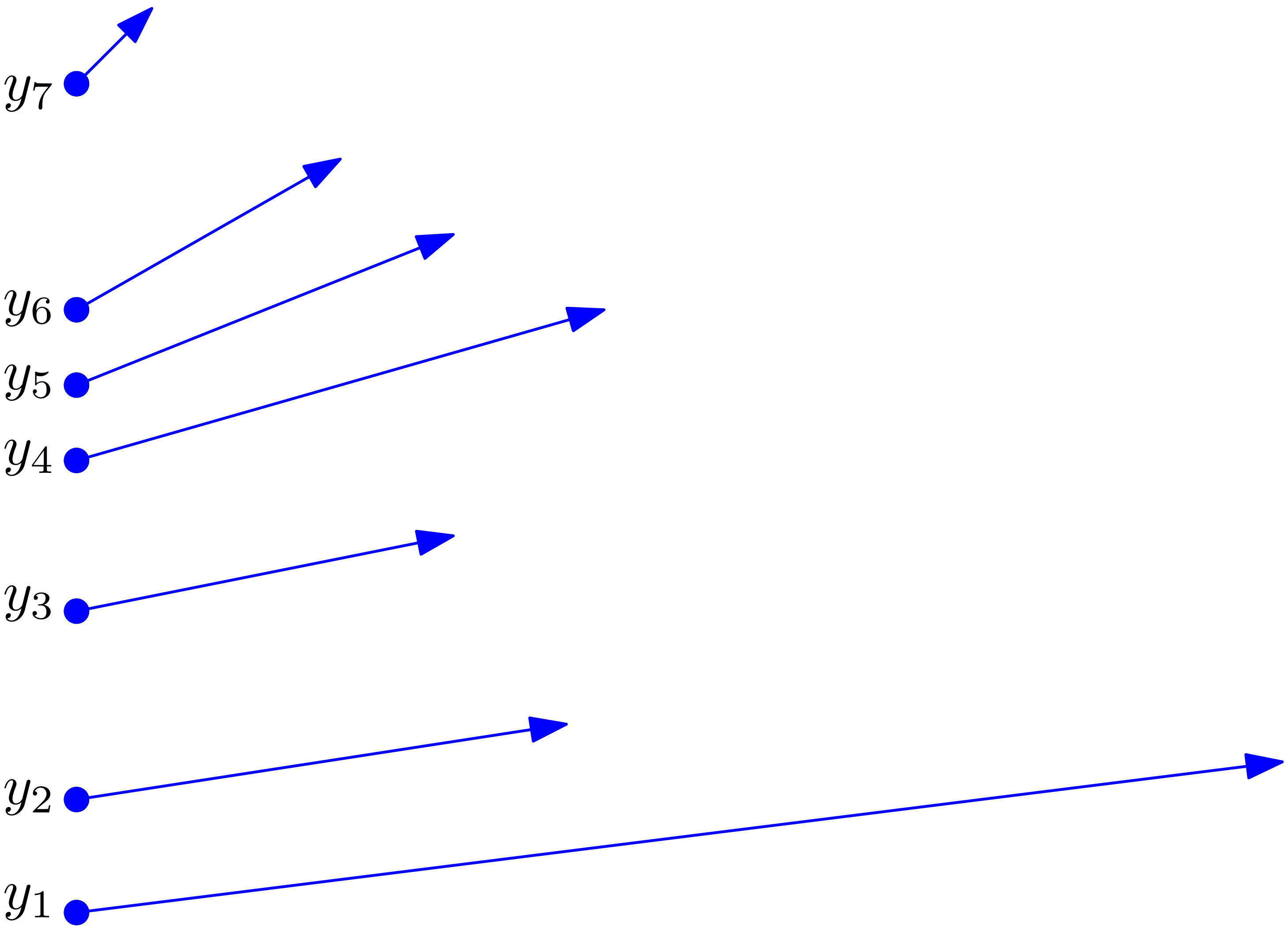


Find the maximum number of riders that can be selected and that will ALL ride forever.

Admission Control



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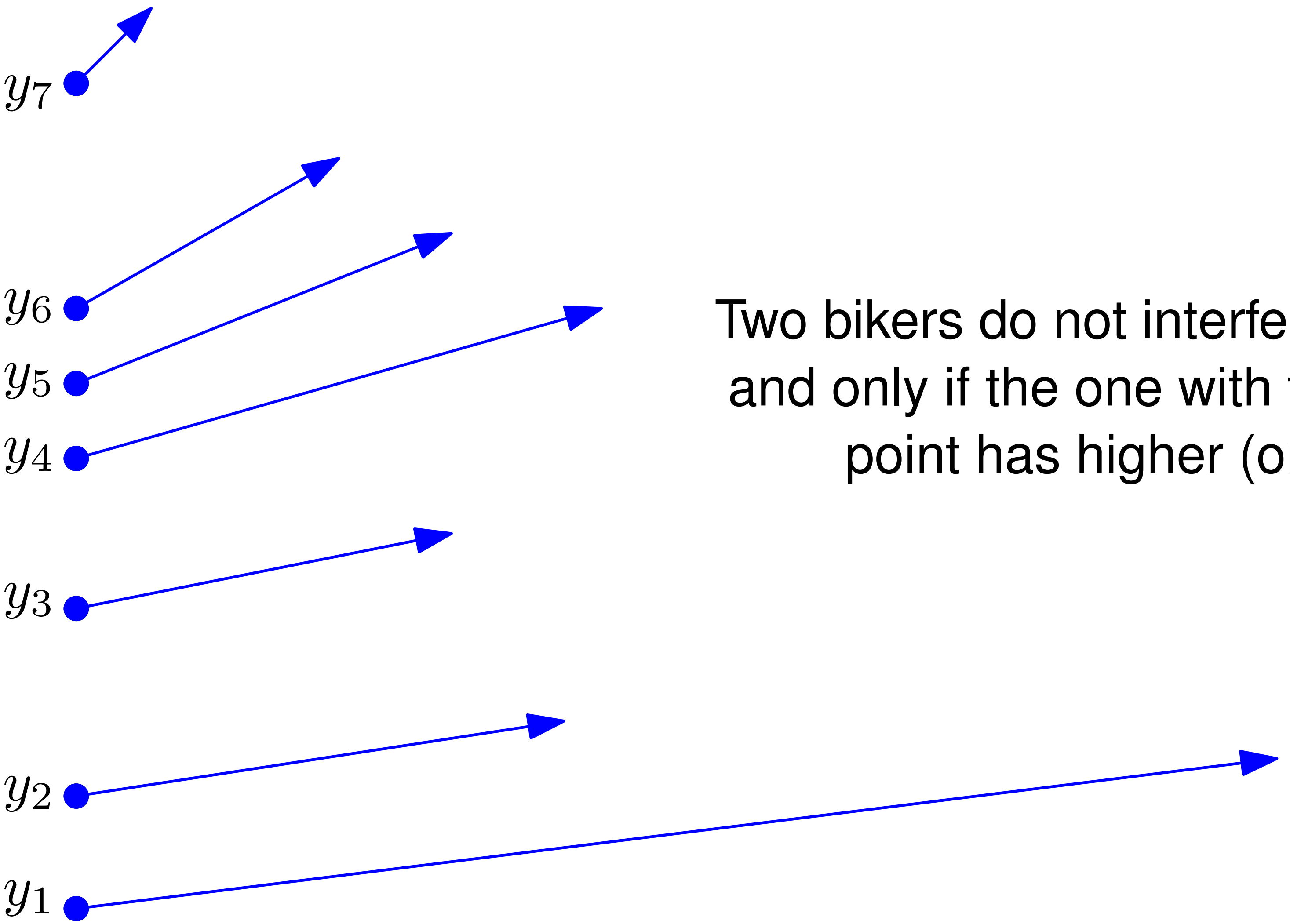
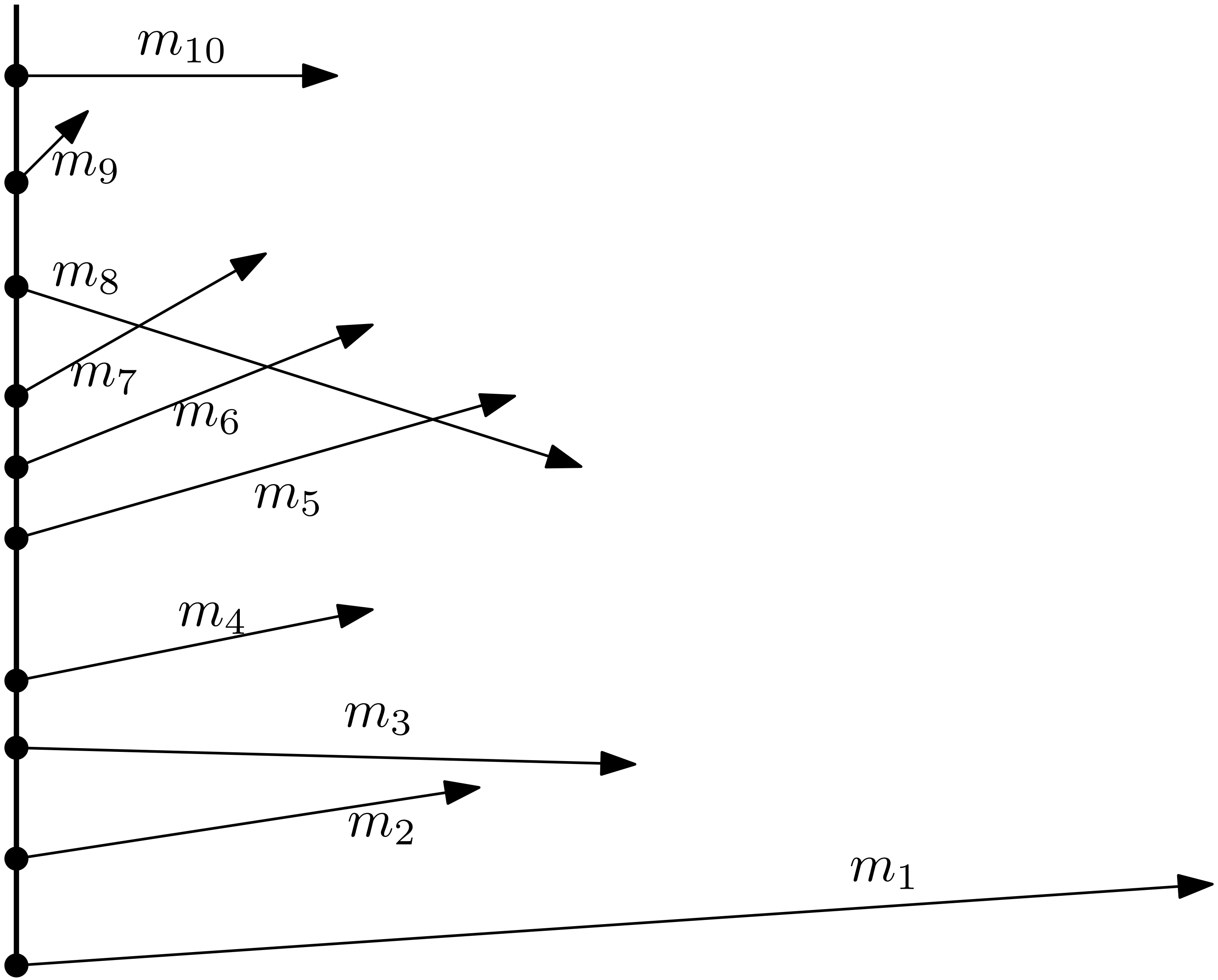


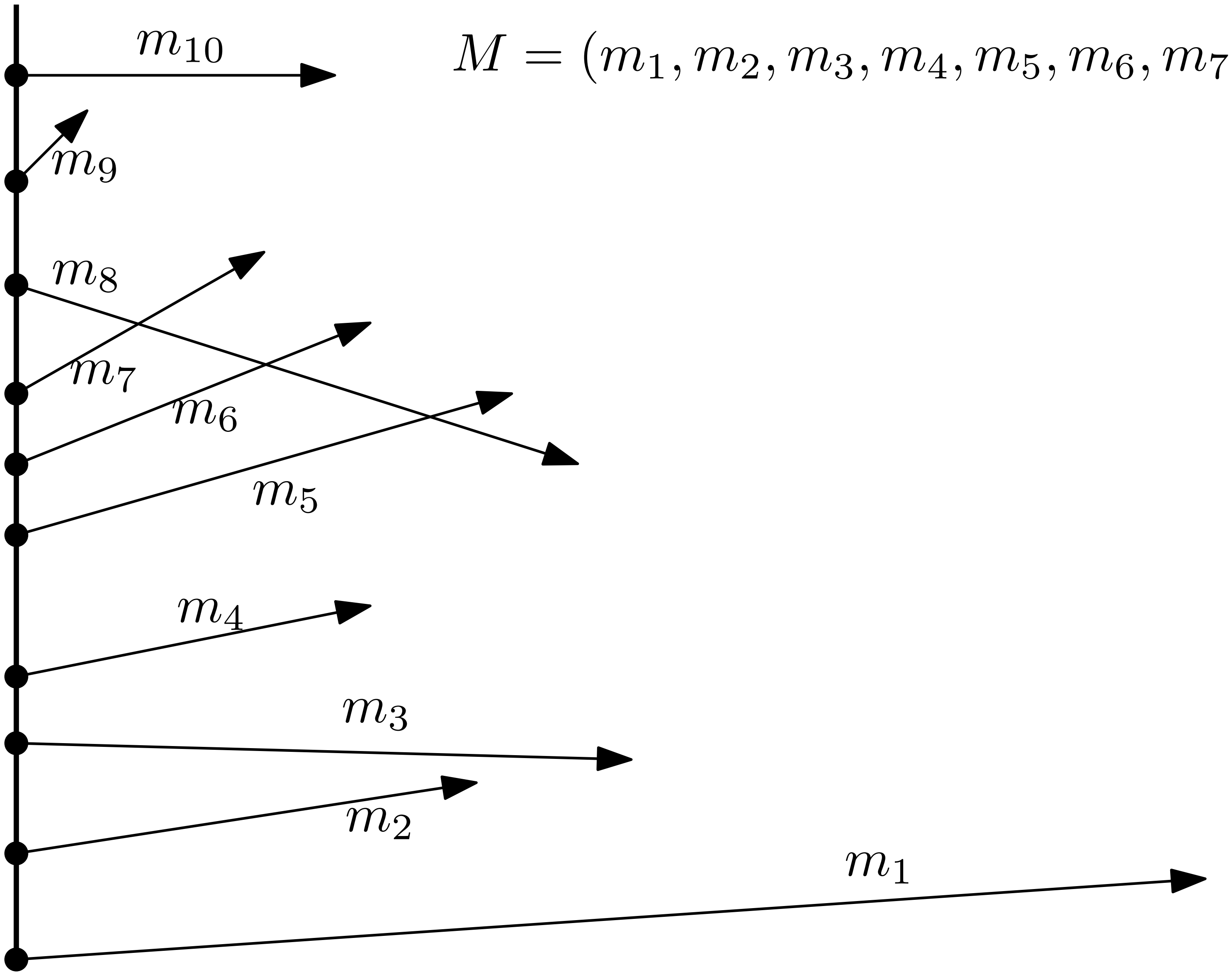
Two bikers do not interfere with each other if and only if the one with the highest starting point has higher (or equal) slope.

Admission Control

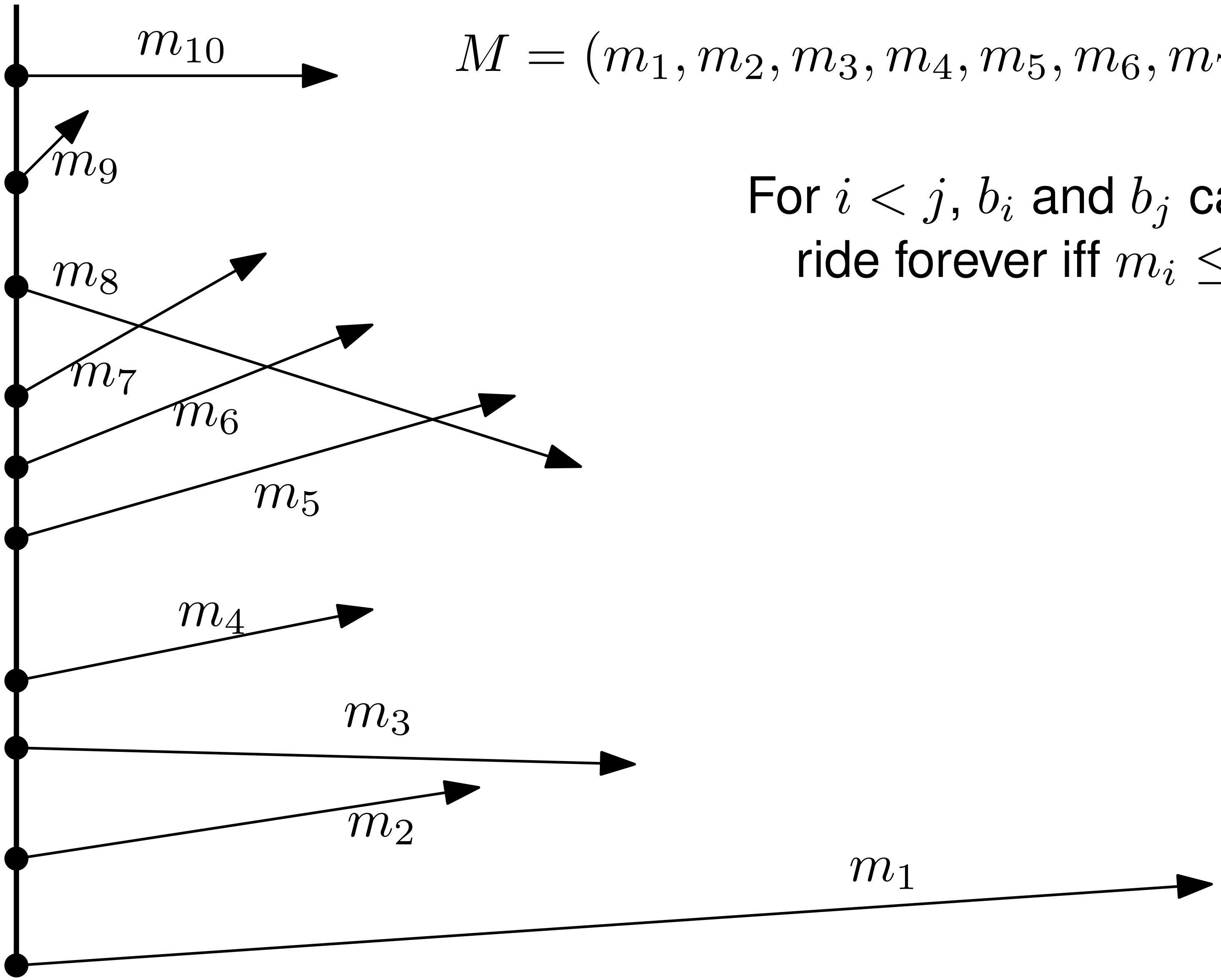


Admission Control

$$M = (m_1, m_2, m_3, m_4, m_5, m_6, m_7, m_8, m_9, m_{10})$$



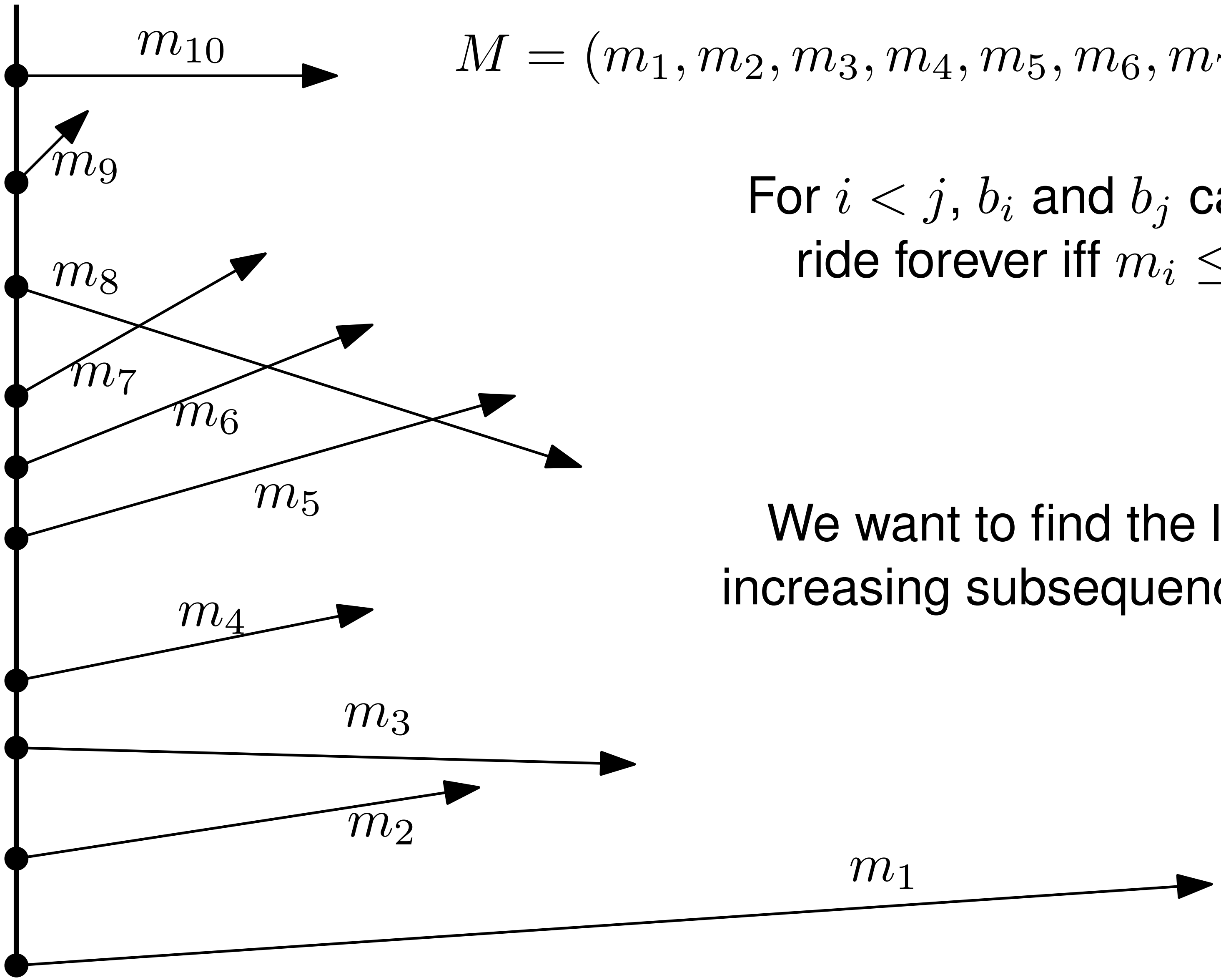
Admission Control



$$M = (m_1, m_2, m_3, m_4, m_5, m_6, m_7, m_8, m_9, m_{10})$$

For $i < j$, b_i and b_j can both ride forever iff $m_i \leq m_j$.

Admission Control



$$M = (m_1, m_2, m_3, m_4, m_5, m_6, m_7, m_8, m_9, m_{10})$$

For $i < j$, b_i and b_j can both ride forever iff $m_i \leq m_j$.

We want to find the largest increasing subsequence of M.

Largest increasing subsequence

$$M = (m_1, m_2, m_3, m_4, m_5, m_6, m_7, m_8, m_9, m_{10})$$

Largest increasing subsequence

$$M = (m_1, m_2, m_3, m_4, m_5, m_6, m_7, m_8, m_9, m_{10})$$

- Classical Dynamic programming approach leads to $O(n^2)$ time algorithm.
- For longest increasing subsequence however, there is an $O(n \log n)$ time algorithm to solve the problem.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$

$L2$

$L3$

$L4$

$L5$

$L6$

Largest increasing subsequence

$$M = (\boxed{0}, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$

$L3$

$L4$

$L5$

$L6$

Largest increasing subsequence

$$M = (0, \boxed{8}, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ 8

$L3$

$L4$

$L5$

$L6$

Largest increasing subsequence

$$M = (0, 8, \boxed{4}, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ 8

$L3$

$L4$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, \boxed{4}, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ \cancel{8}\ \ 4$

$L3$

$L4$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, \boxed{4}, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 4$

$L3$

$L4$

$L5$

$L6$

Largest increasing subsequence

$$M = (0, 8, 4, \boxed{12}, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 4$

$L3$ $0\ 4\ 12$

$L4$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

12 Increases the length of all previous subsequences, so we have a new longer increasing subsequence.

Largest increasing subsequence

$$M = (0, 8, 4, 12, \boxed{2,} 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ \cancel{4}\quad 2$

$L3$ $0\ 4\ 12$

$L4$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, \boxed{10}, 6, 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 2$

$L3$ $0\ 4\ \cancel{12}\quad 10$

$L4$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, \boxed{6,} 14, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 2$

$L3$ $0\ 4\ \cancel{10}\quad 6$

$L4$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, \boxed{14}, 1, 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 2$

$L3$ $0\ 4\ 6$

$L4$ $0\ 4\ 6\ 14$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

14 increases the length of all previous subsequences, so we create a new one.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, \boxed{1,} 9, 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ \cancel{2}\quad 1$

$L3$ $0\ 4\ 6$

$L4$ $0\ 4\ 6\ 14$

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, \boxed{9,} 5, 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 1$

$L3$ $0\ 4\ 6$

$L4$ $0\ 4\ 6\ 1\cancel{4}$ 9

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, \boxed{5,} 13, 3, 11, 7, 15)$$

$L1$ 0

$L2$ 0 1

$L3$ 0 4 $\cancel{6}$ 5

$L4$ 0 4 6 9

$L5$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, \boxed{13}, 3, 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 1$

$L3$ $0\ 4\ 5$

$L4$ $0\ 4\ 6\ 9$

$L5$ $0\ 4\ 6\ 9\ 13$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13\boxed{, 3,} 11, 7, 15)$$

$L1$ 0

$L2$ $0\ 1$

$L3$ $0\ 4\ \cancel{5}\quad 3$

$L4$ $0\ 4\ 6\ 9$

$L5$ $0\ 4\ 6\ 9\ 13$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, \boxed{11}, 7, 15)$$

$L1$ 0

$L2$ $0\ 1$

$L3$ $0\ 4\ 3$

$L4$ $0\ 4\ 6\ 9$

$L5$ $0\ 4\ 6\ 9\ \cancel{13}\quad 11$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, \boxed{7,} 15)$$

$L1$ 0

$L2$ $0\ 1$

$L3$ $0\ 4\ 3$

$L4$ $0\ 4\ 6\ \cancel{9}\quad 7$

$L5$ $0\ 4\ 6\ 9\ 13$

$L6$

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, \boxed{15})$$

$L1$ 0

$L2$ 0 1

$L3$ 0 4 3

$L4$ 0 4 6 7

$L5$ 0 4 6 9 13

$L6$ 0 4 6 9 13 15

We search the first subsequence than ends with a number larger than the current number.

Largest increasing subsequence

$$M = (0, 8, 4, 12, 2, 10, 6, 14, 1, 9, 5, 13, 3, 11, 7, \boxed{15})$$

$L1$ 0

$L2$ $0\ 1$

$L3$ $0\ 4\ 3$

$L4$ $0\ 4\ 6\ 7$

$L5$ $0\ 4\ 6\ 9\ 13$

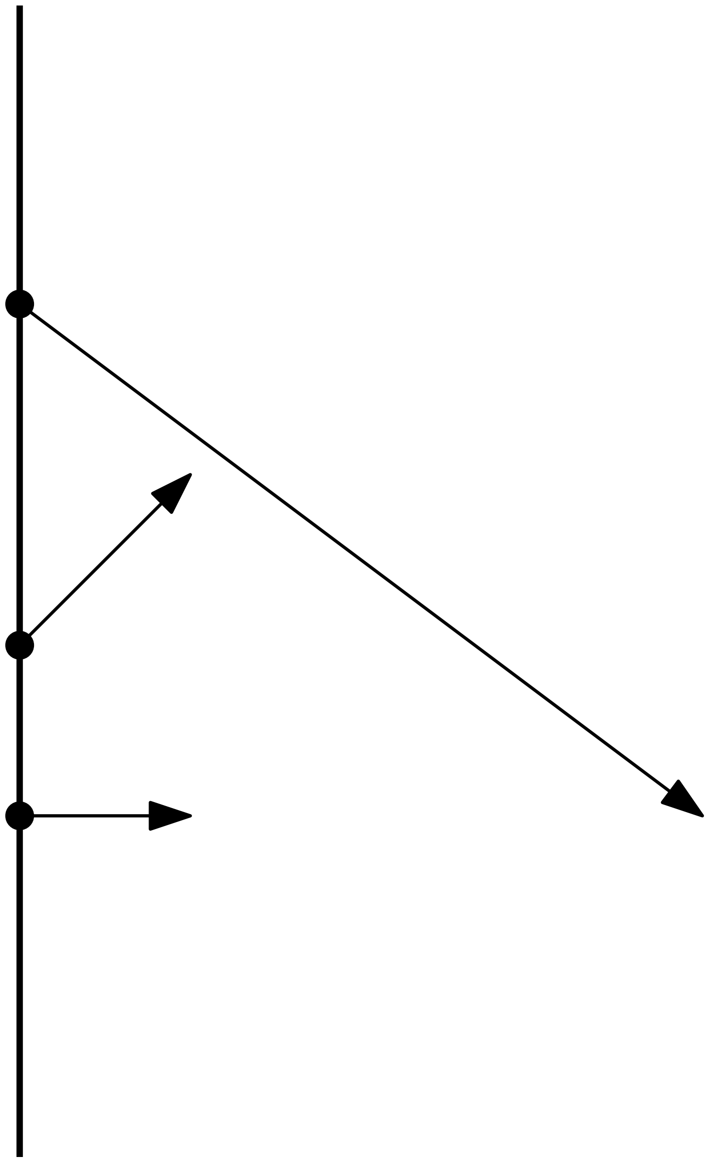
$L6$ $0\ 4\ 6\ 9\ 13\ 15$

We search the first subsequence than ends with a number larger than the current number.

The algorithm performs a binary search for each element of the original vector. Thus, the running time is $O(n \log n)$.

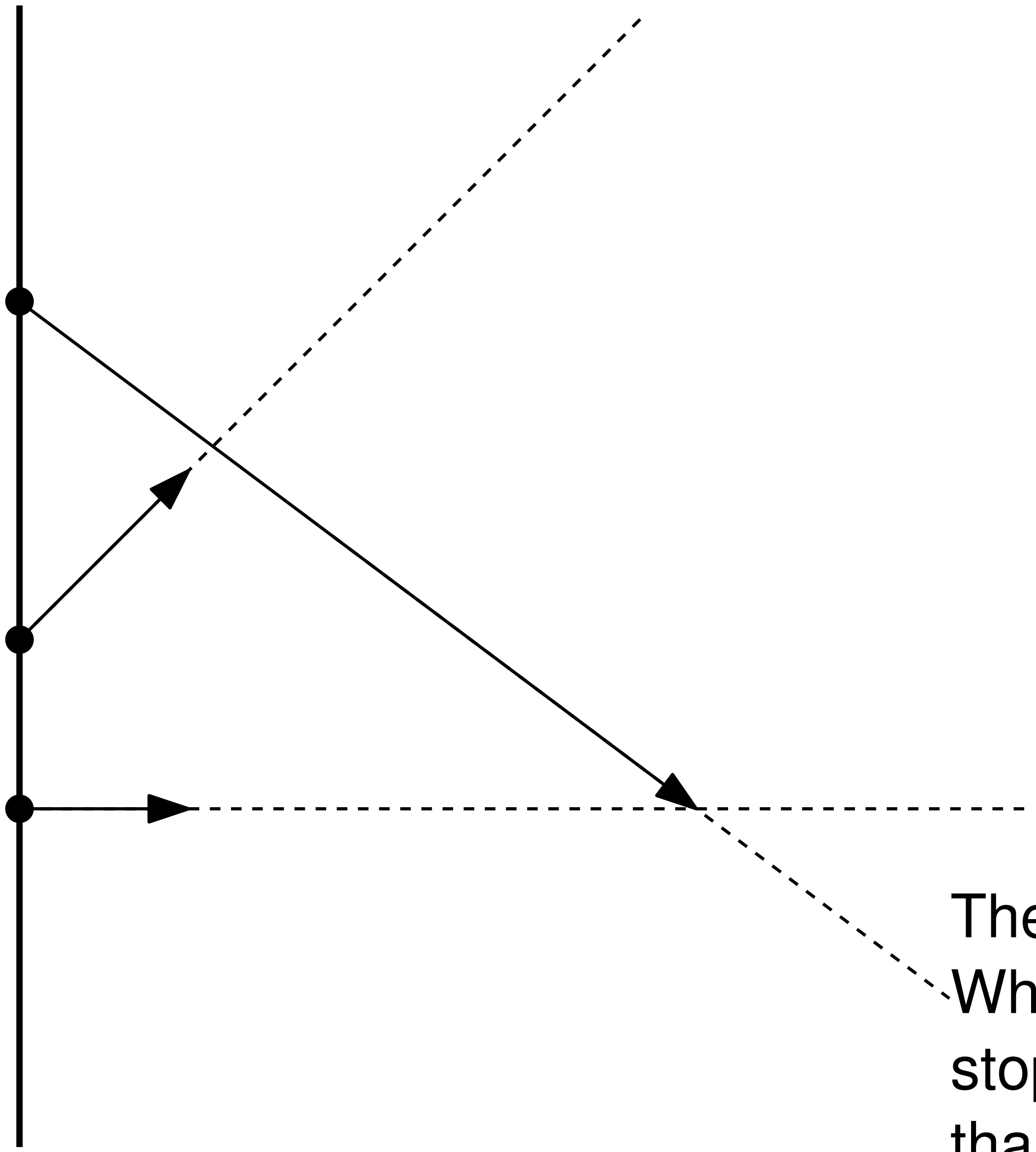
Starting Schedules

We are allowed to modify the starting time s_i of each bike b_i.



There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules



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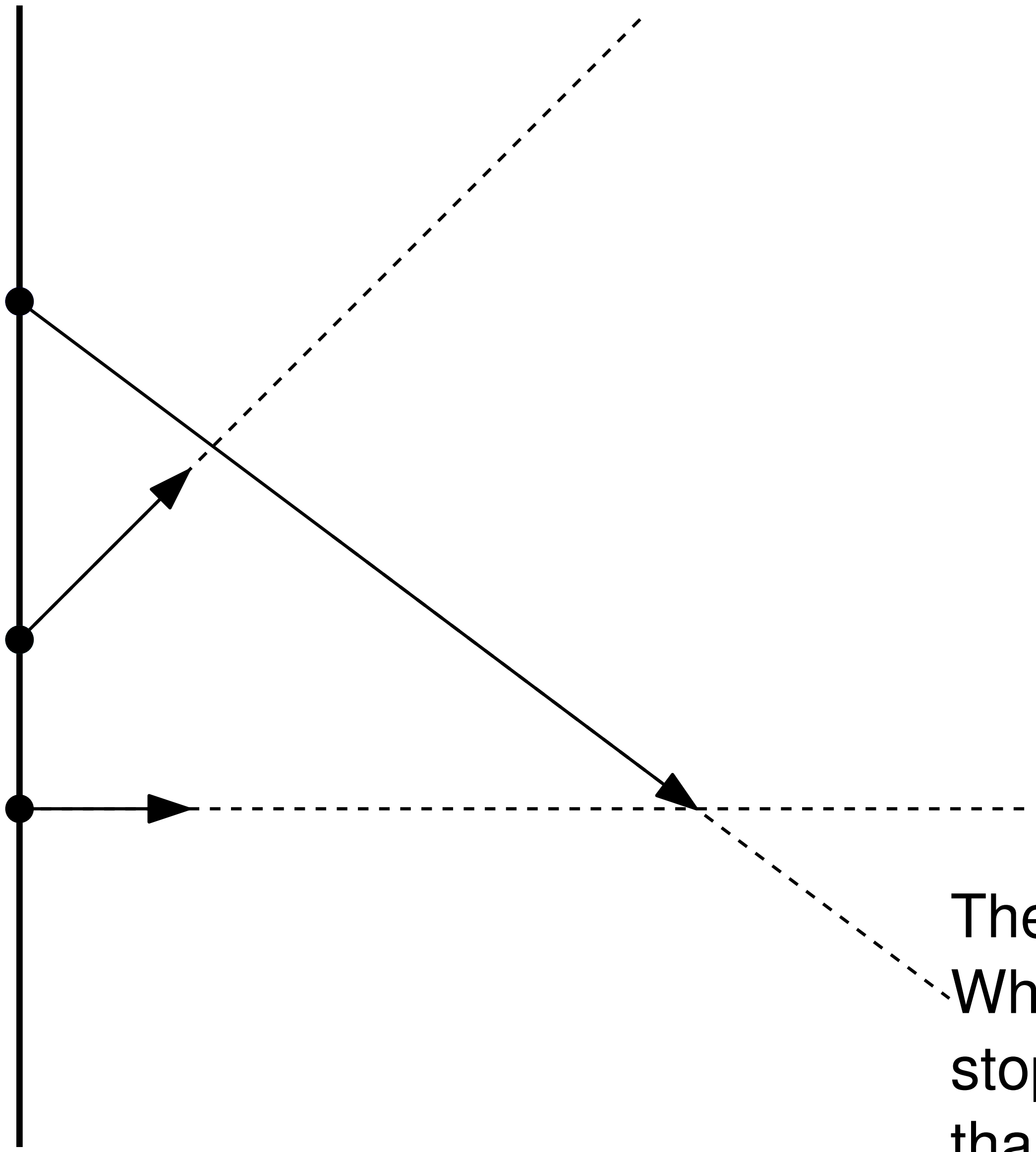

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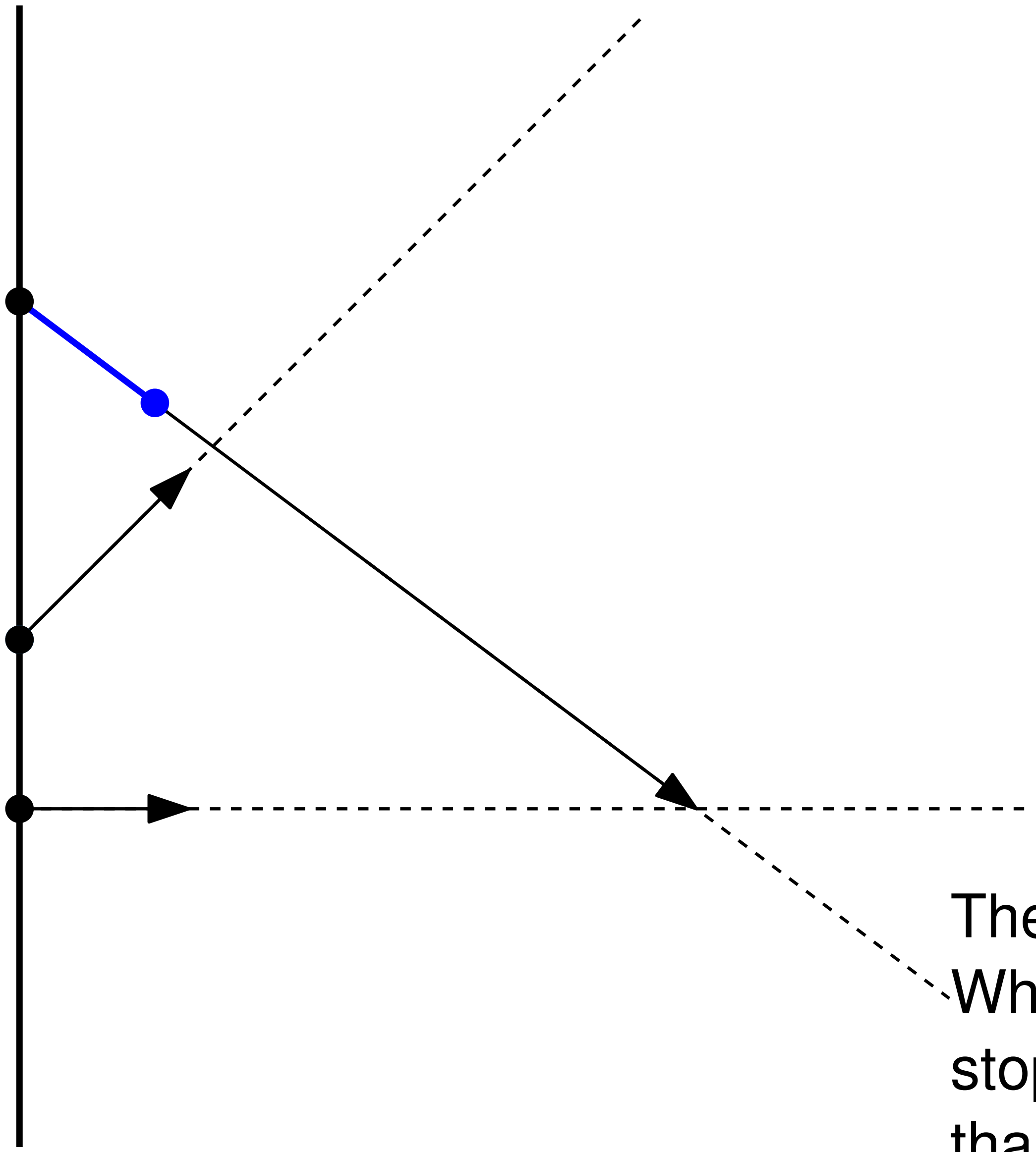

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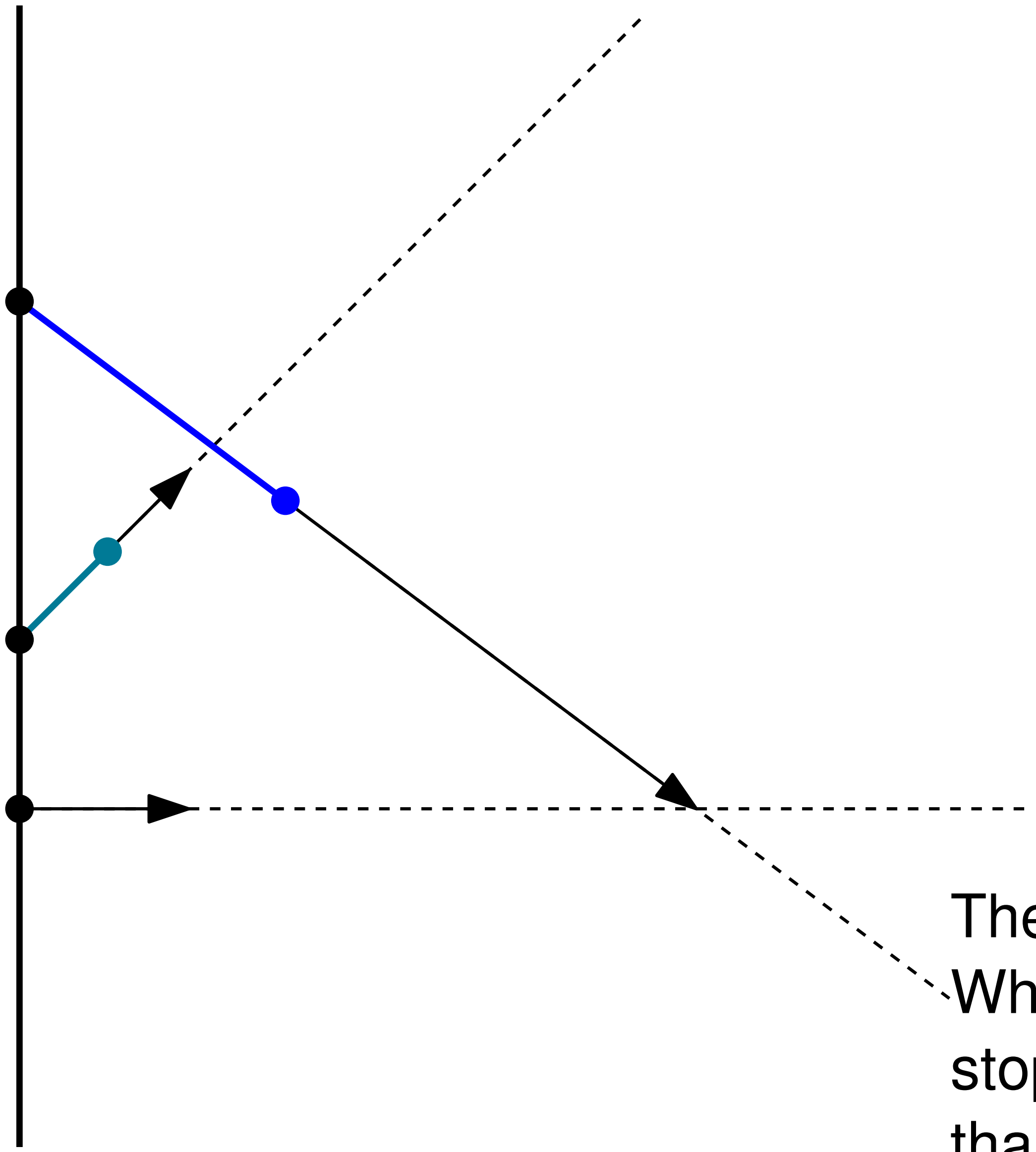

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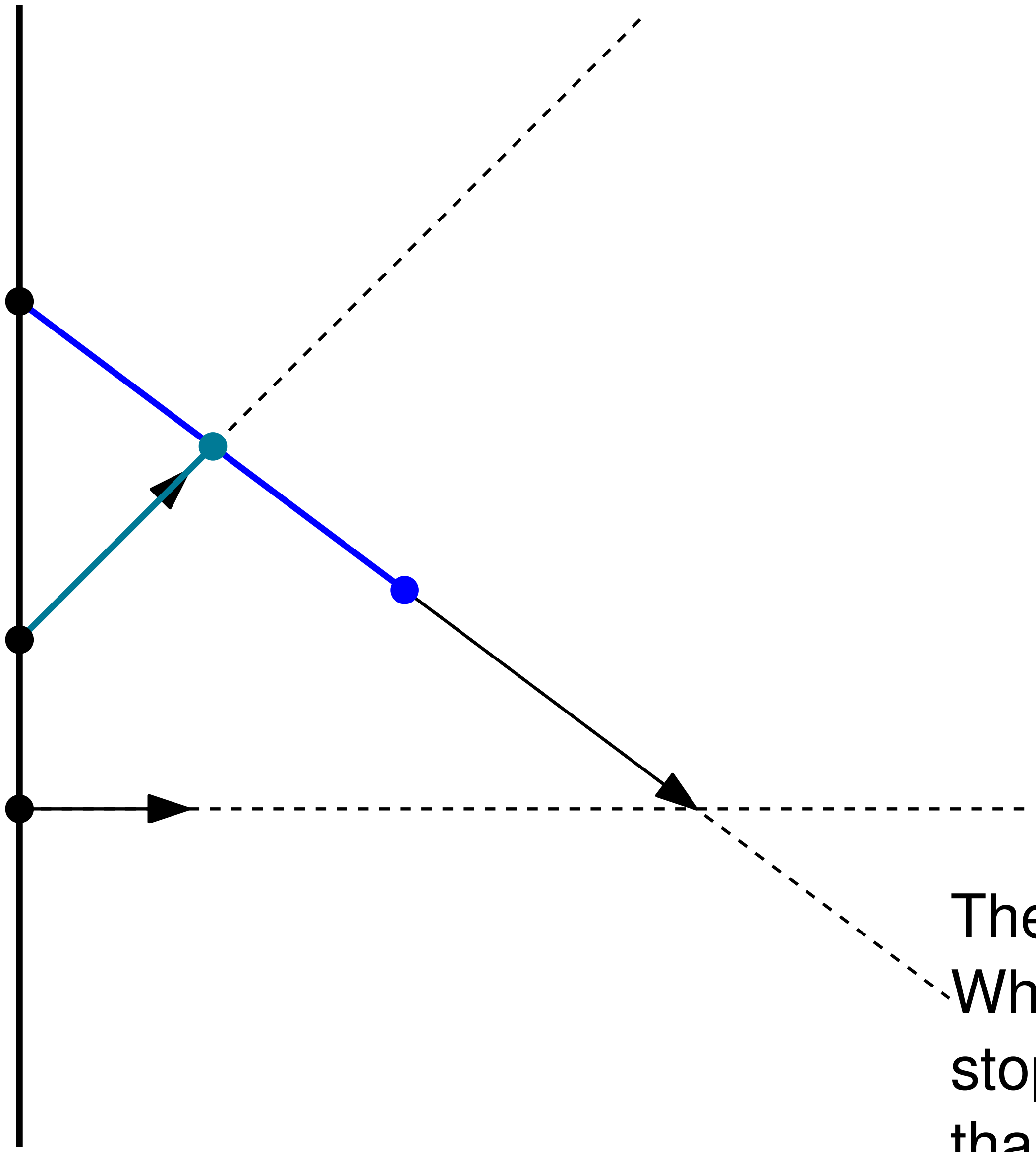

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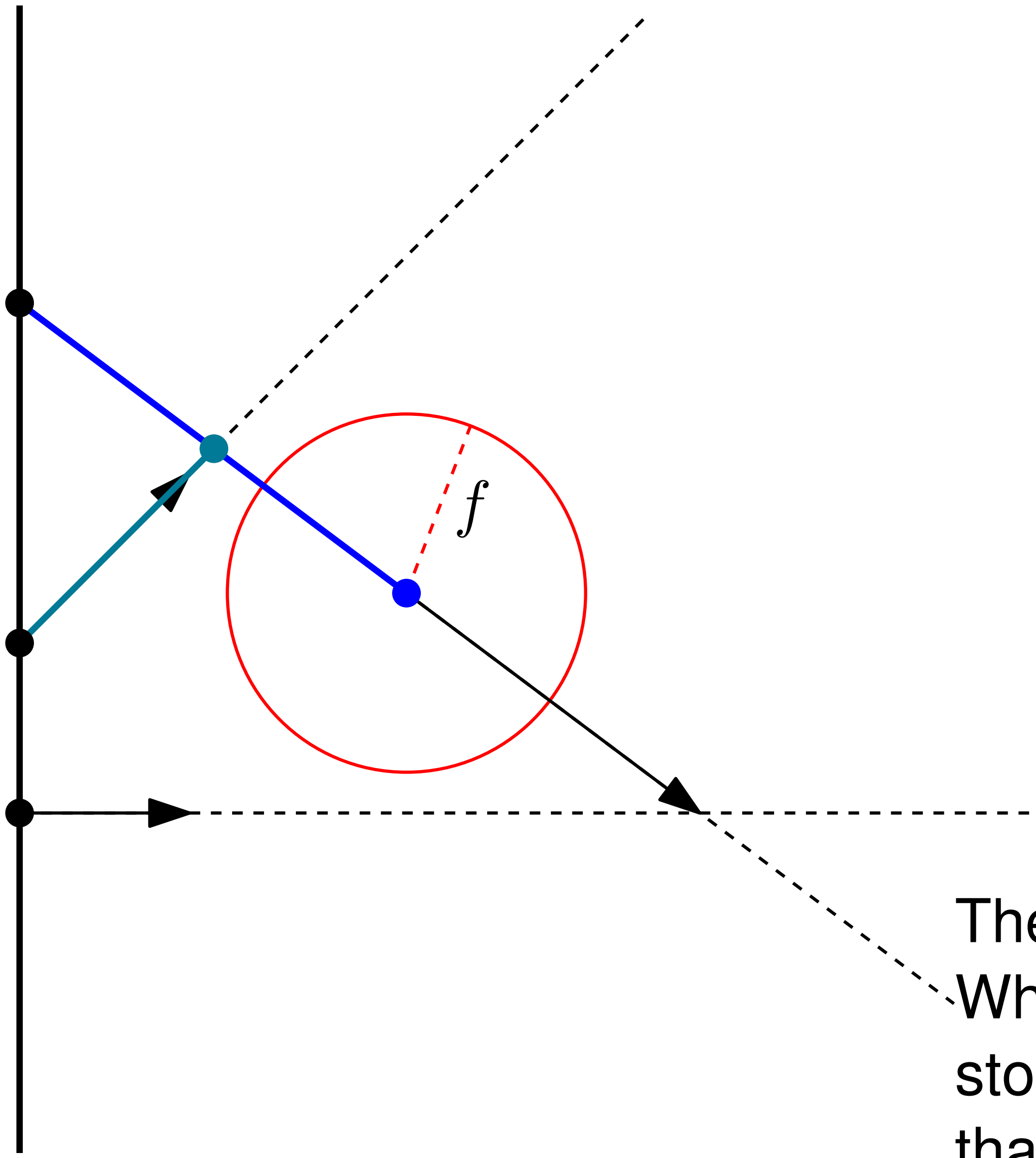

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Starting Schedules

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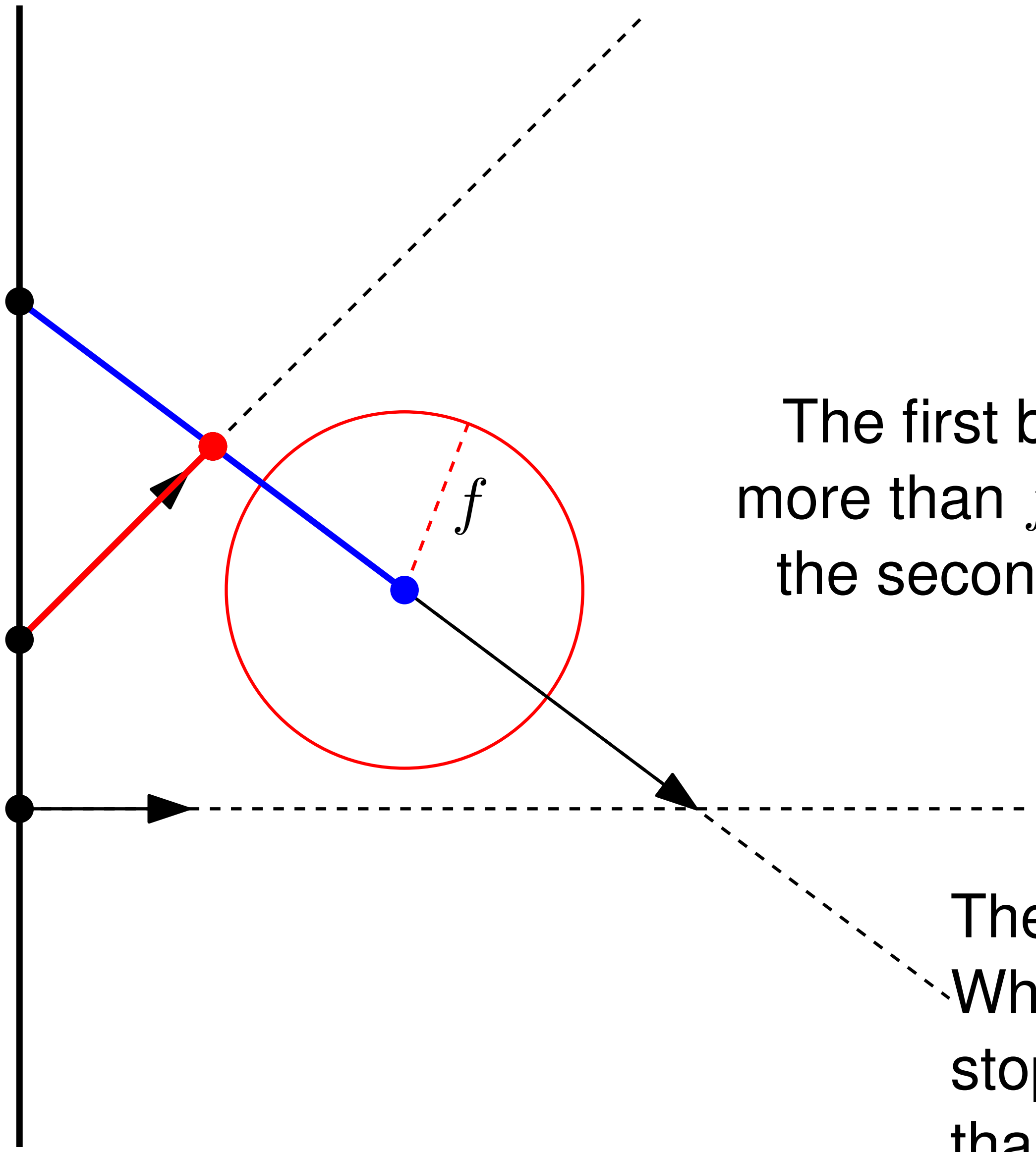
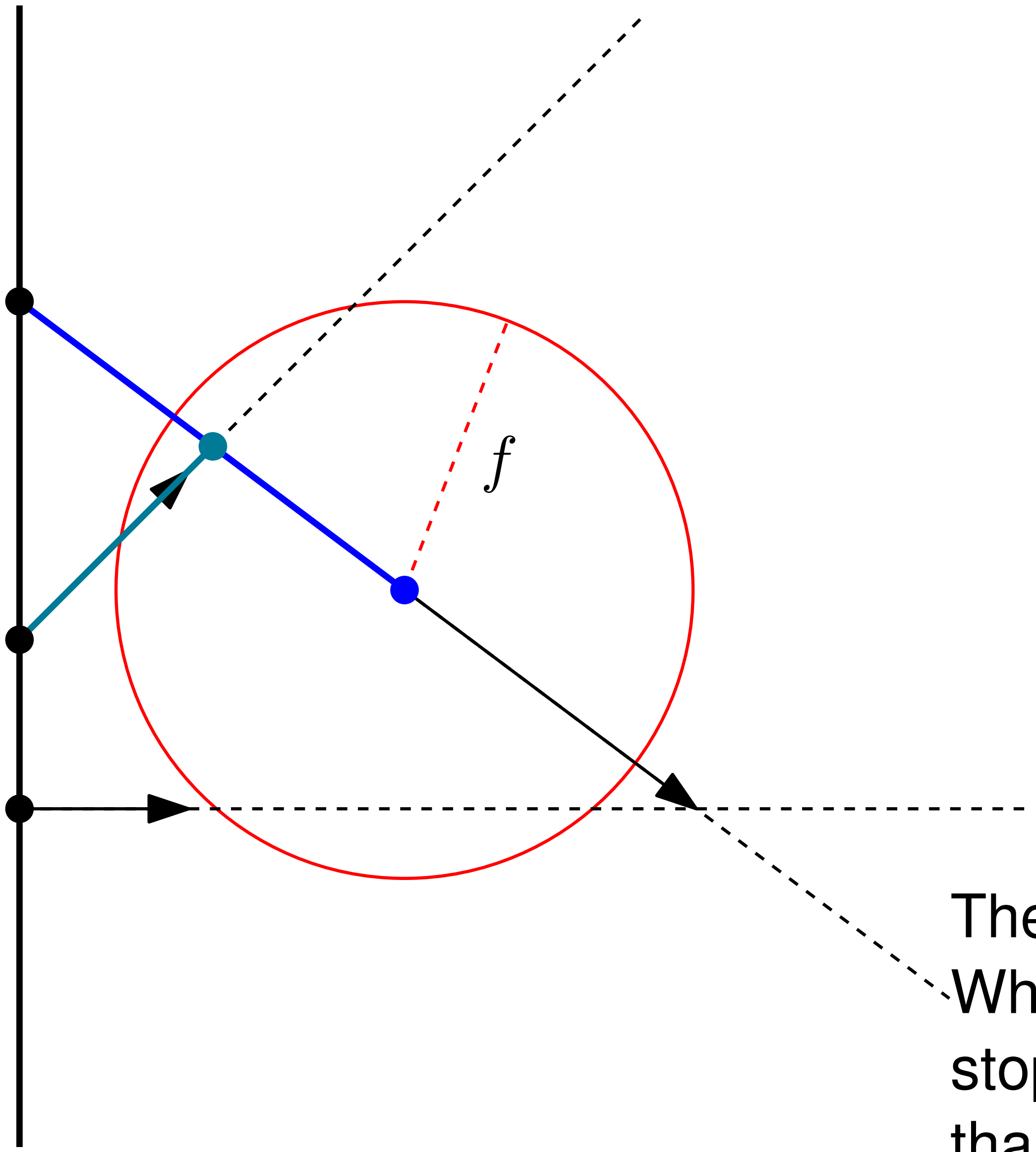


The first biker passed more than f time ago, so the second must stop.

There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

We are allowed to modify the starting time s_i of each bike b_i.



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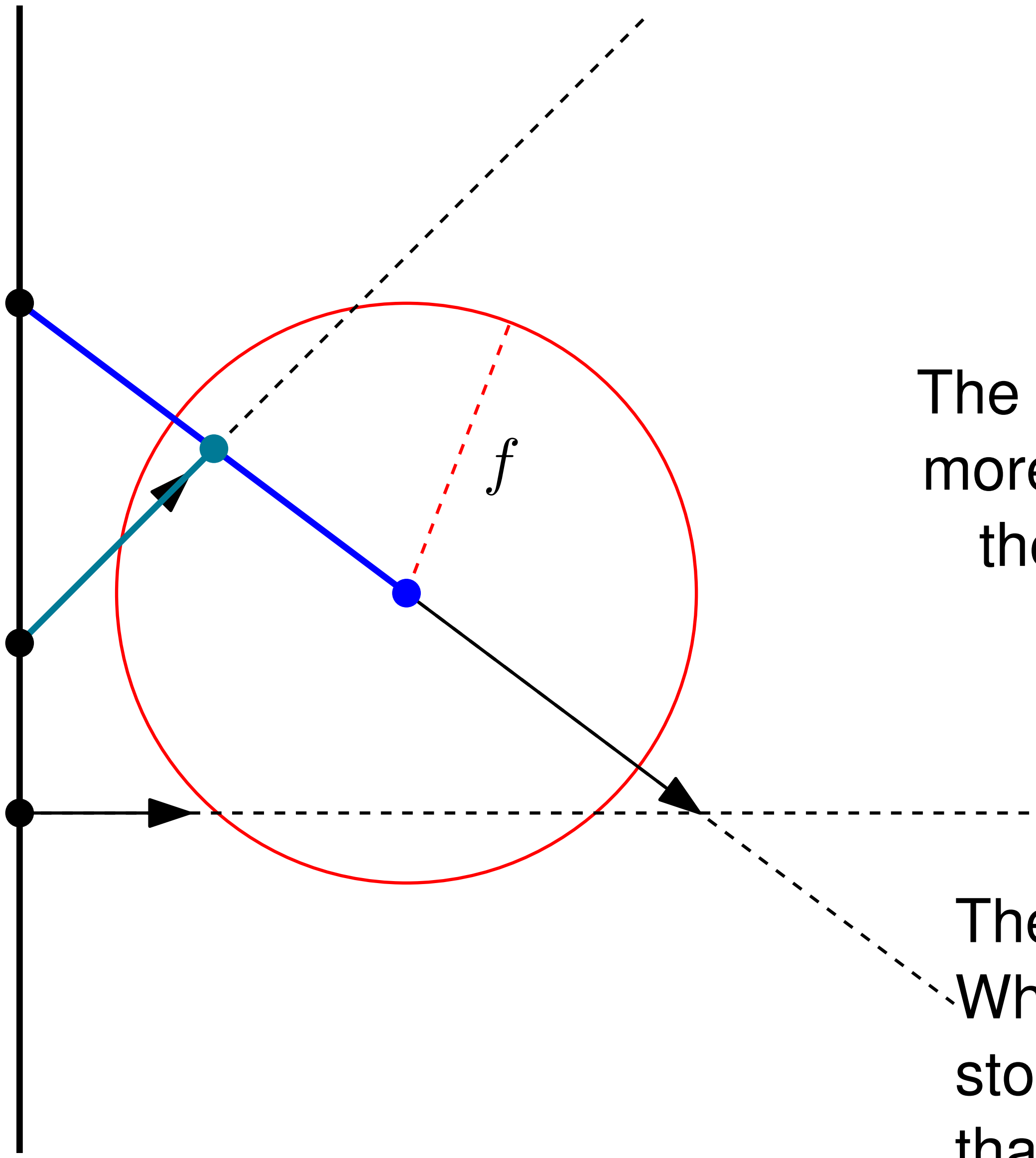
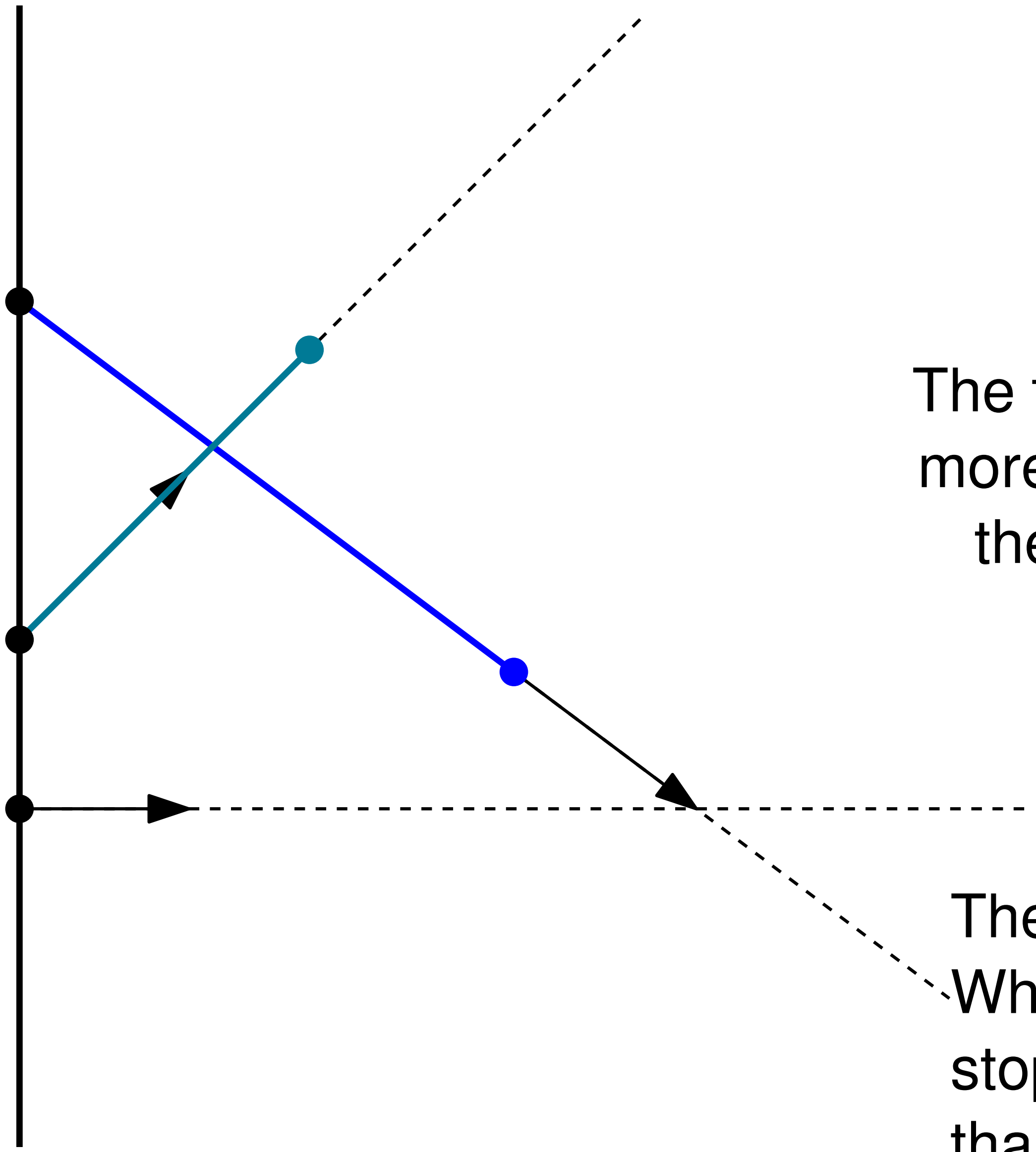


The first biker passed NO more than f time ago, so the second can keep riding.

There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

We are allowed to modify the starting time s_i of each bike b_i.



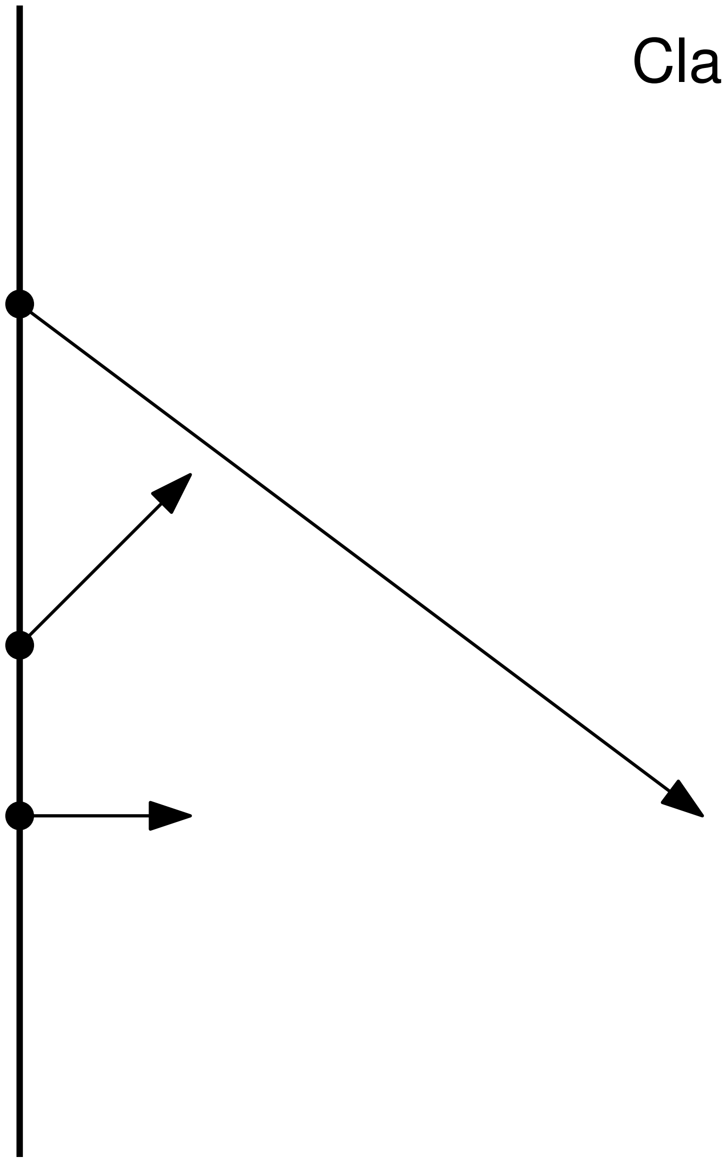
The first biker passed NO more than f time ago, so the second can keep riding.

There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

We are allowed to modify the starting time s_i of each bike b_i.

Claim: We can solve this instance with $f = 0$.



There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

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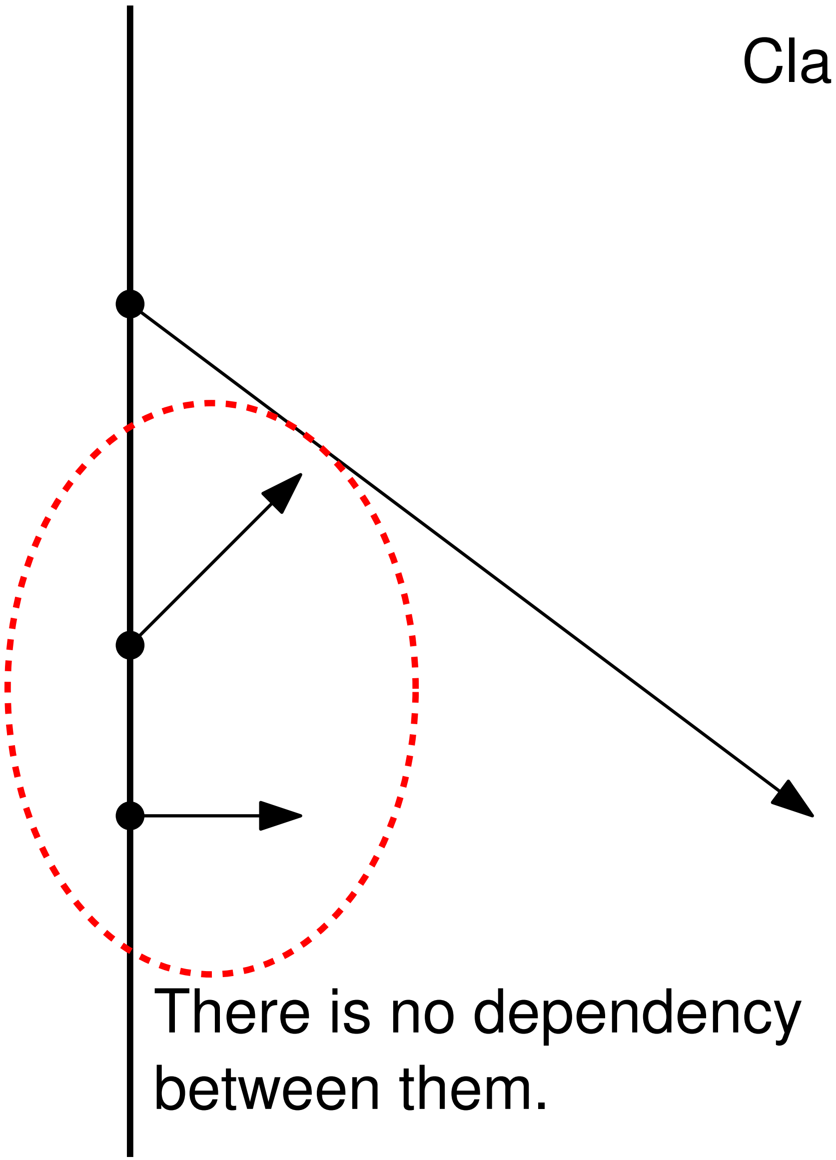
Claim: We can solve this instance with $f = 0$.



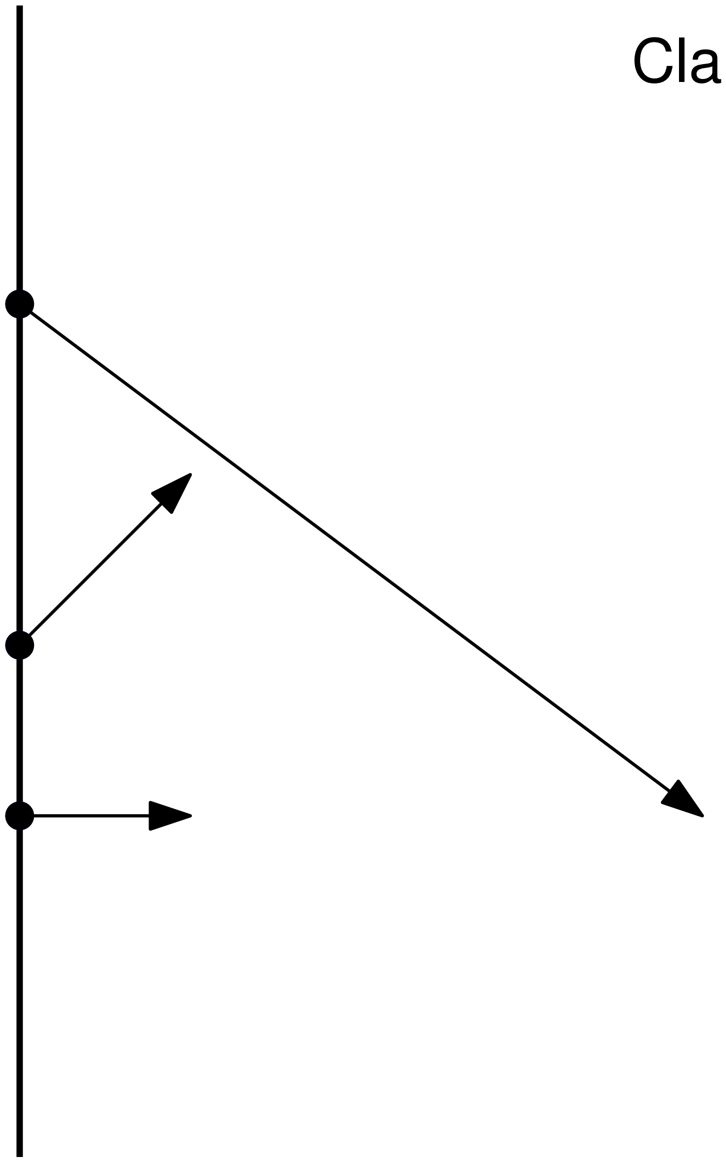
There is no dependency between them.

There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

We are allowed to modify the starting time s_i of each bike b_i.

Claim: We can solve this instance with $f = 0$.



There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

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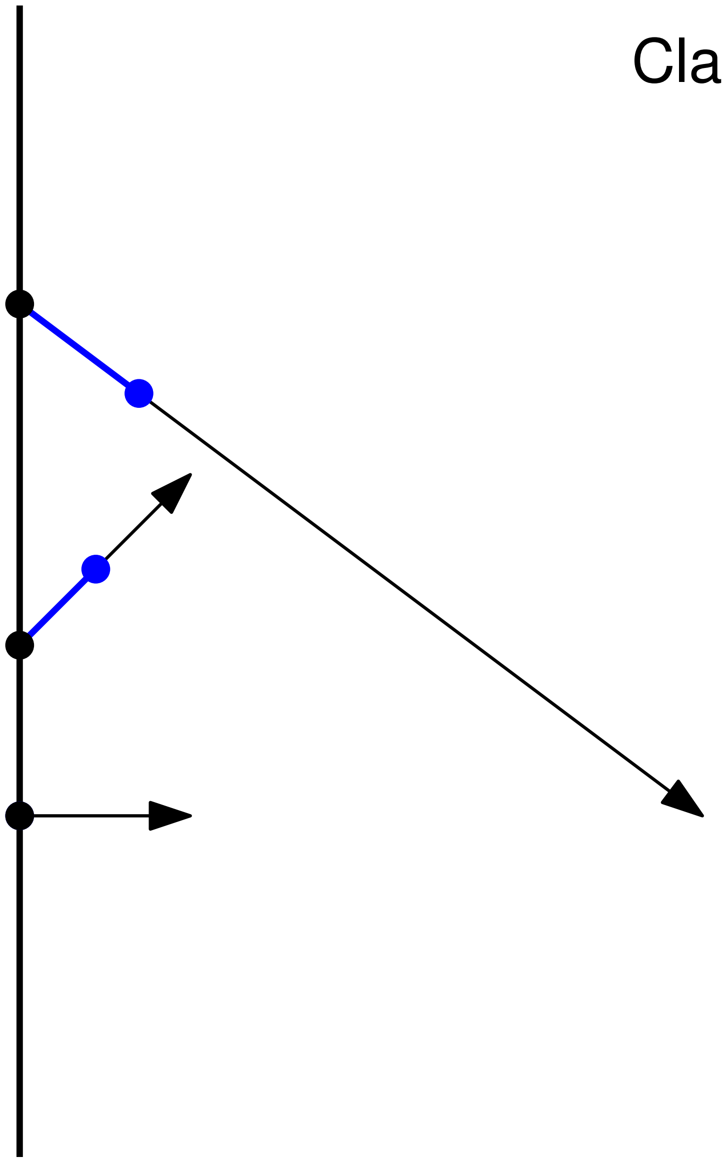

There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

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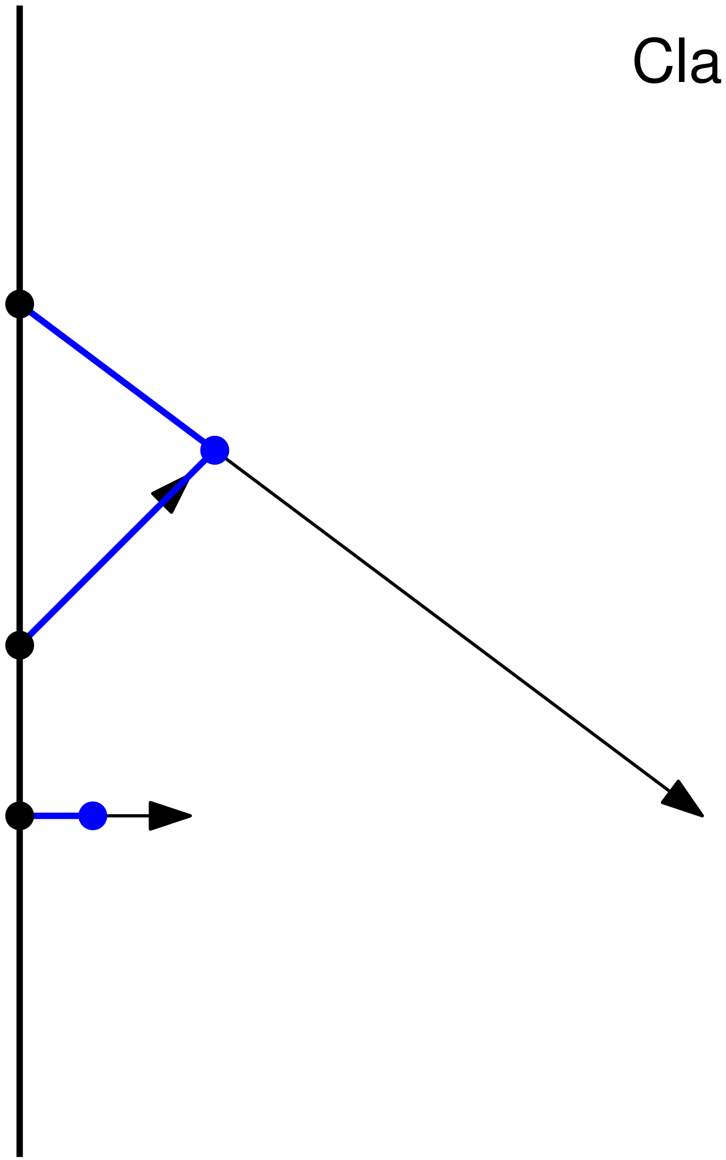
Claim: We can solve this instance with $f = 0$.



There is a frustration tolerance f. Whenever b_i meets the tracks of b_j, it stops unless b_j was there no more than f time units ago.

Starting Schedules

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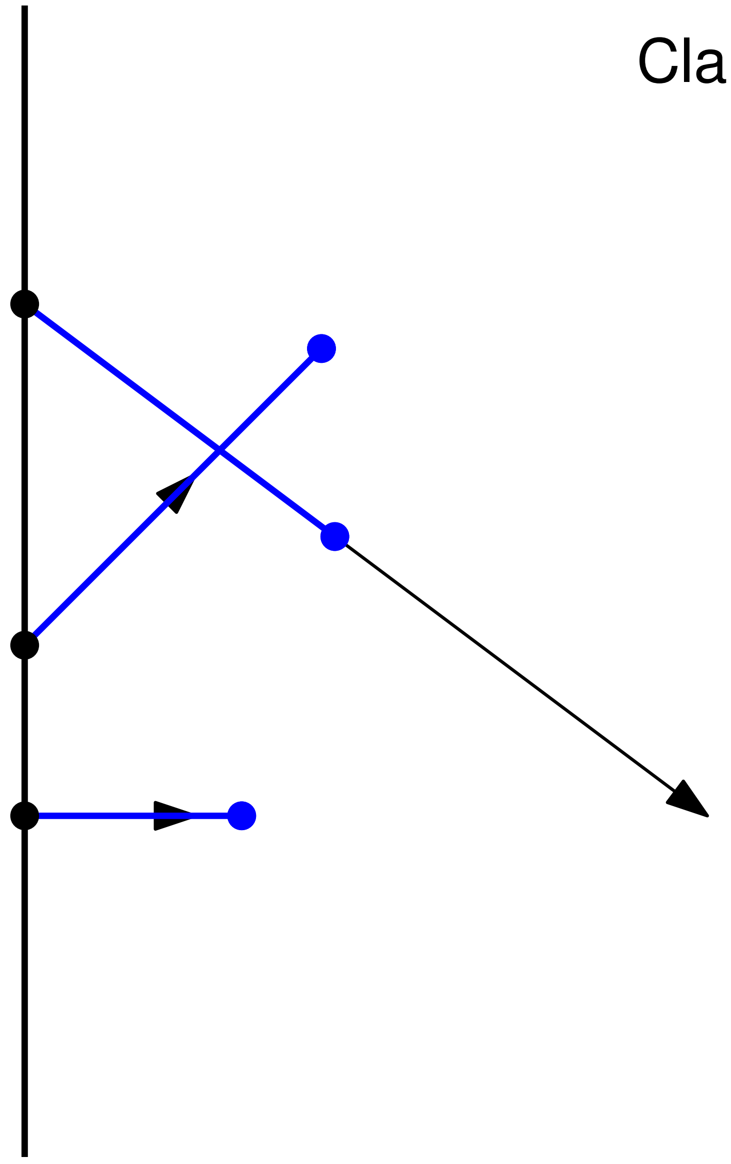

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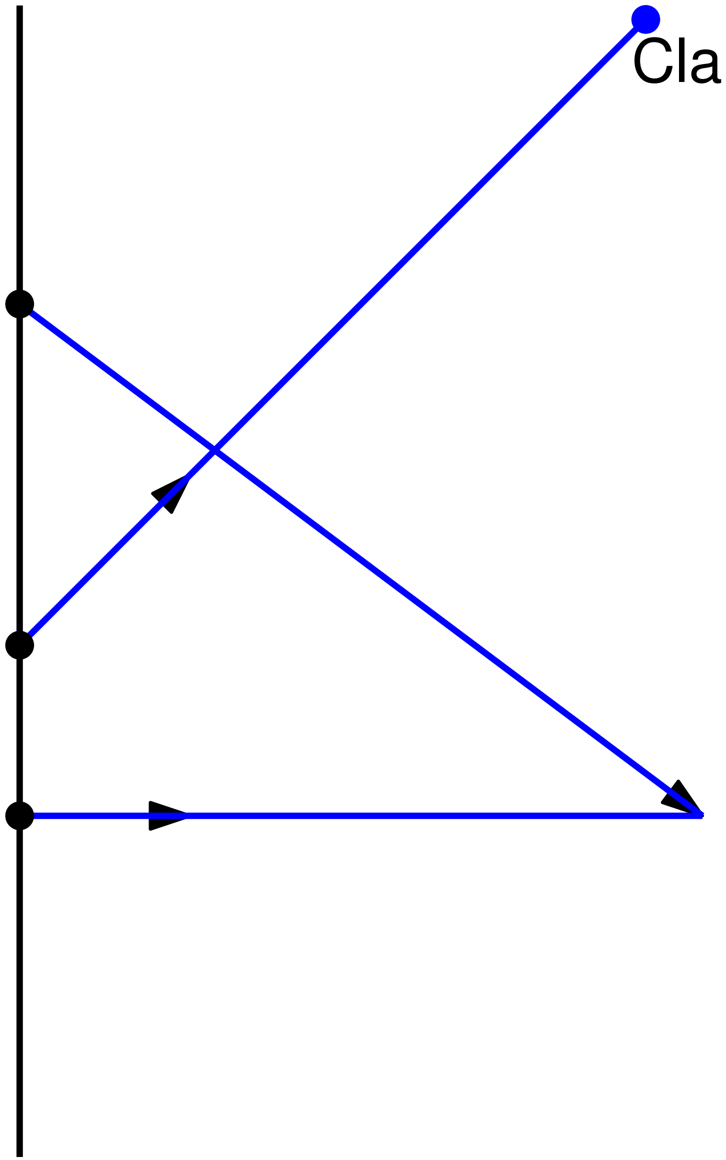

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Solving it with Linear Programming

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From the specifications, we know that there are at most 101 variables, which is OK to use linear programming.

- It starts with a line that contains a single integer `n` so that $1 \leq n \leq 10^2$. Here n denotes the number of bikers.

Solving it with Linear Programming

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What are the constraints?

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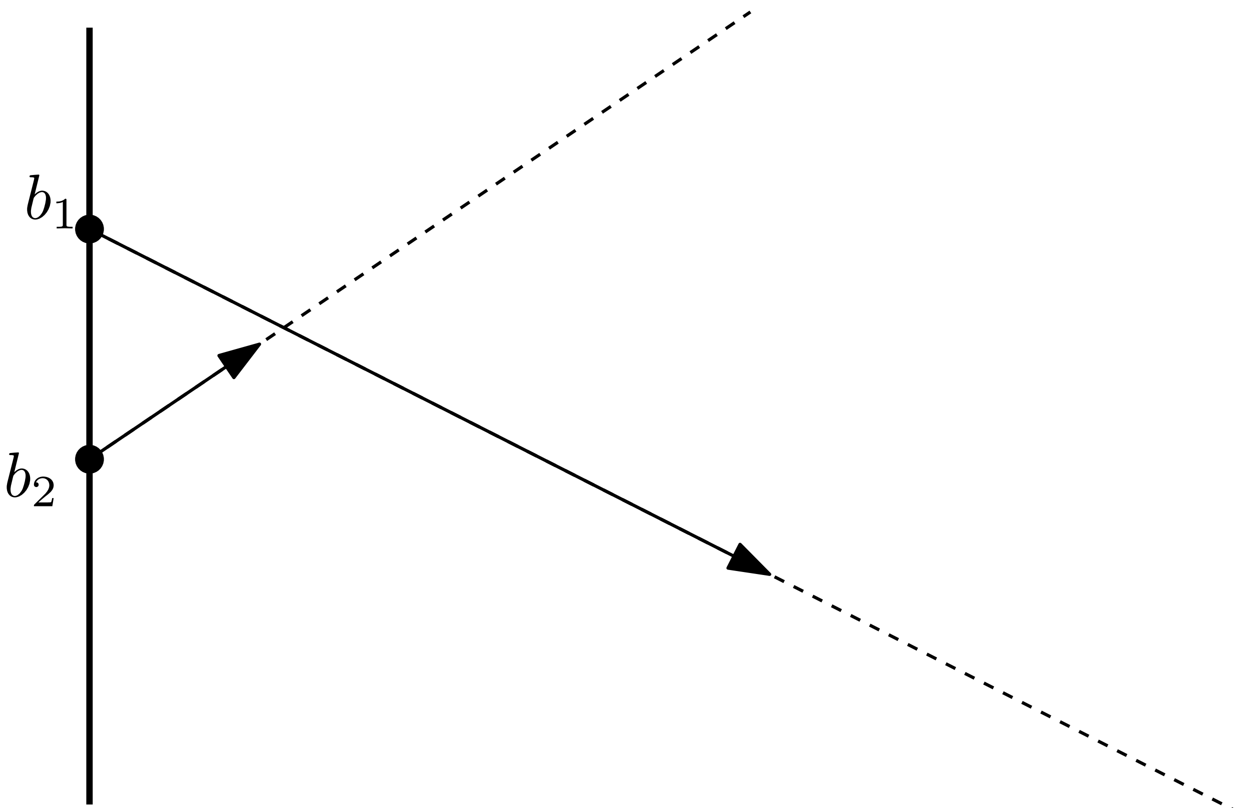
For each pair b_i, b_j such that their paths cross, we get a constraint.



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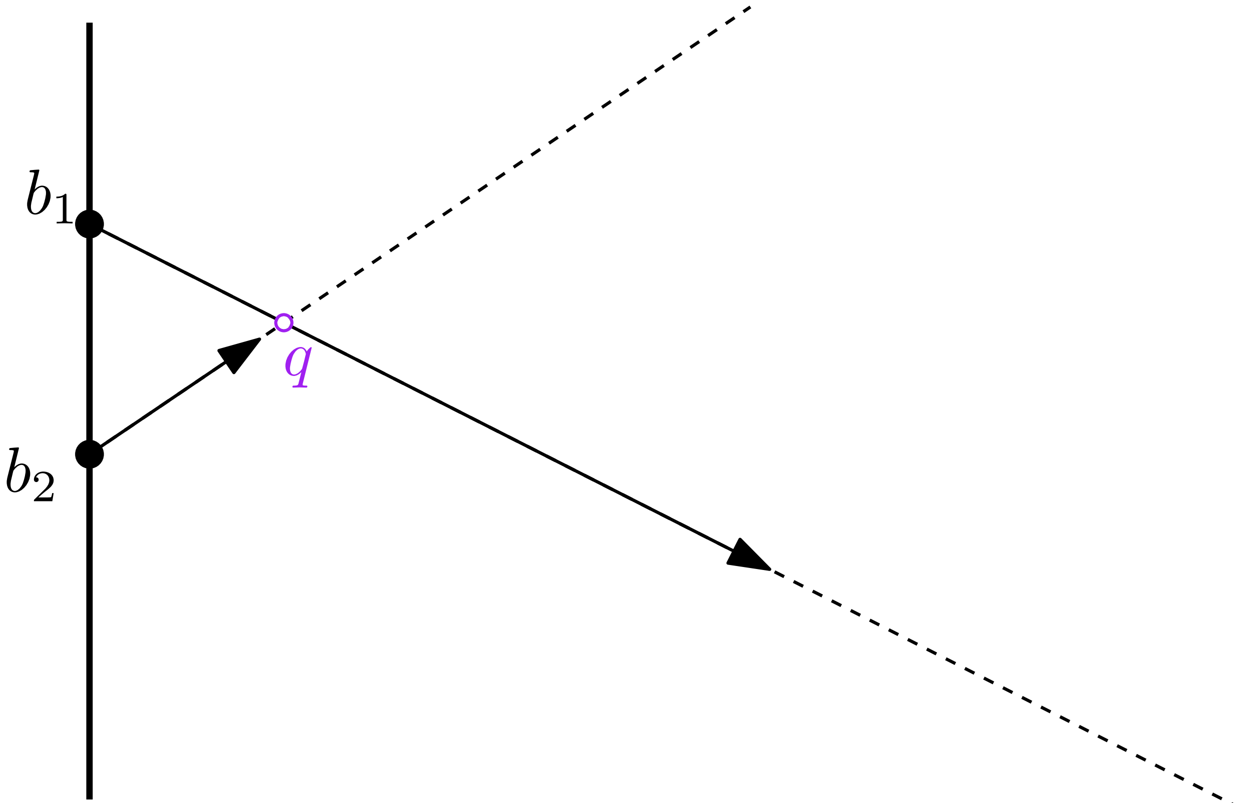

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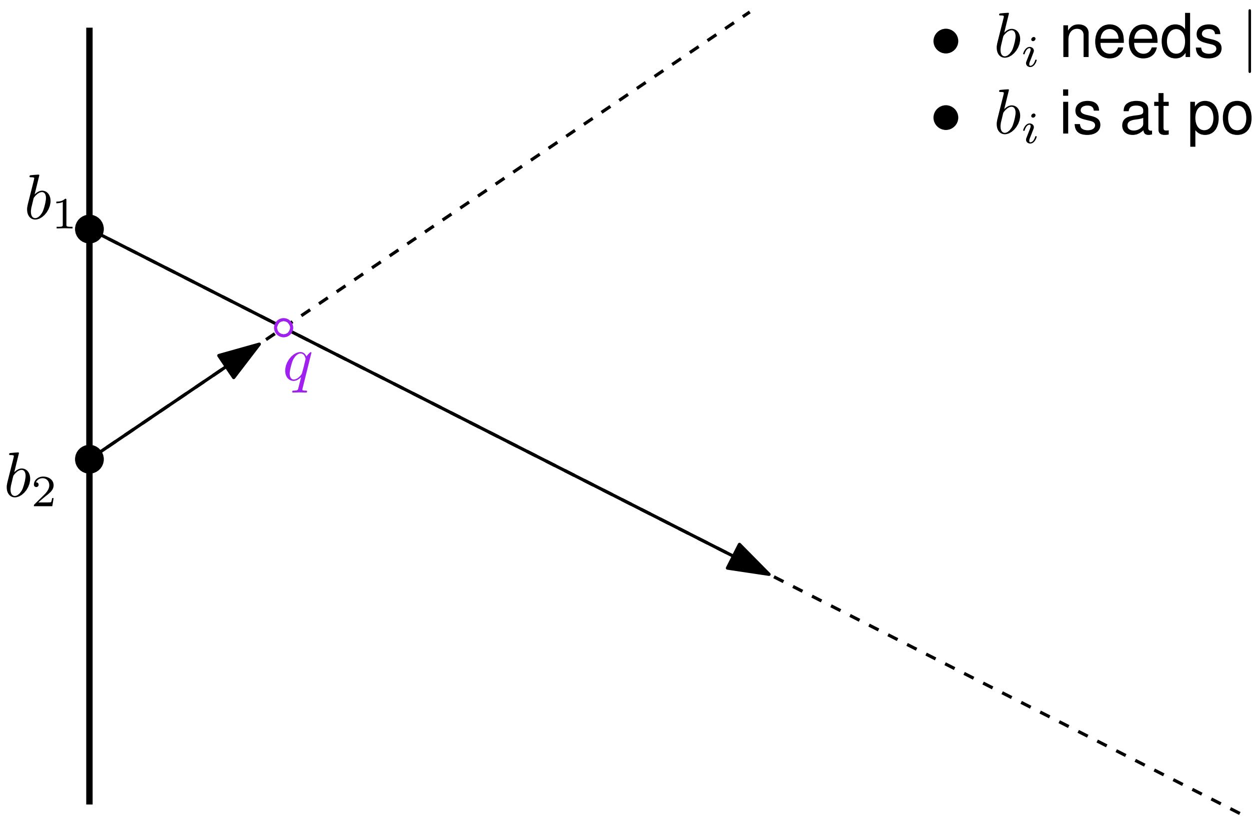
For each pair b_i, b_j such that their paths cross, we get a constraint.

- b_i needs $||b_i - q||$ time to reach q.
- b_i is at position q at time $s_i + ||b_i - q||$.



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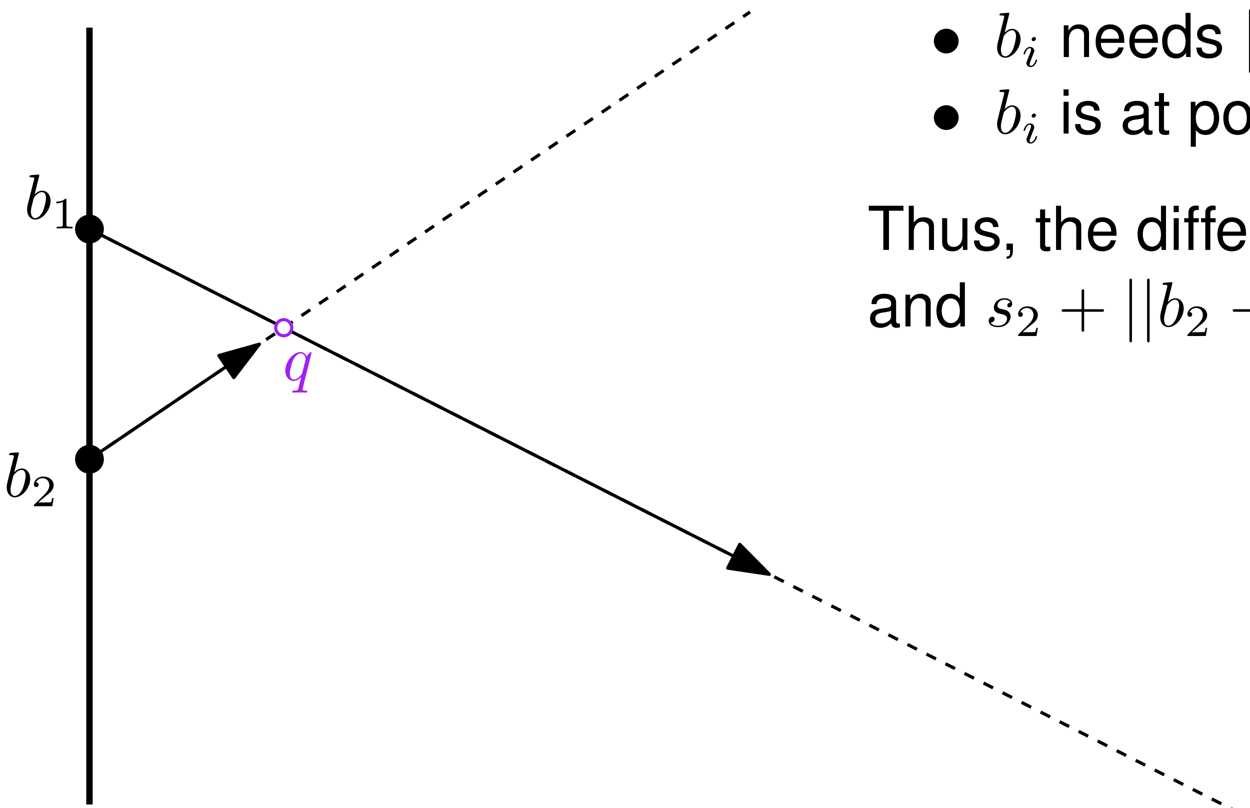

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Thus, the difference between $s_1 + ||b_1 - q||$ and $s_2 + ||b_2 - q||$ can be at most f.

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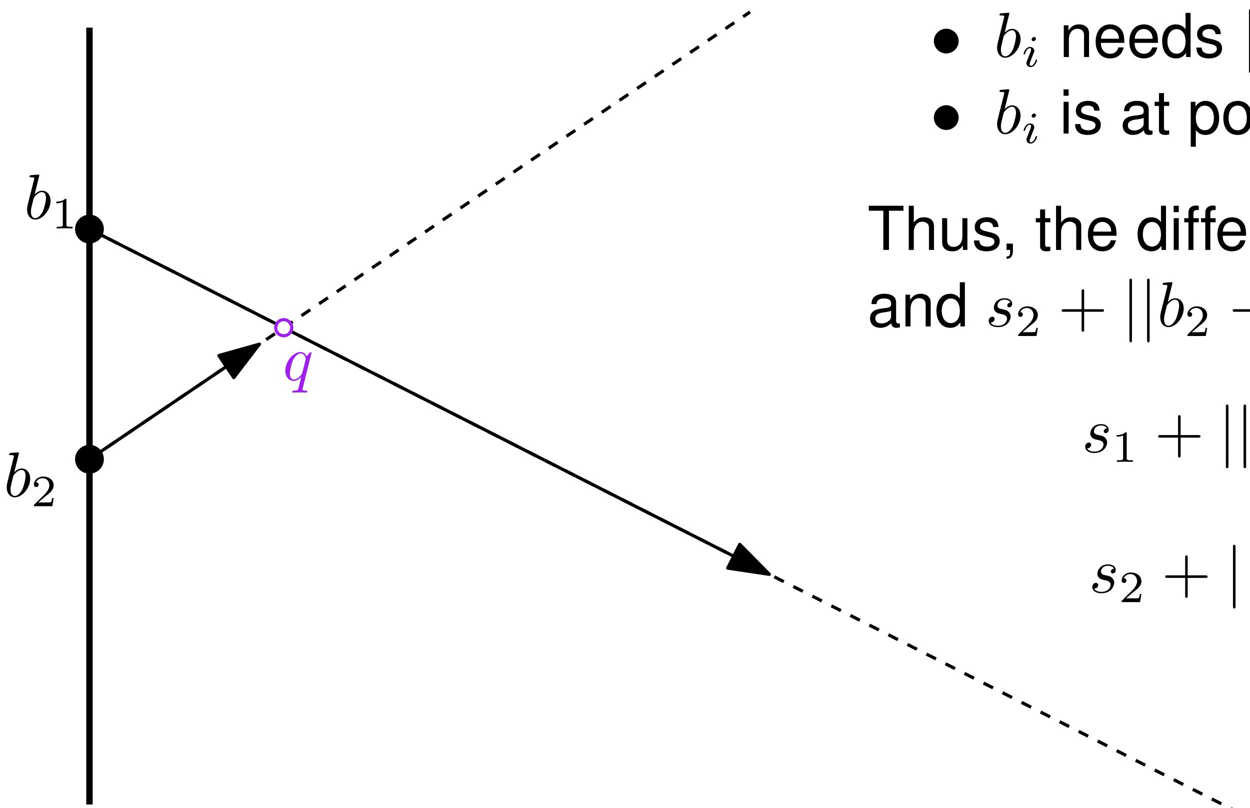

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$$s_1 + ||b_1 - q|| \leq s_2 + ||b_2 - q|| + f,$$

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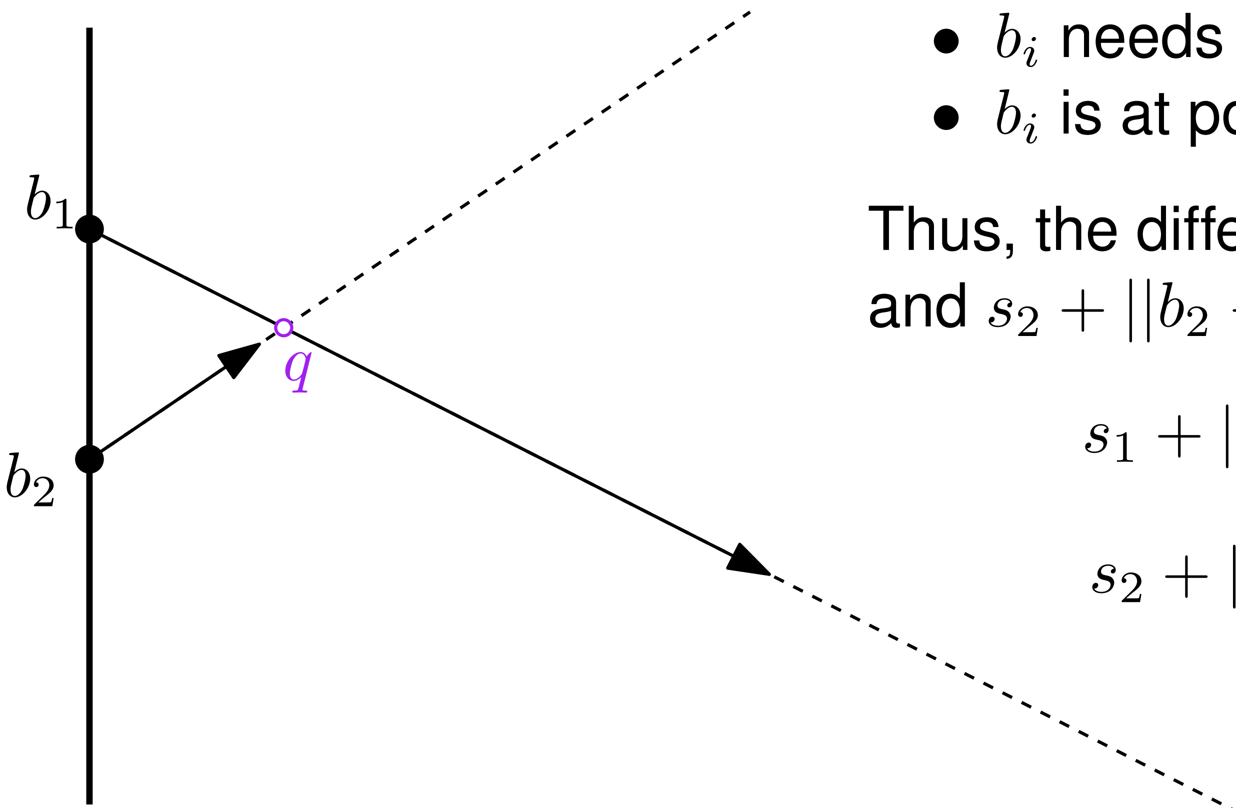

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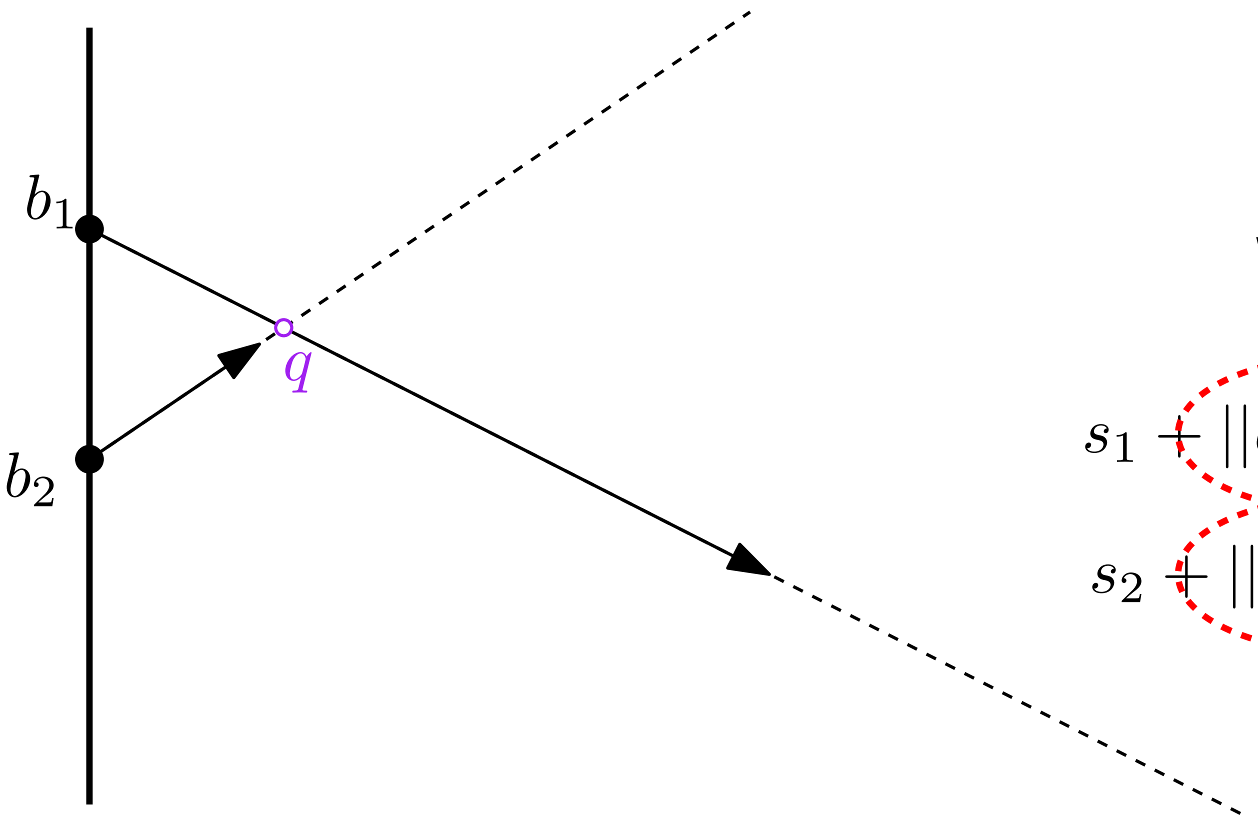
There are $O(n^2)$ constraints, which is at most 10,000.

Solving it with Linear Programming



For each pair b_i, b_j such that their paths cross, we get a constraint.

What are these terms?

$$s_1 + ||b_1 - q|| \leq s_2 + ||b_2 - q|| + f,$$
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Solving it with Linear Programming

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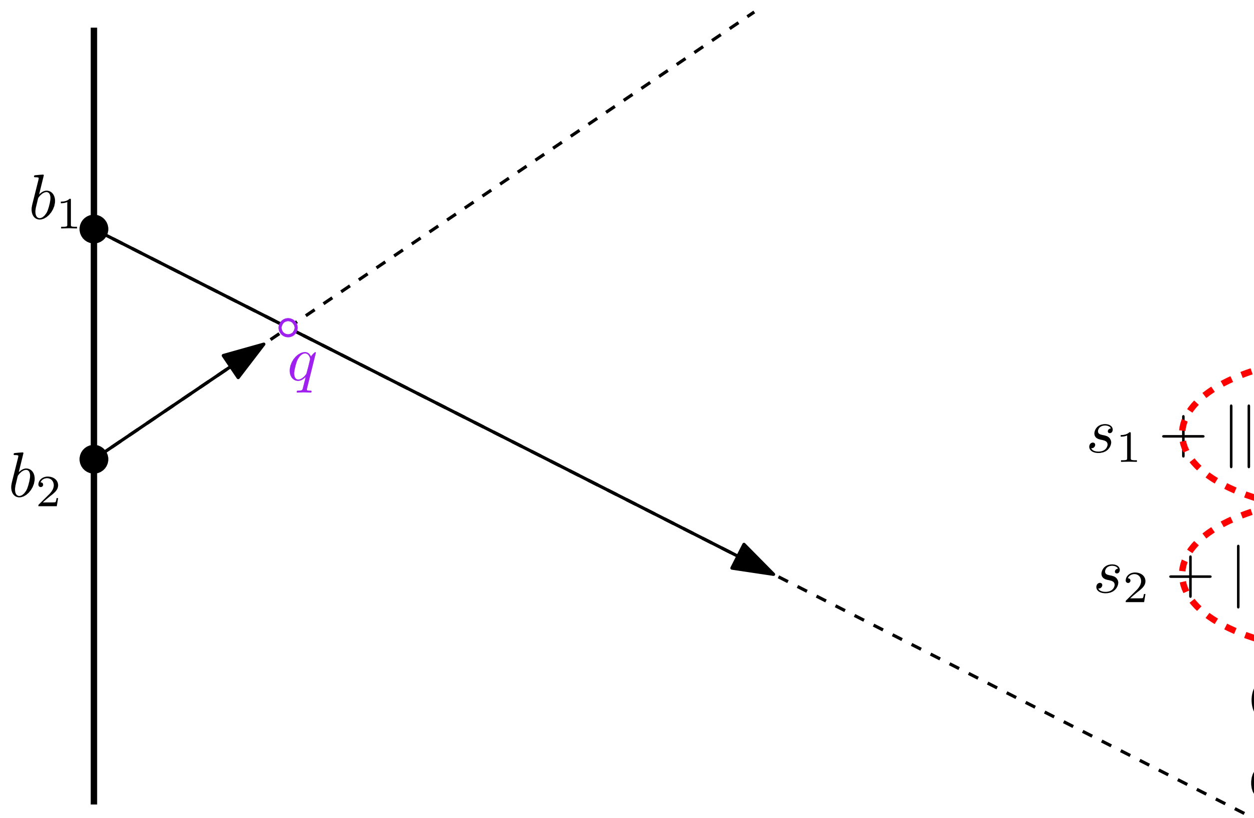

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One needs square roots to compute these constants.

Solving it with Linear Programming

In addition, we need all variables to be non-negative. Then, we minimize f subject to these constraints.

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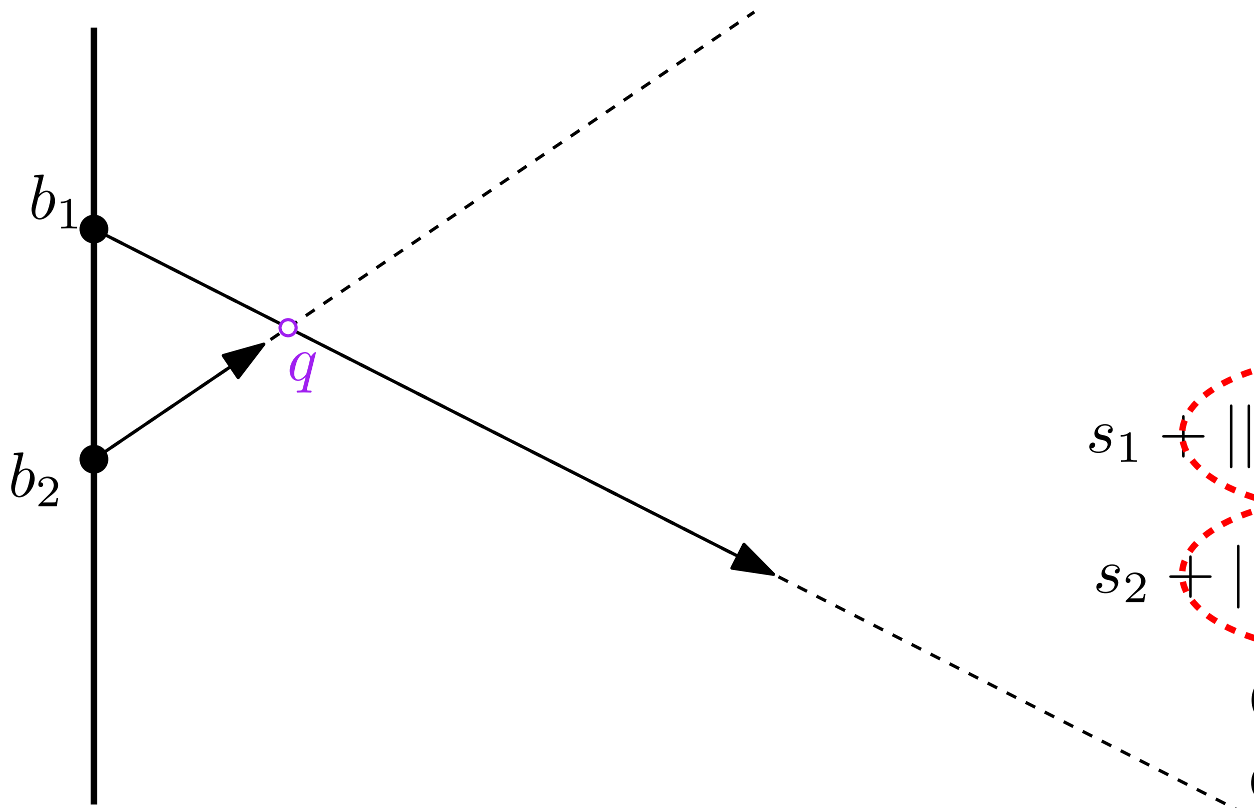

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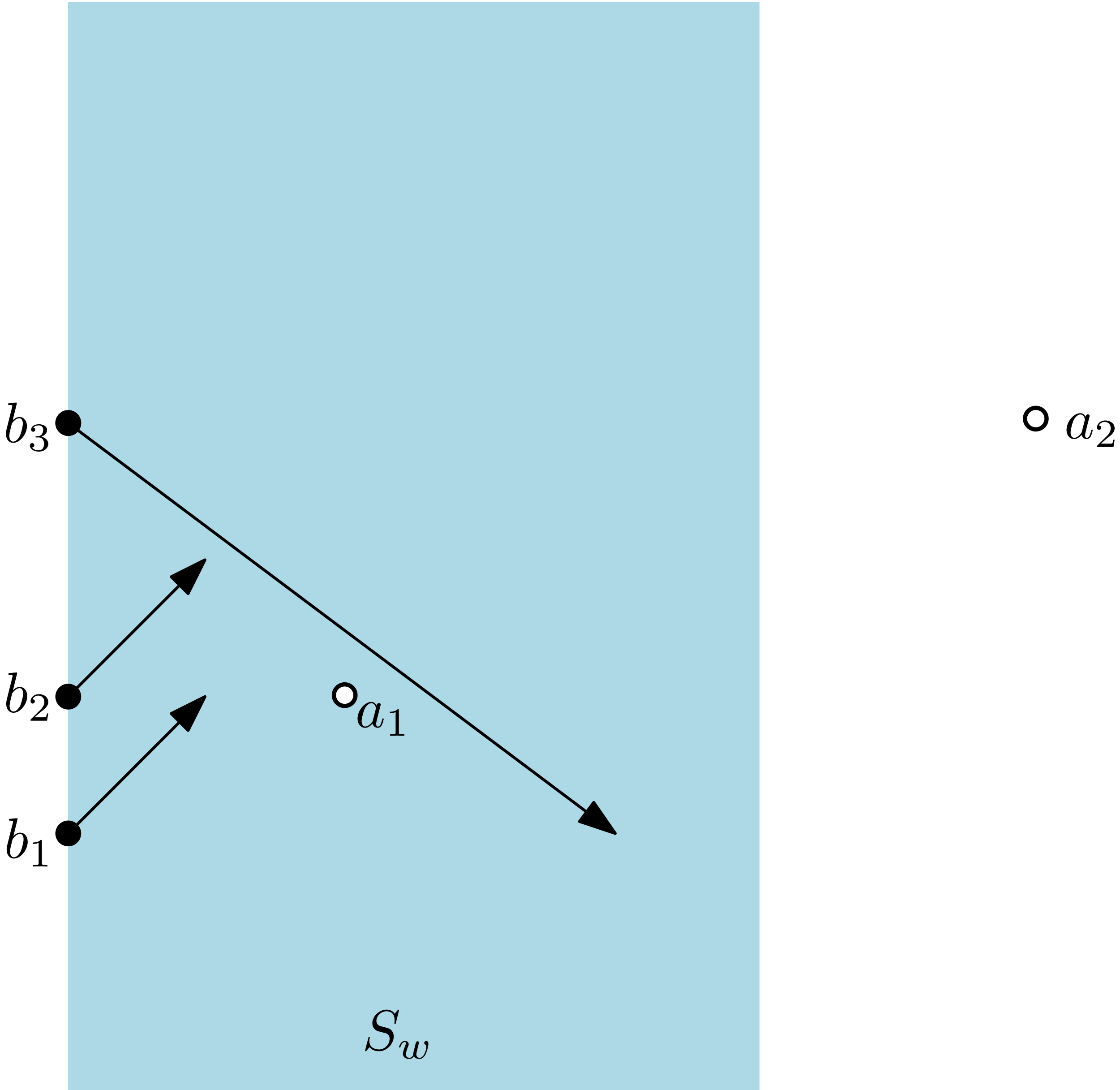
Beethoven



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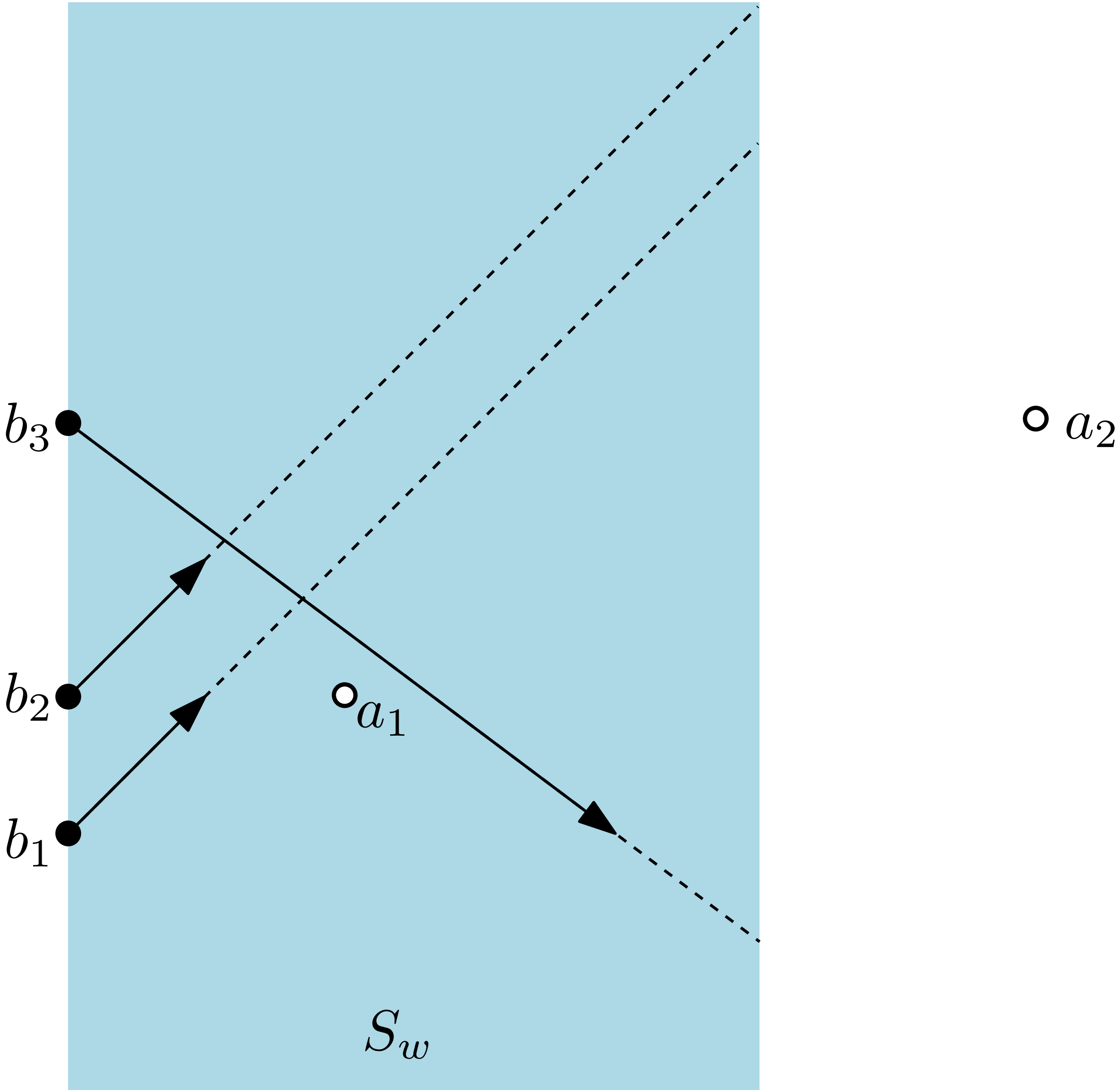

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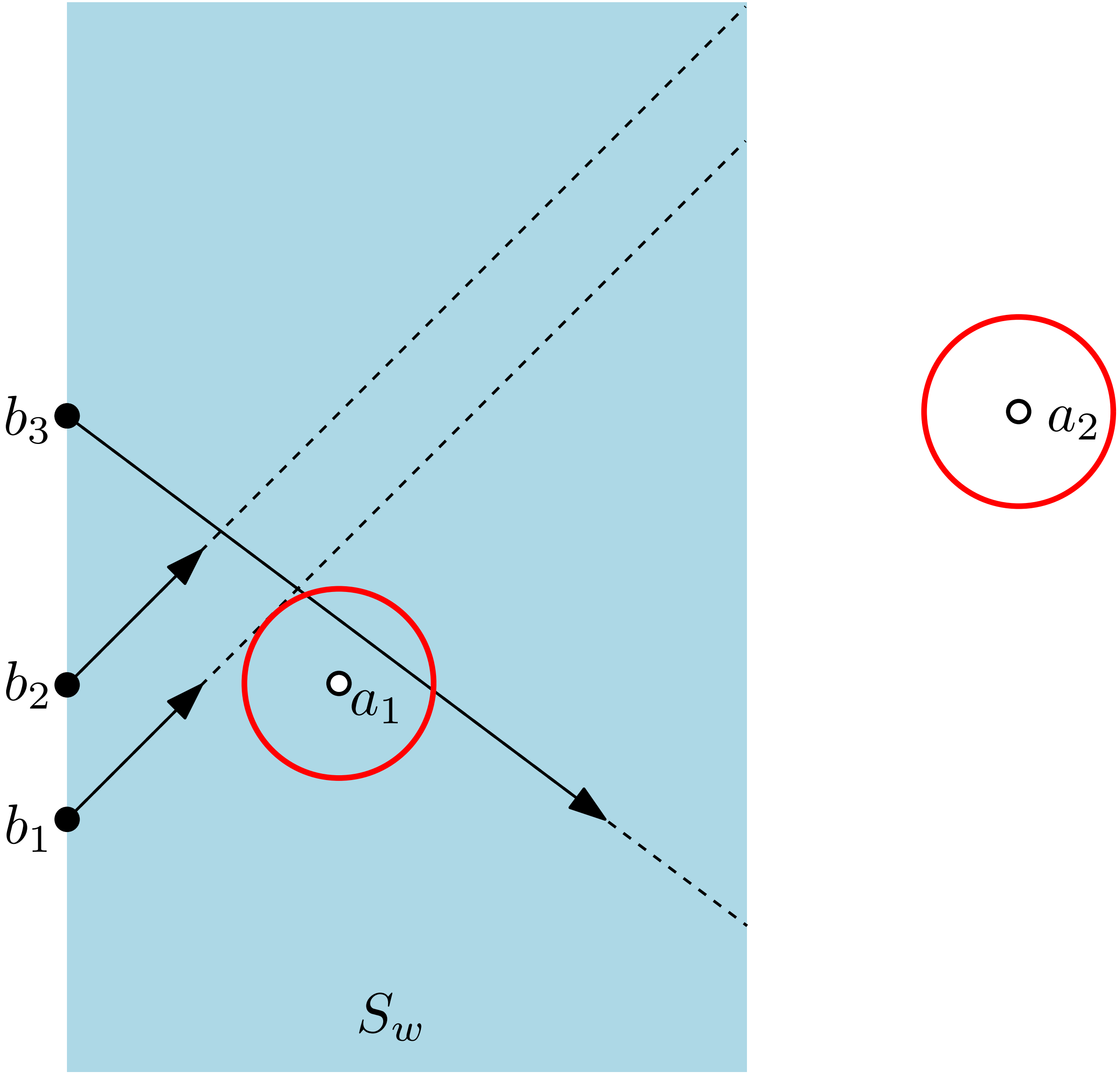

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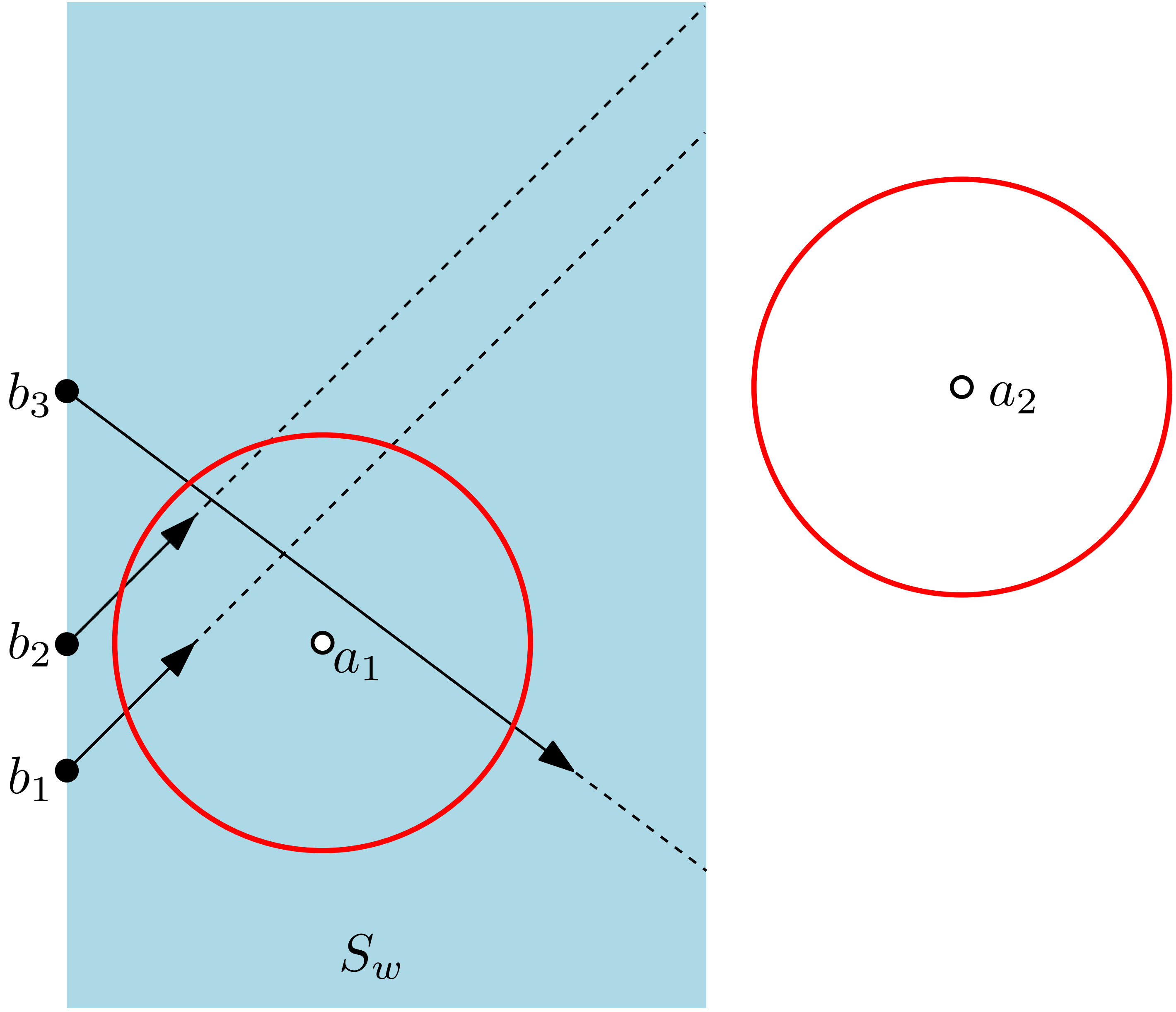

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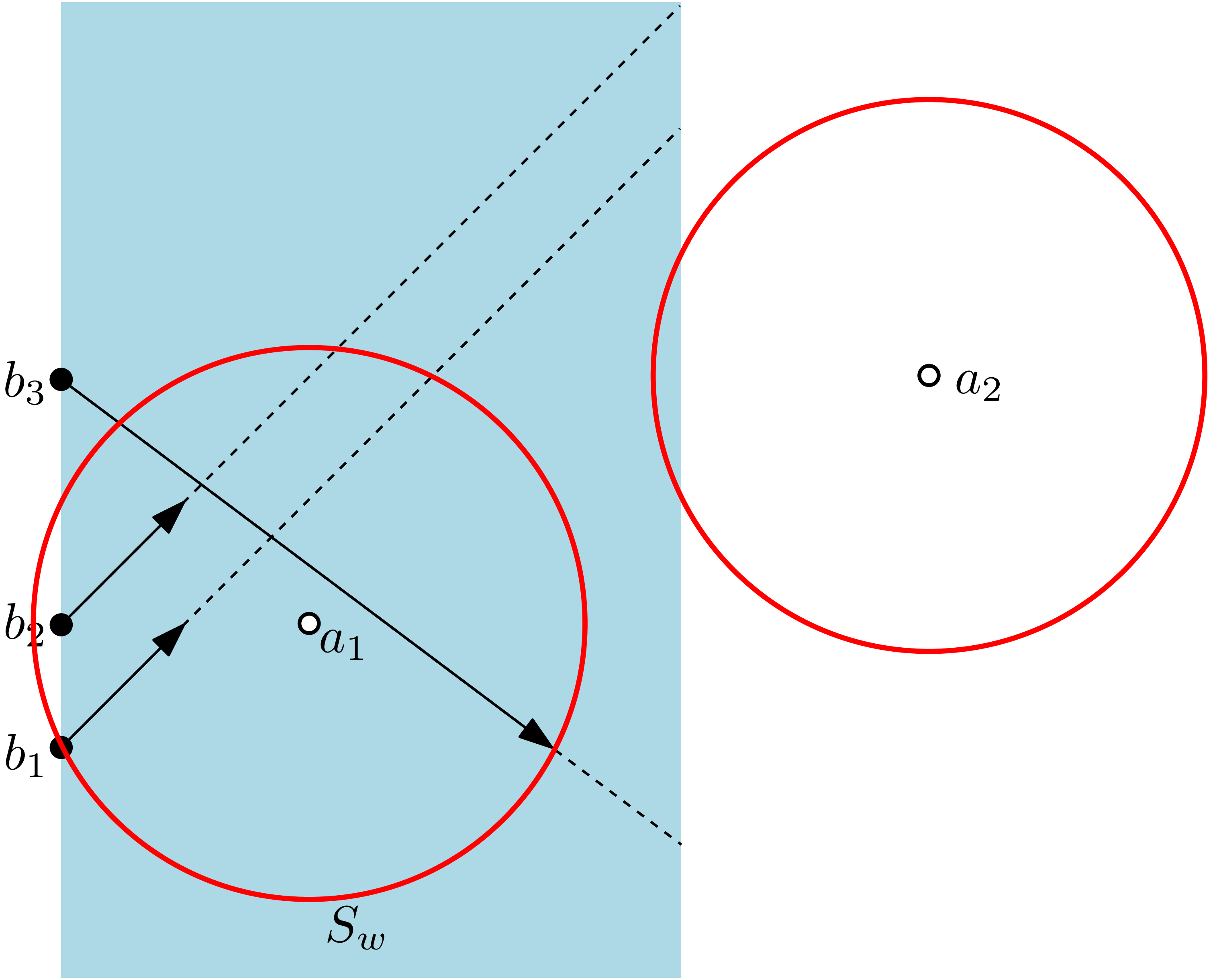

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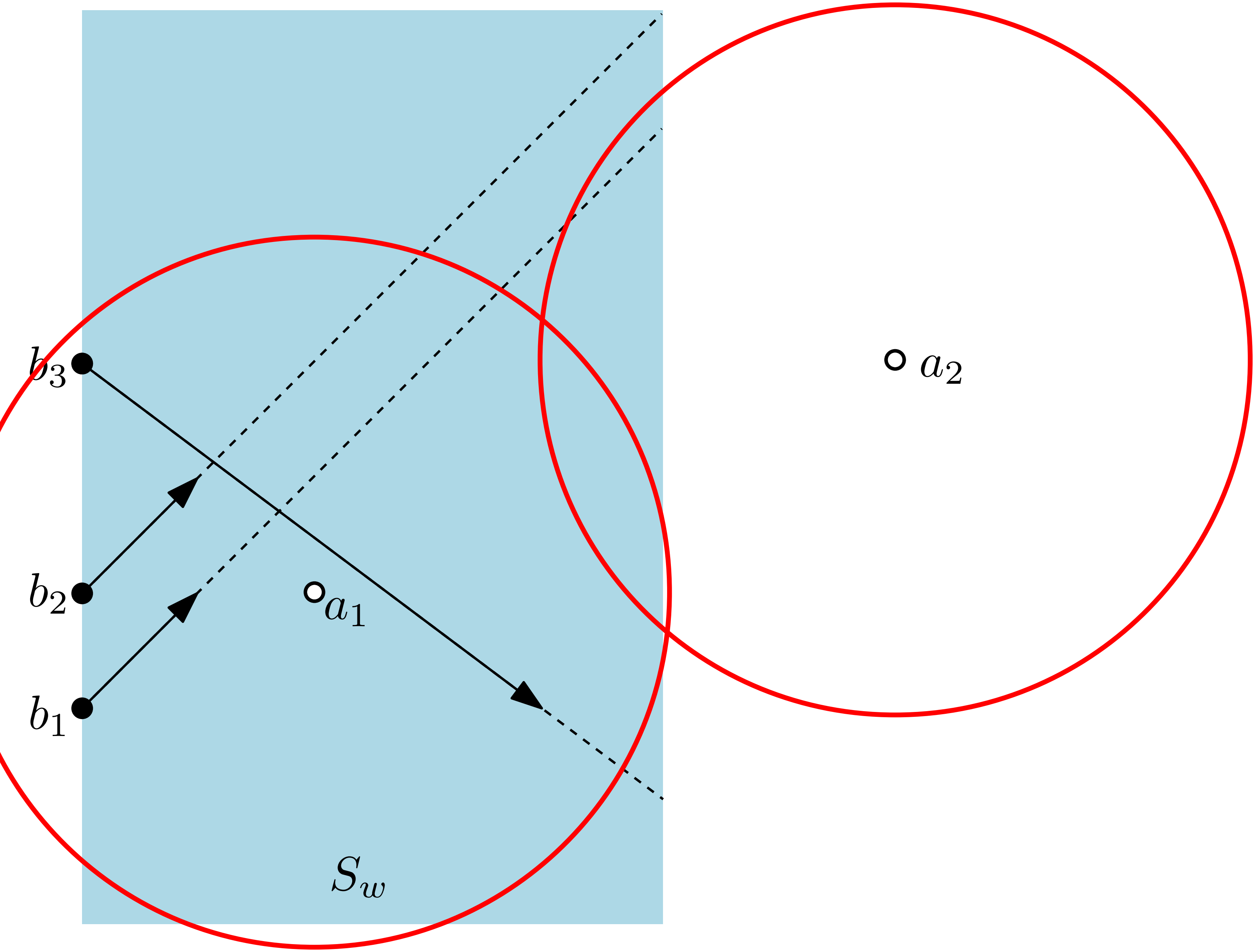

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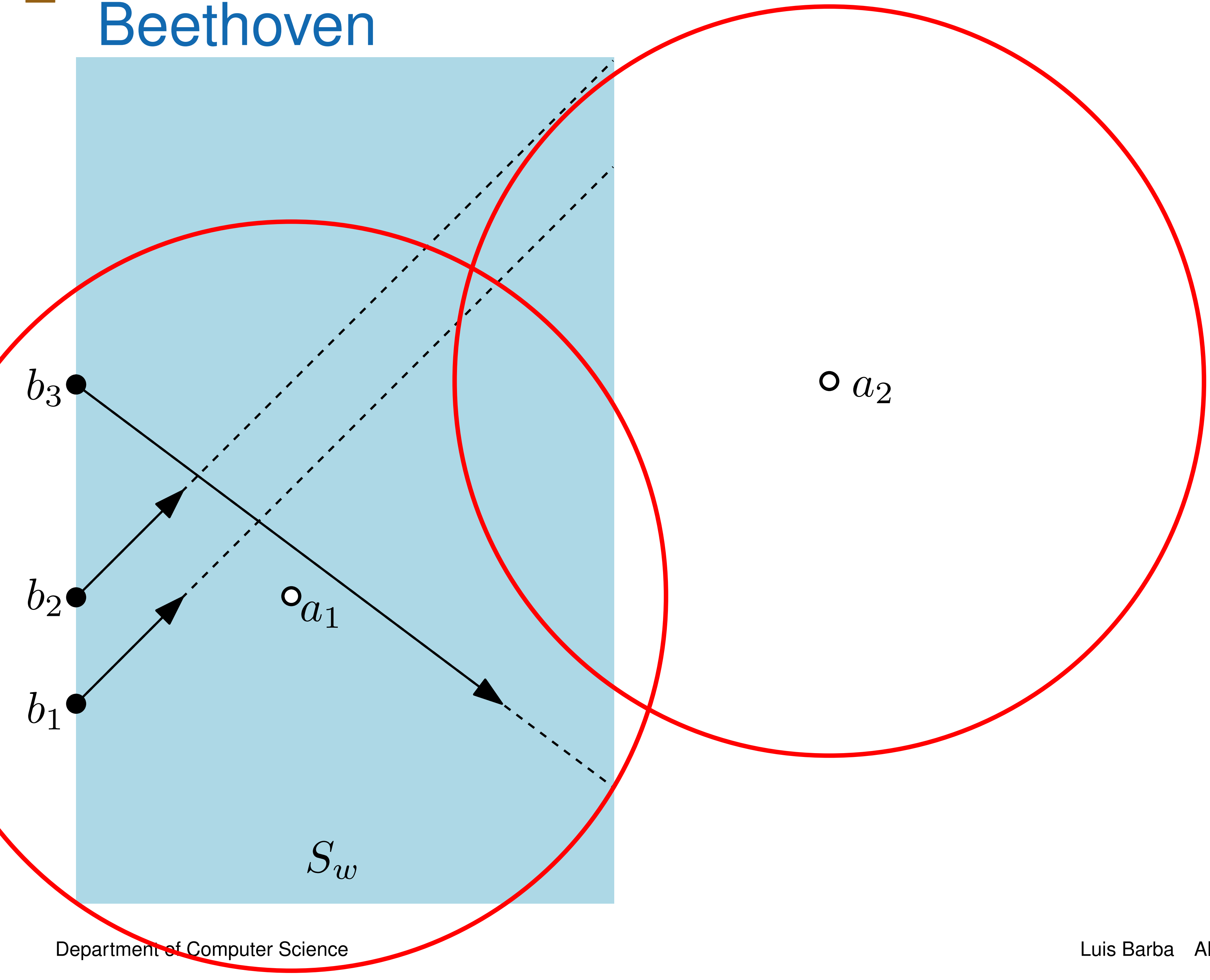

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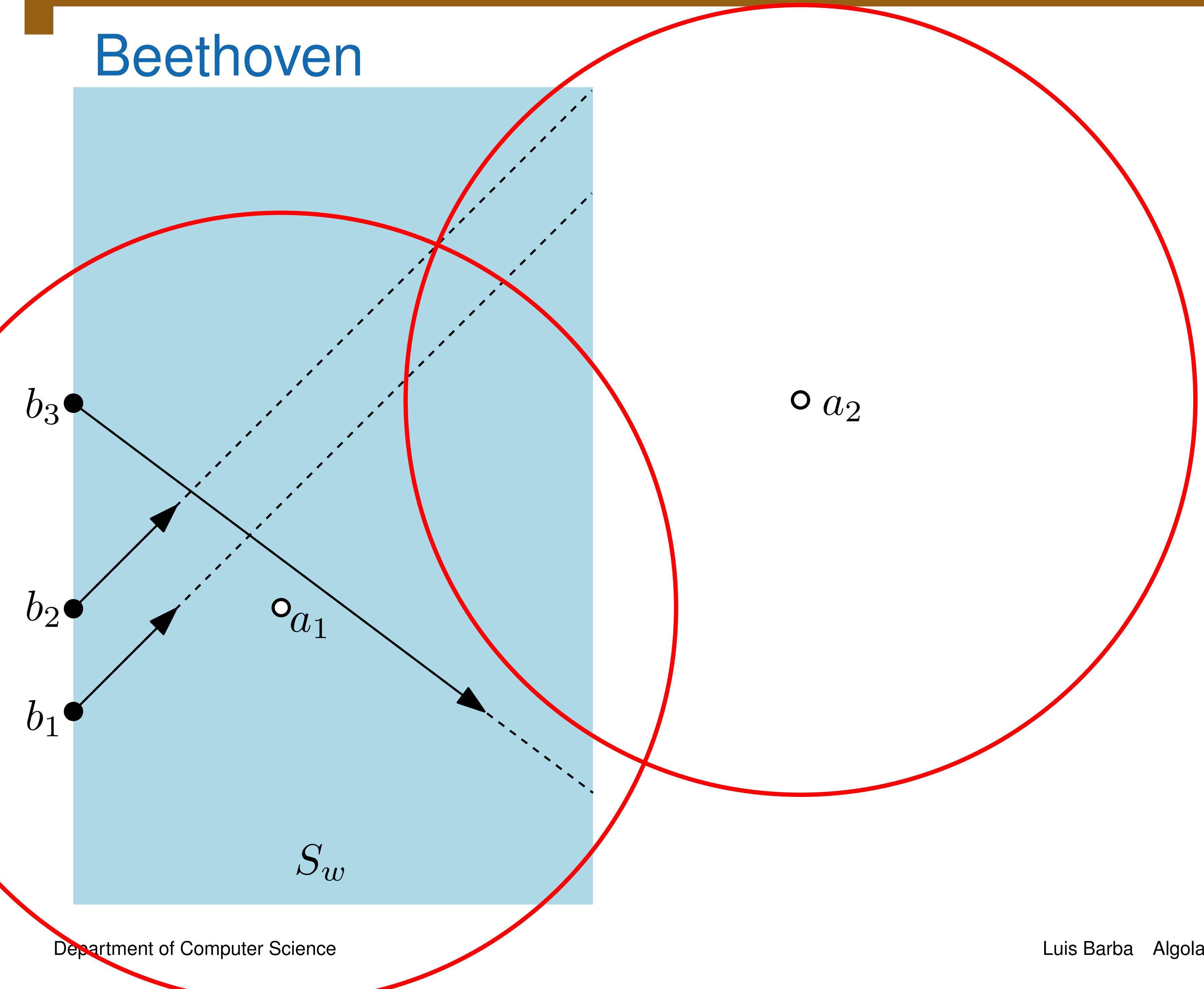
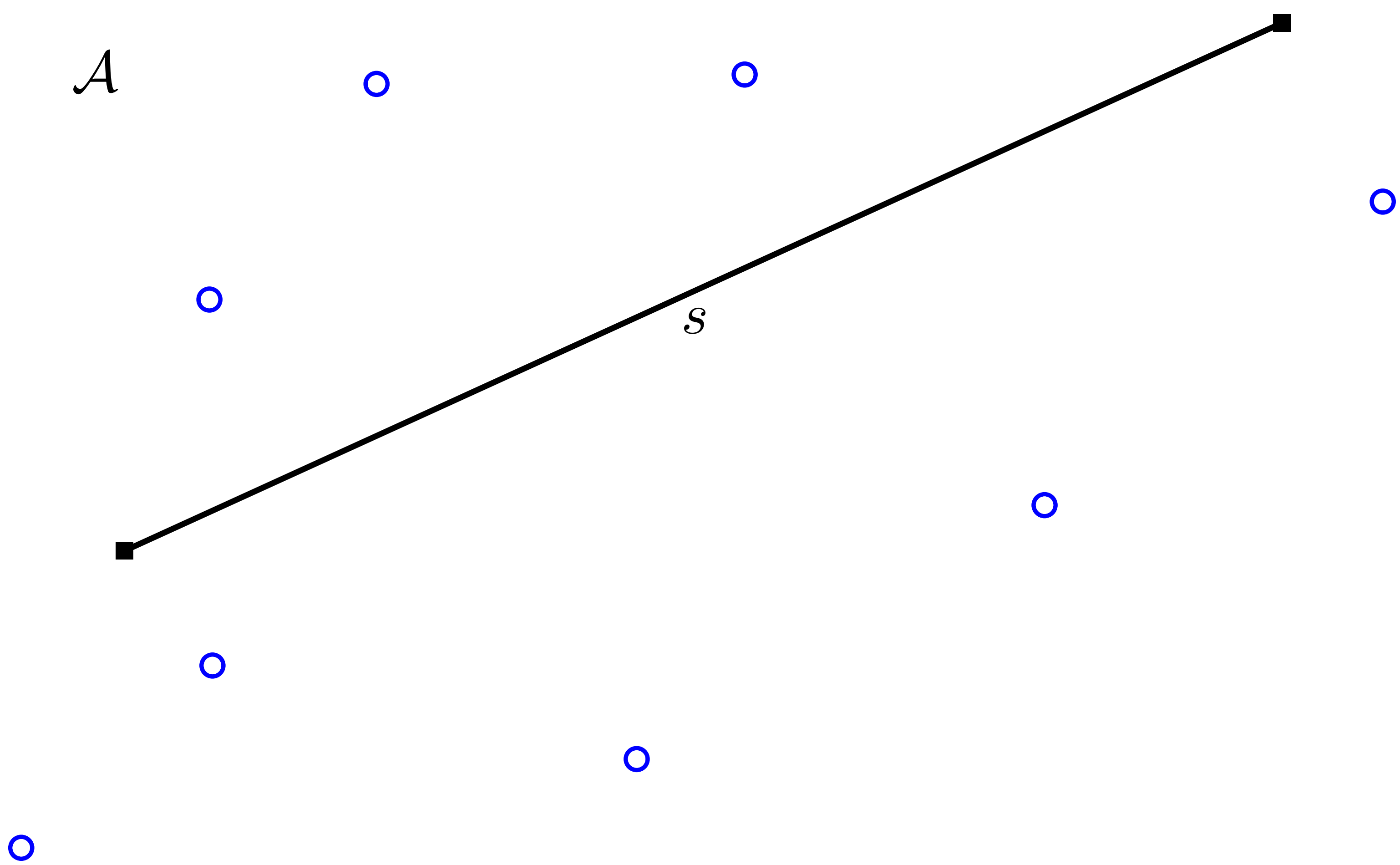


Working with a single segment



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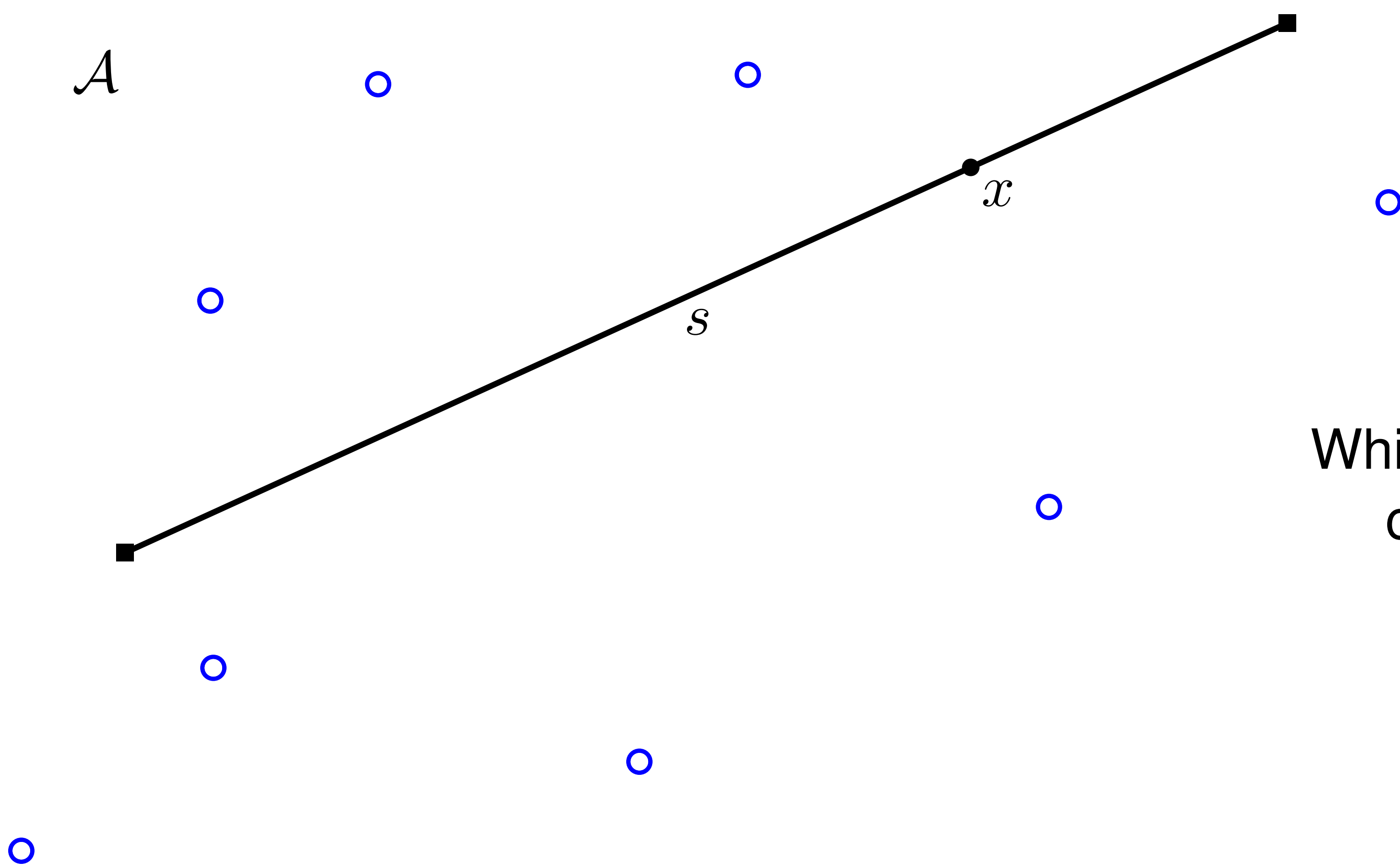
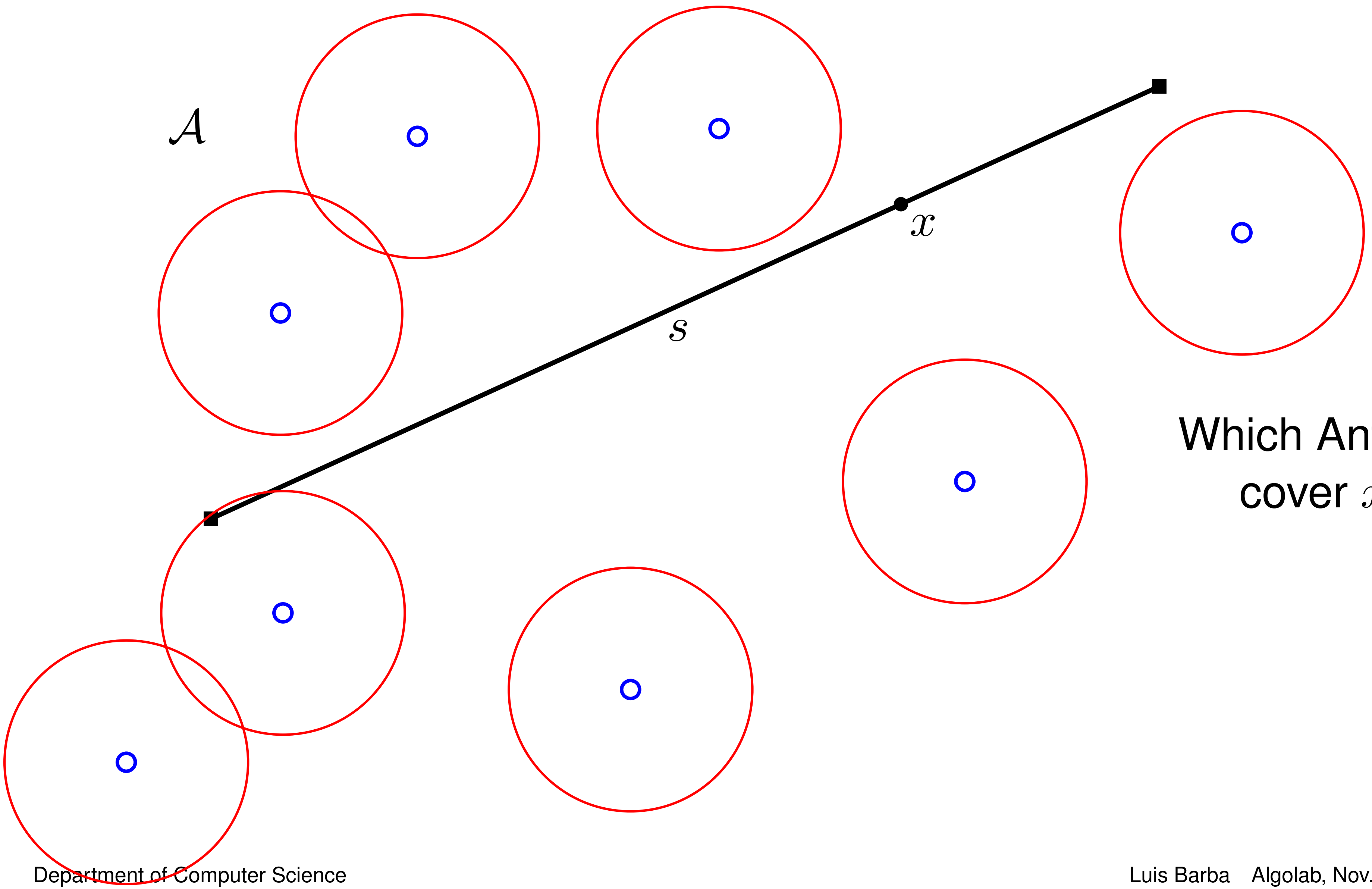


Which Antenna will cover x first?

Working with a single segment



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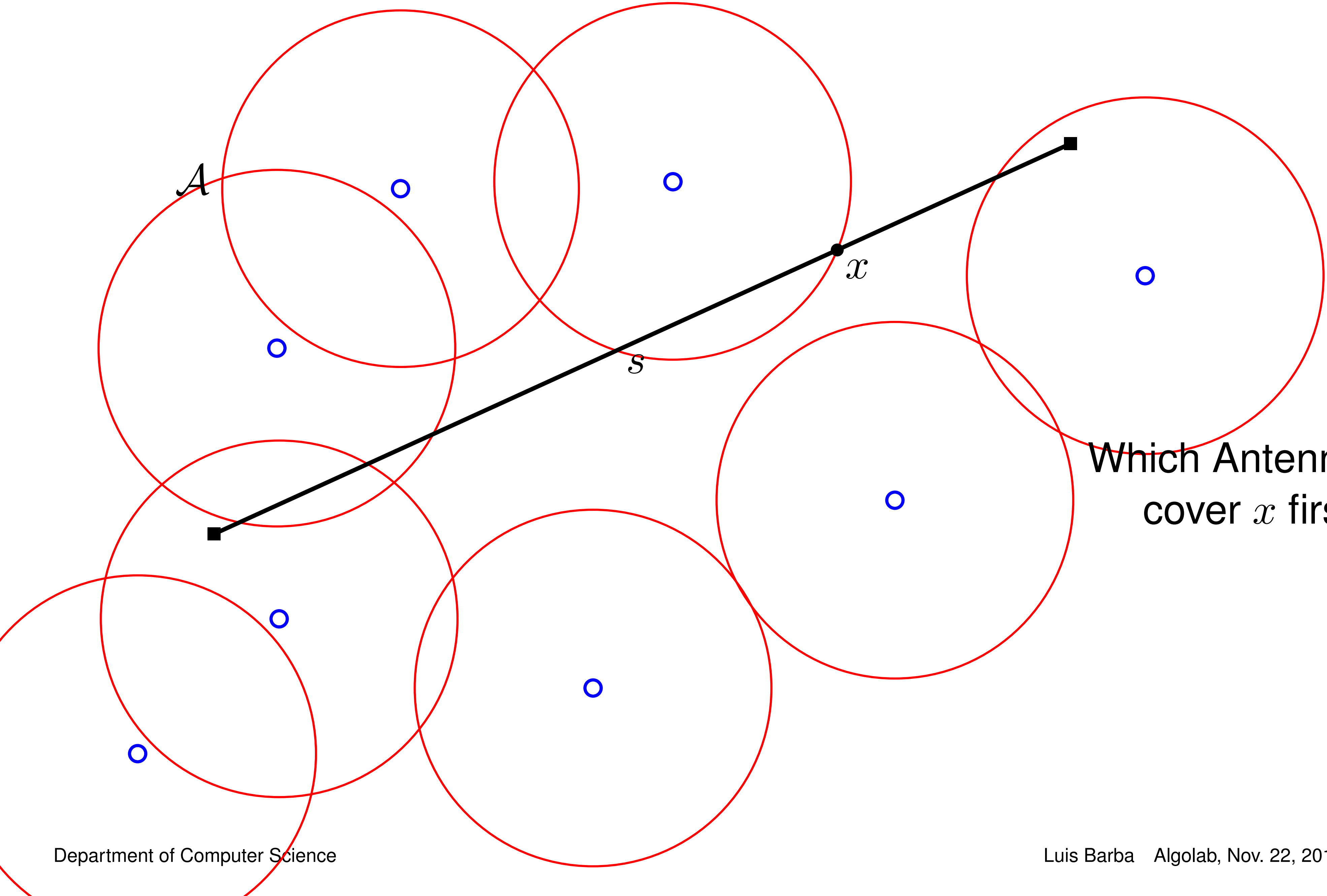

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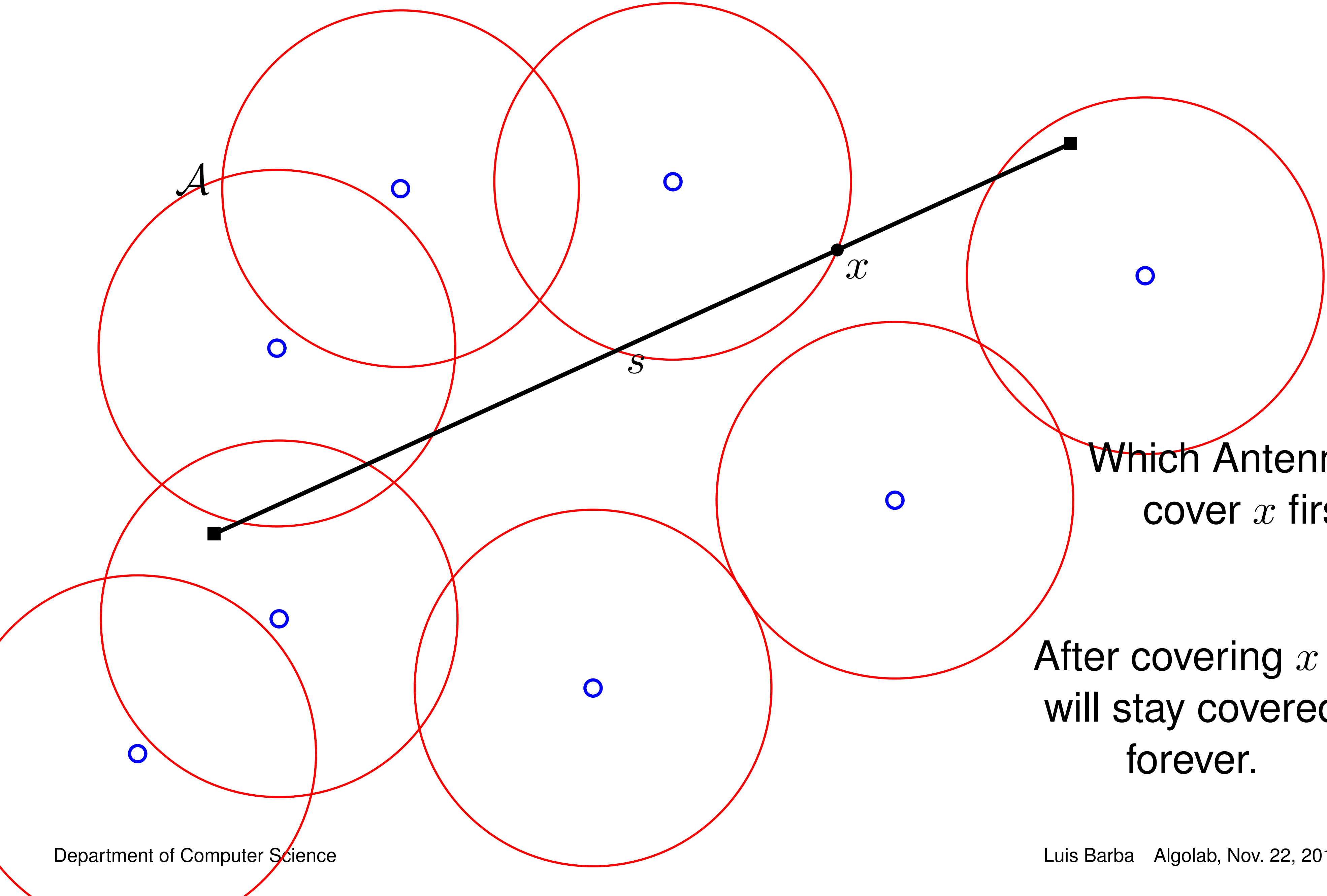

Which Antenna will cover x first?

After covering x it will stay covered forever.

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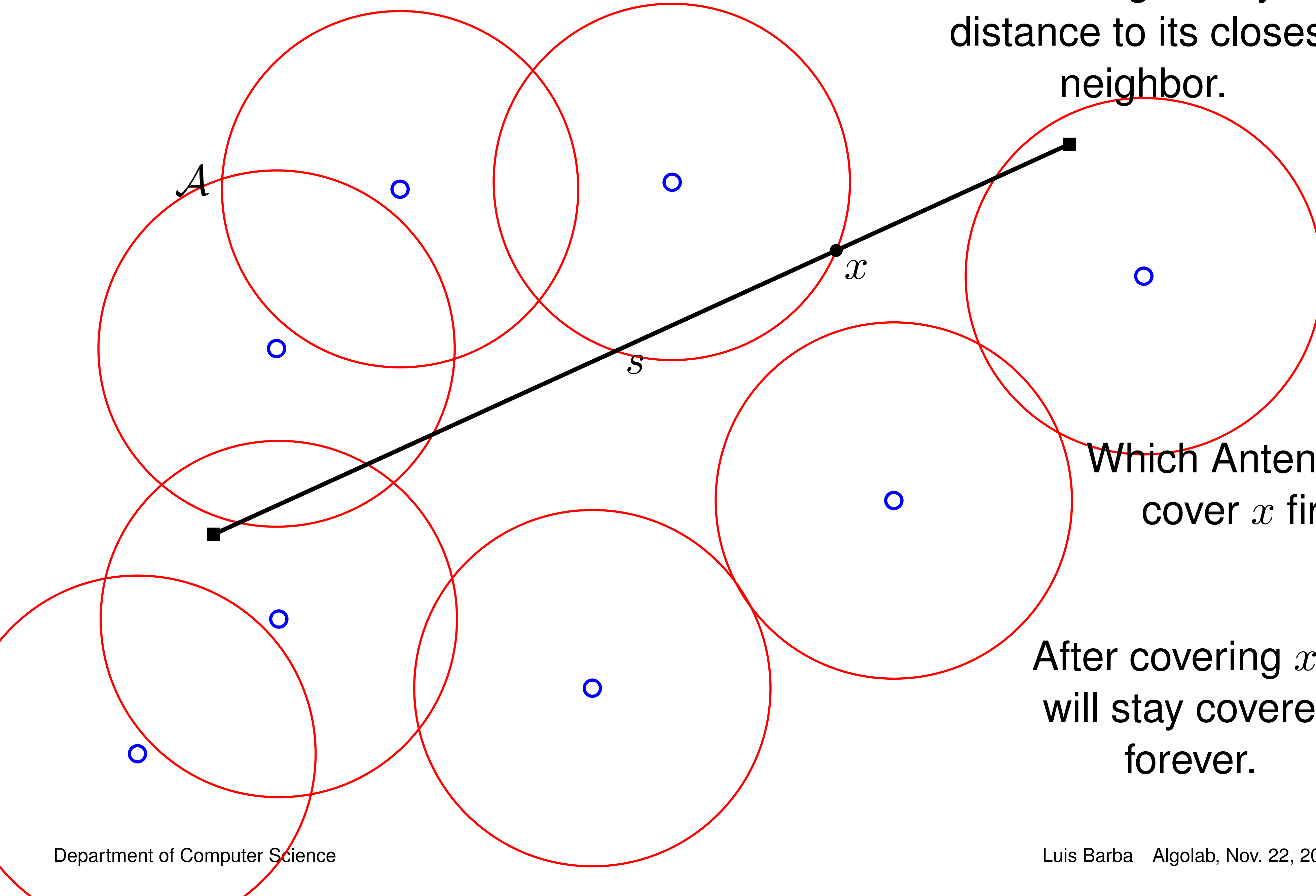
Working with a single segment

The minimum radius to cover x is given by the distance to its closest neighbor.



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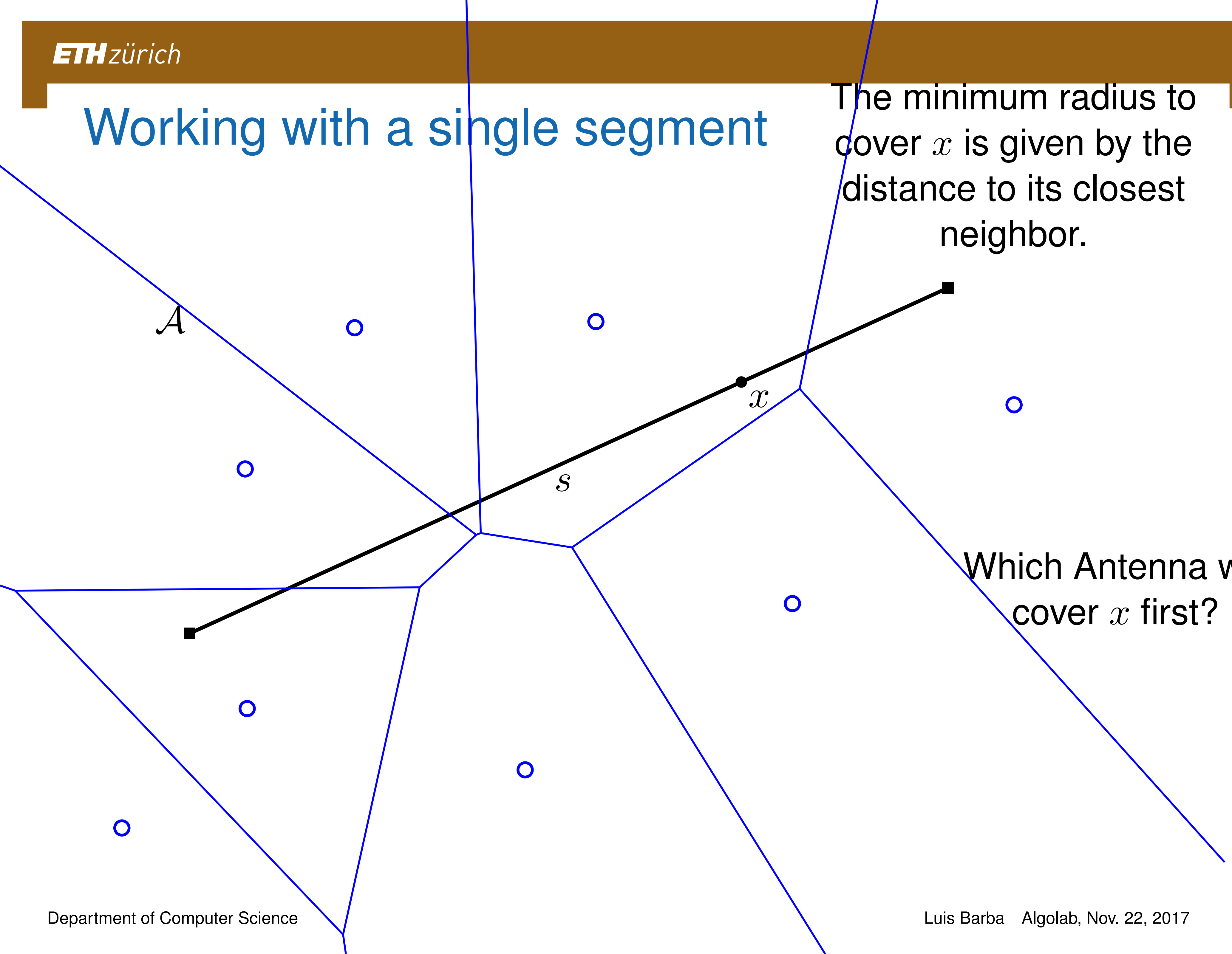

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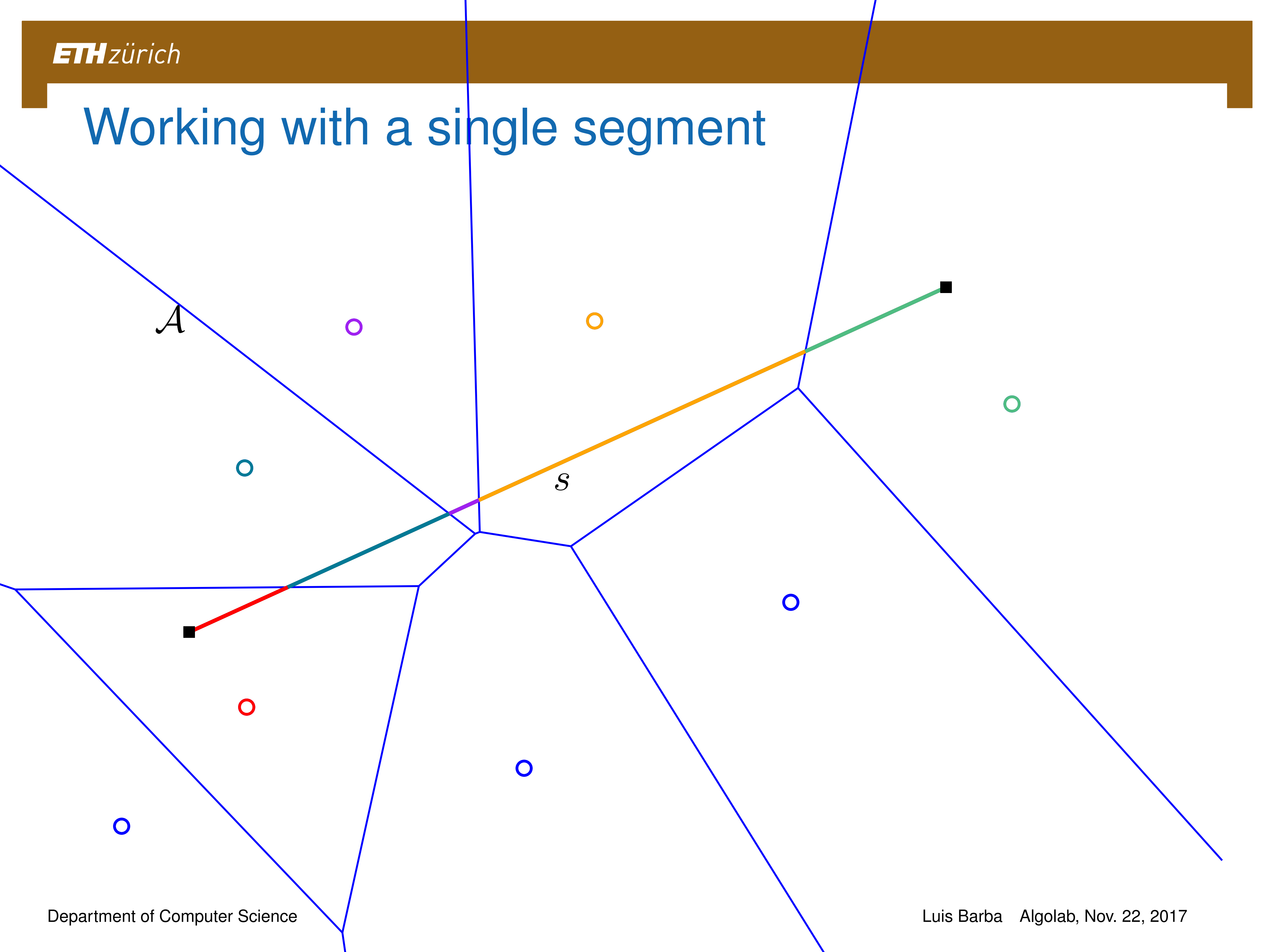
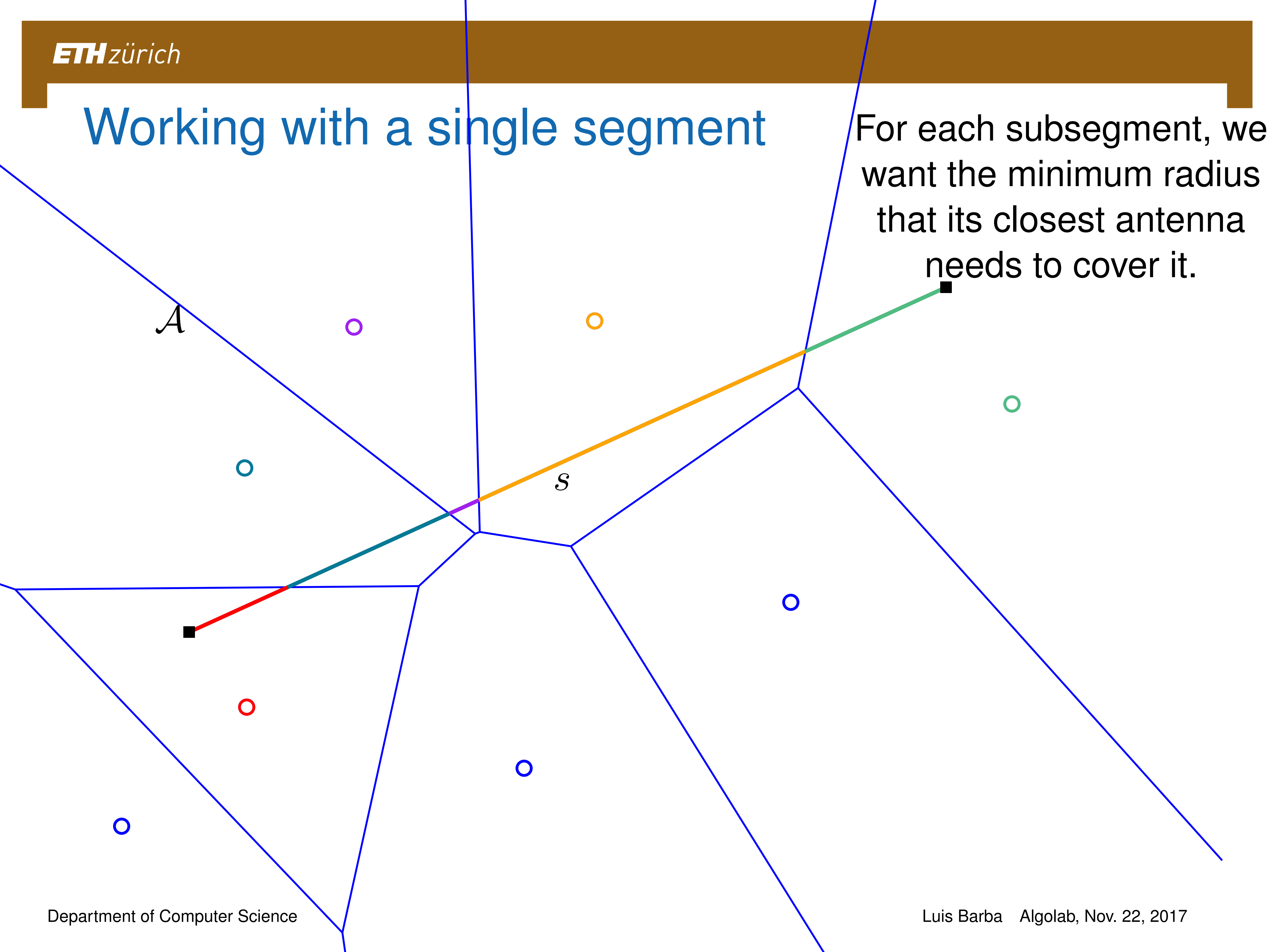


Working with a single segment

For each subsegment, we want the minimum radius that its closest antenna needs to cover it.



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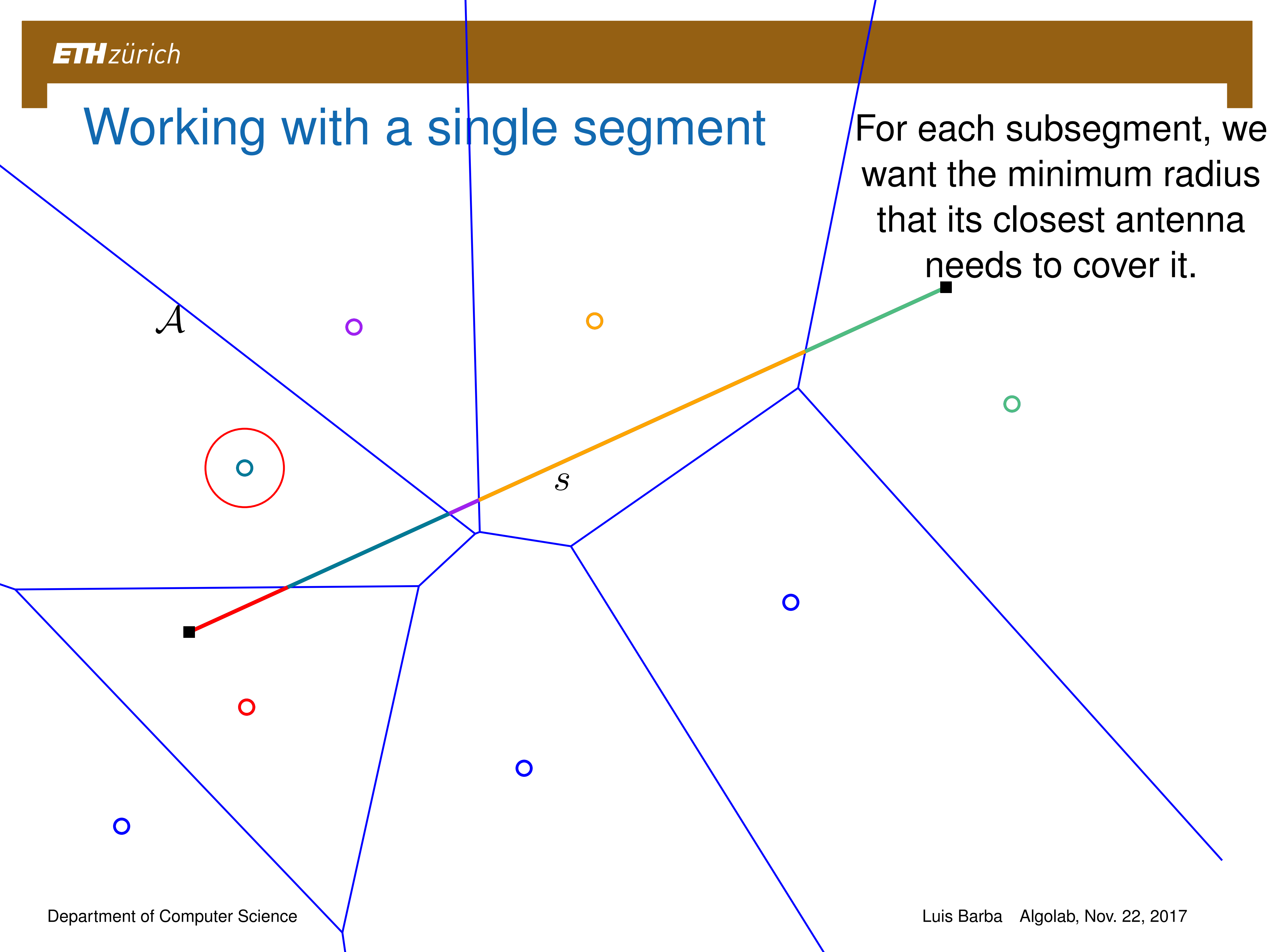

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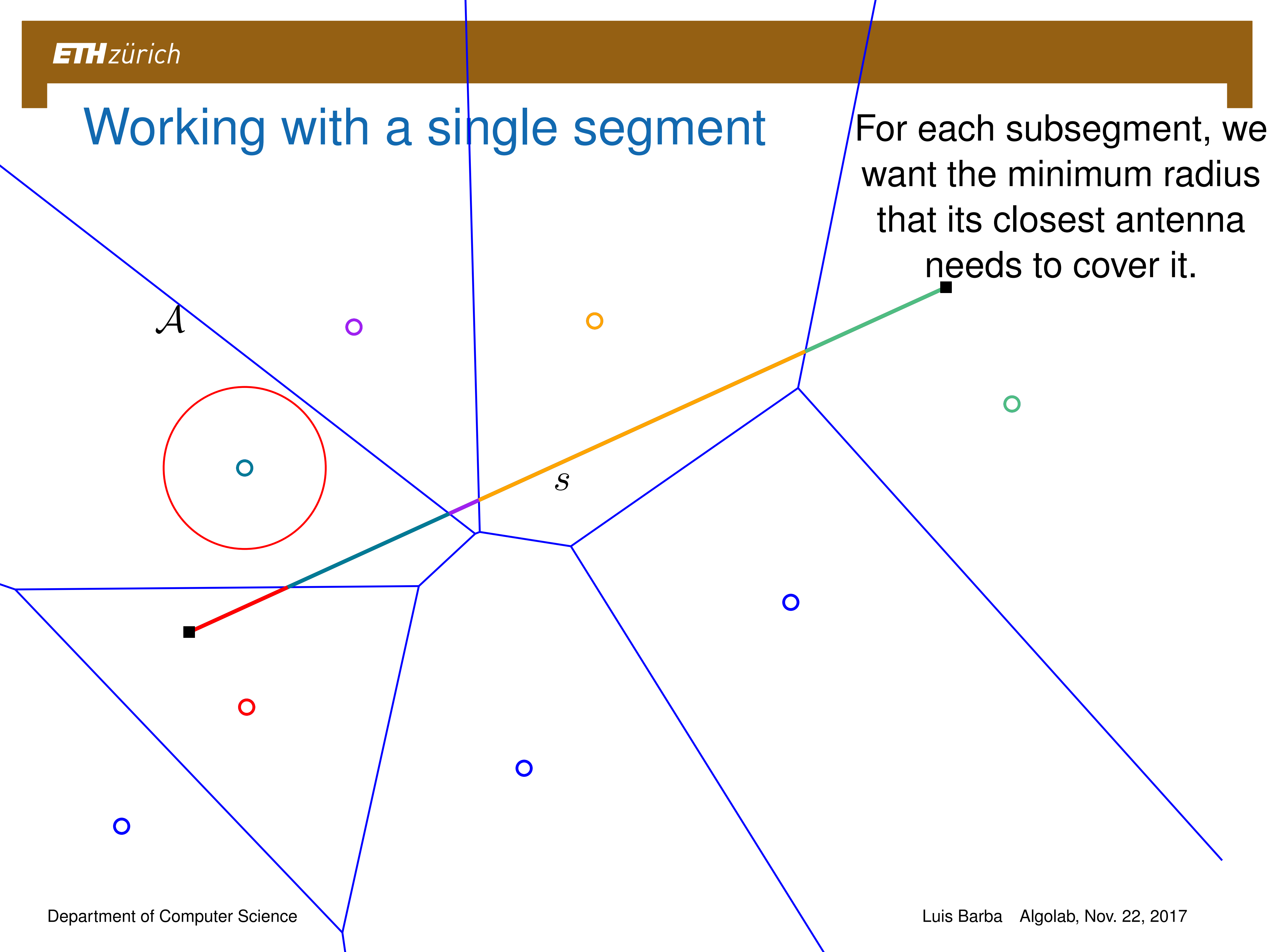

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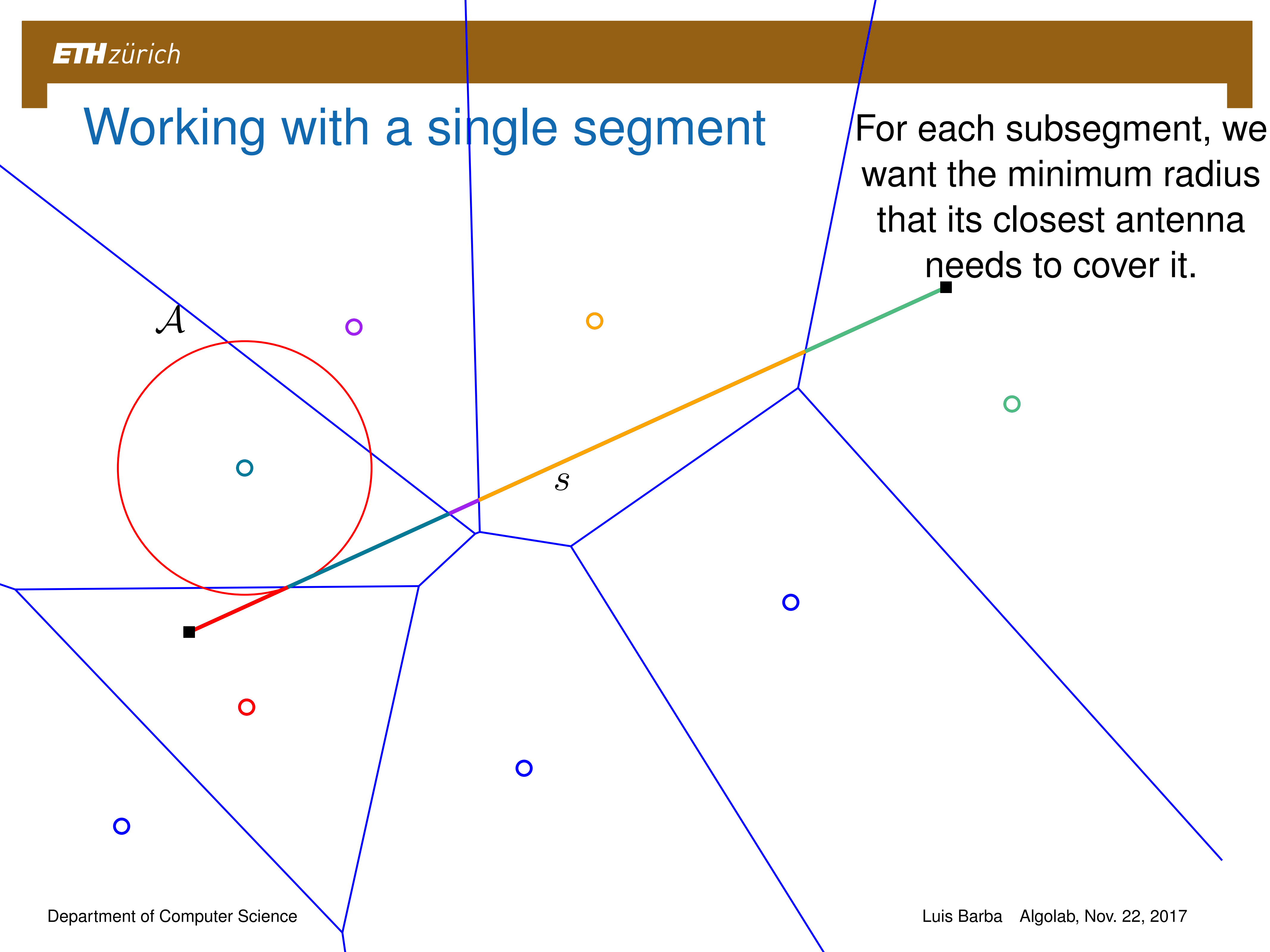

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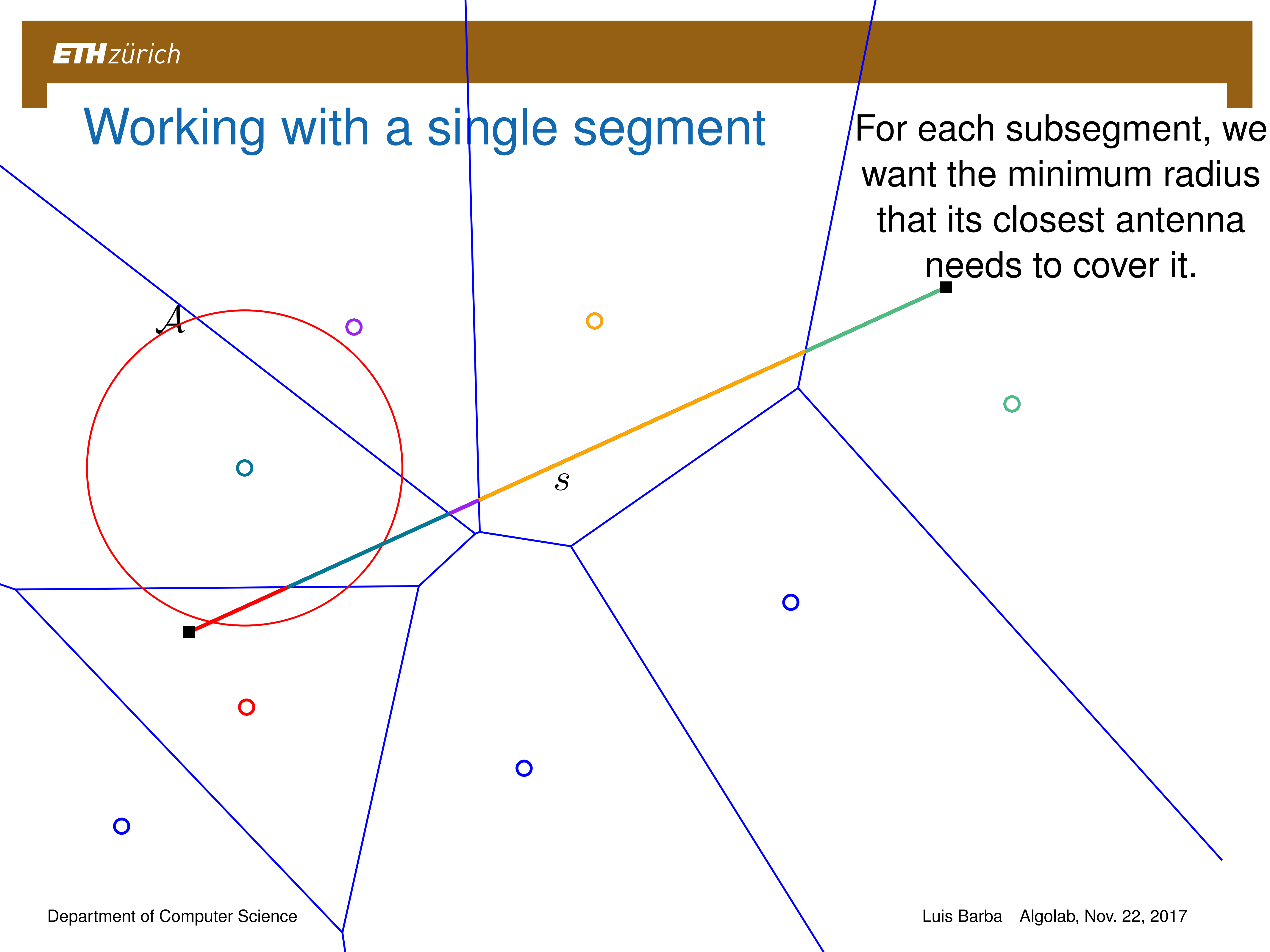

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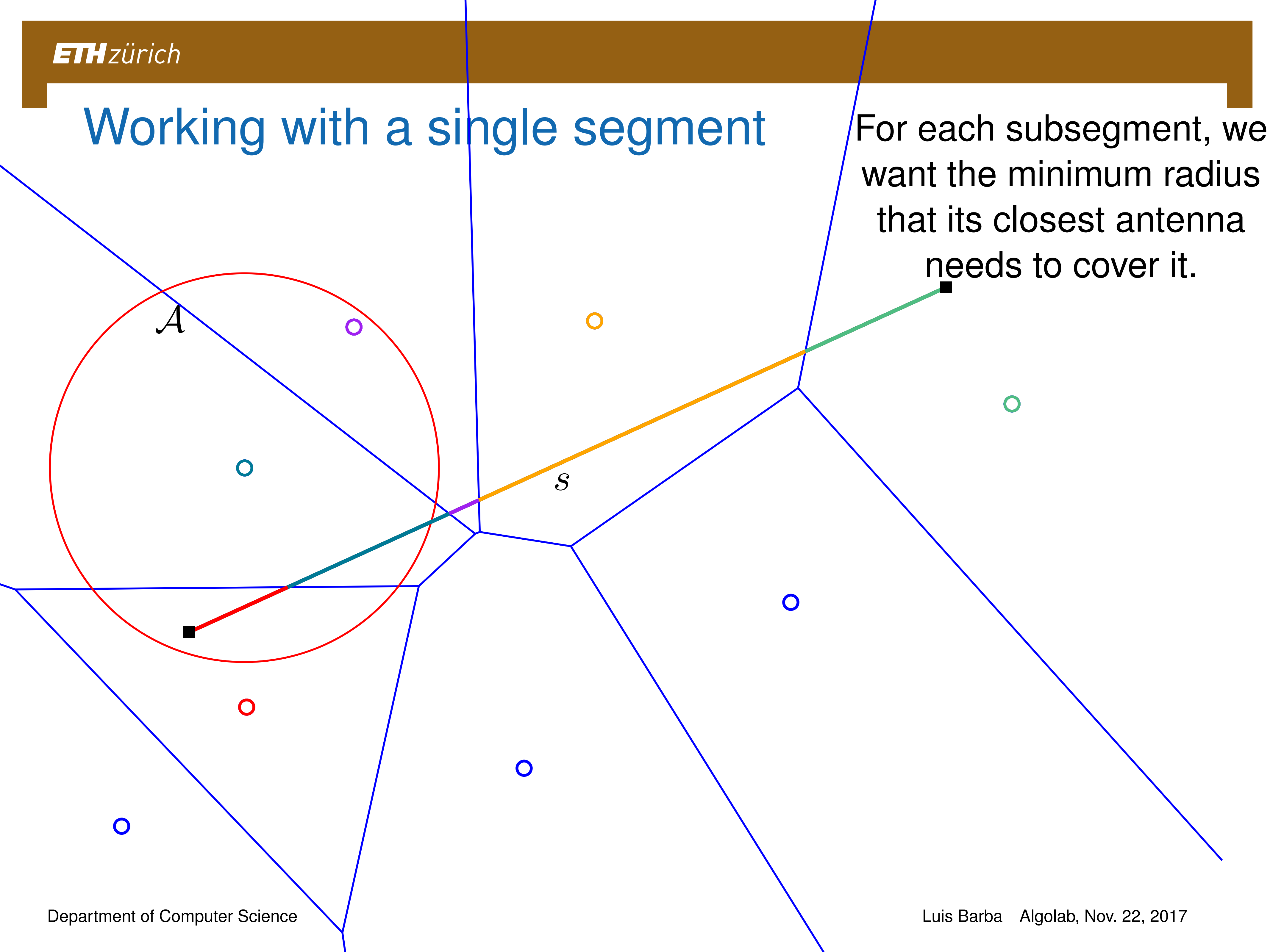

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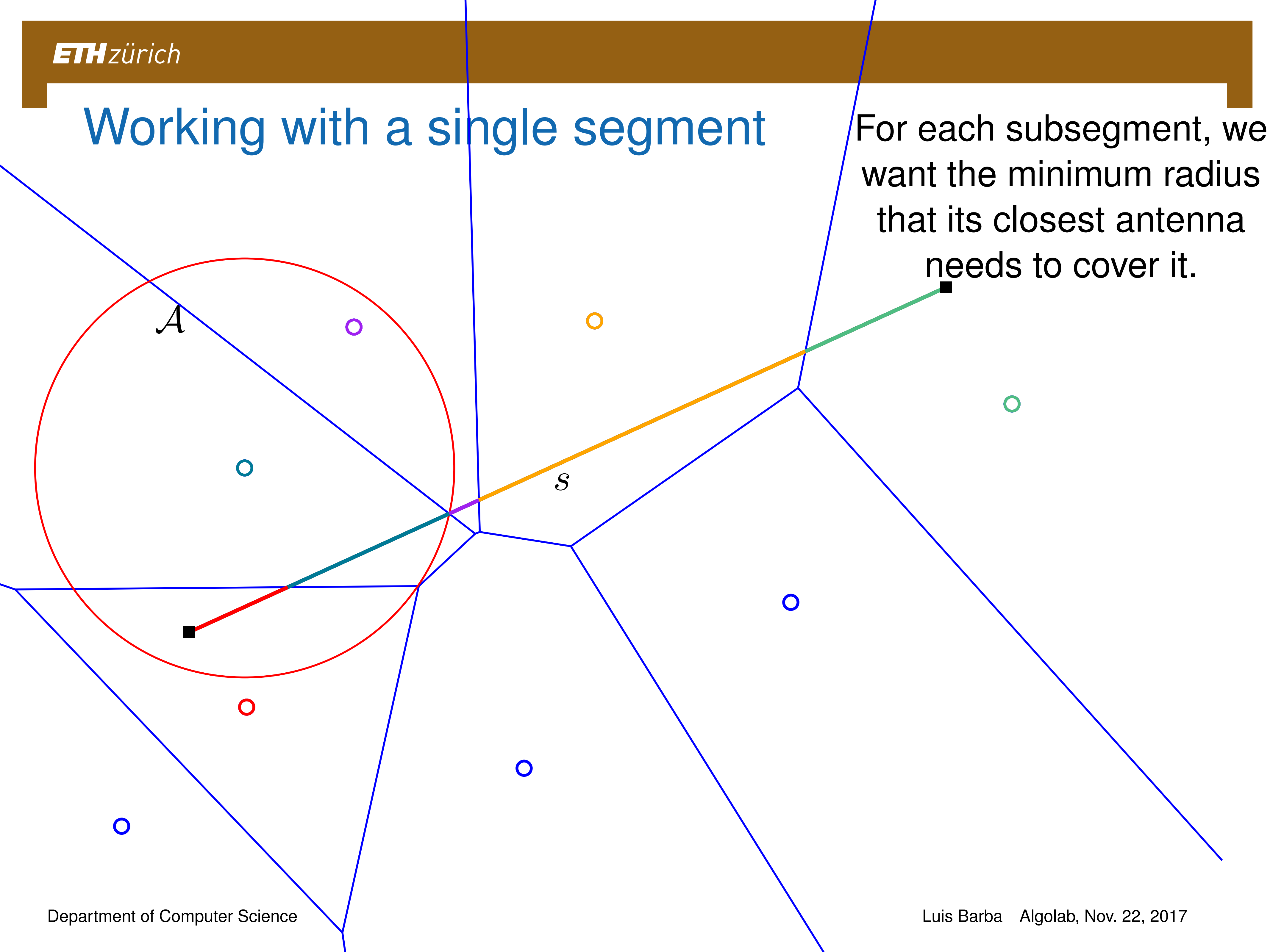

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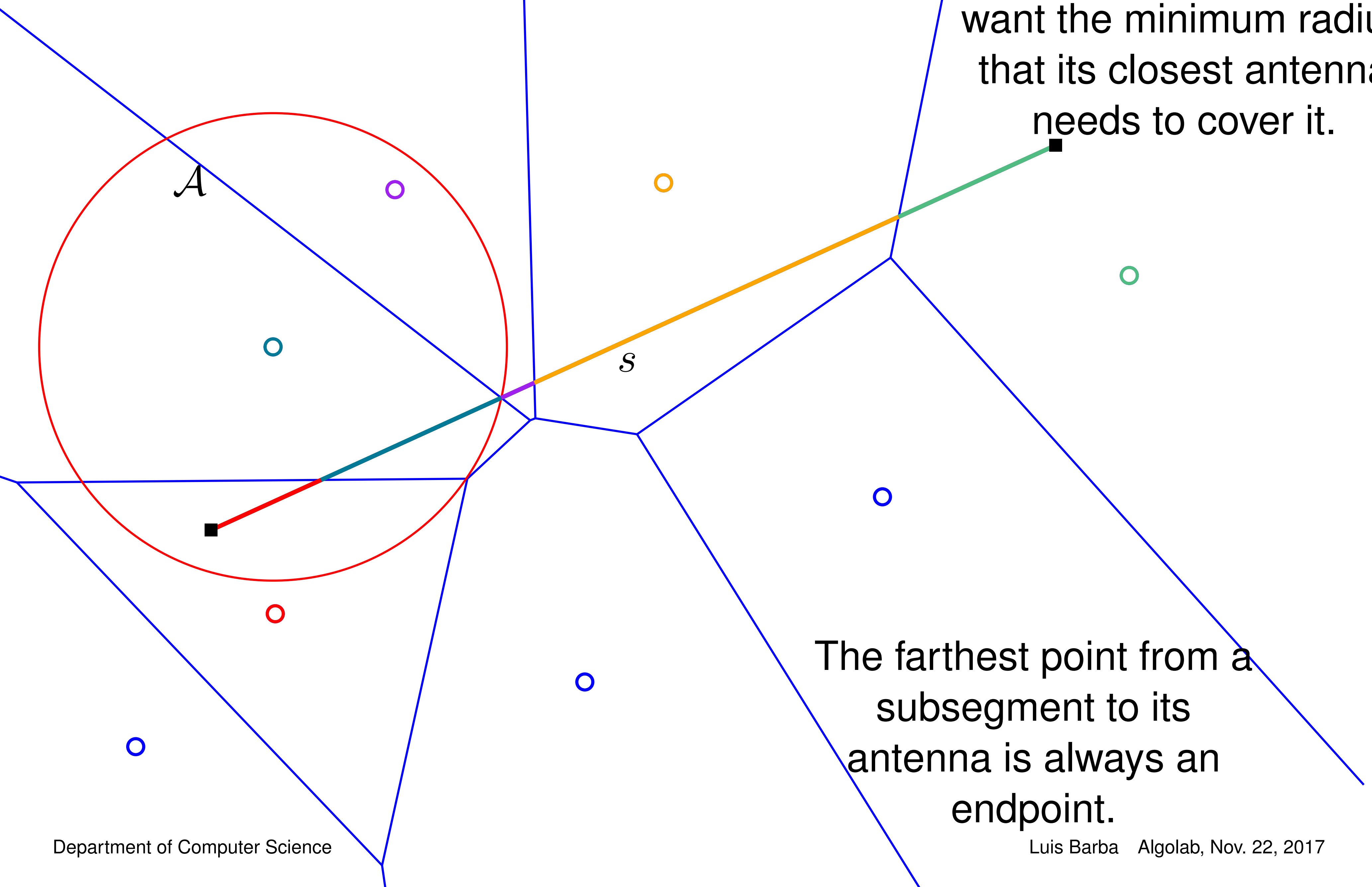

The farthest point from a subsegment to its antenna is always an endpoint.

Working with a single segment

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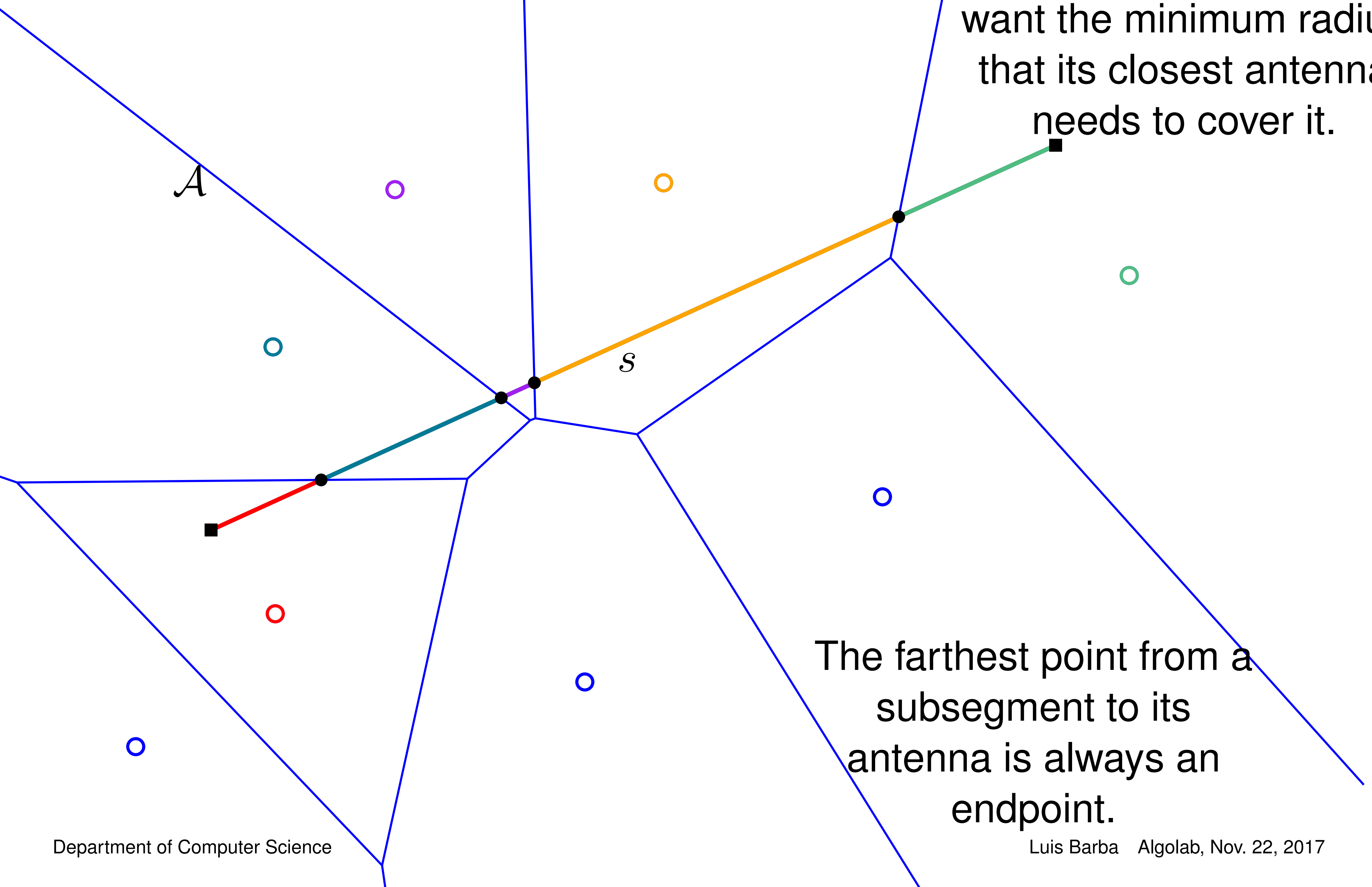

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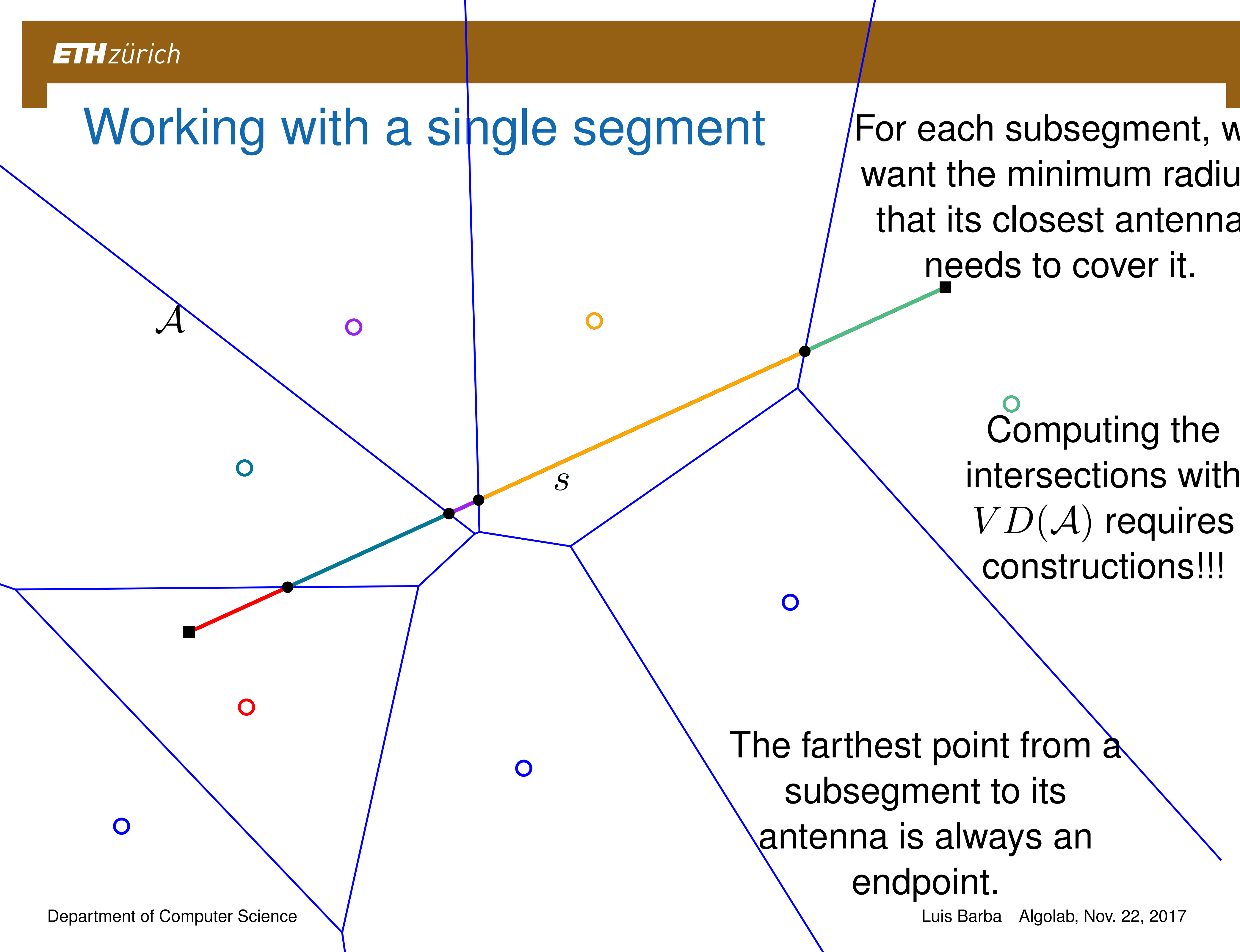

Computing the intersections with $VD(\mathcal{A})$ requires constructions!!!

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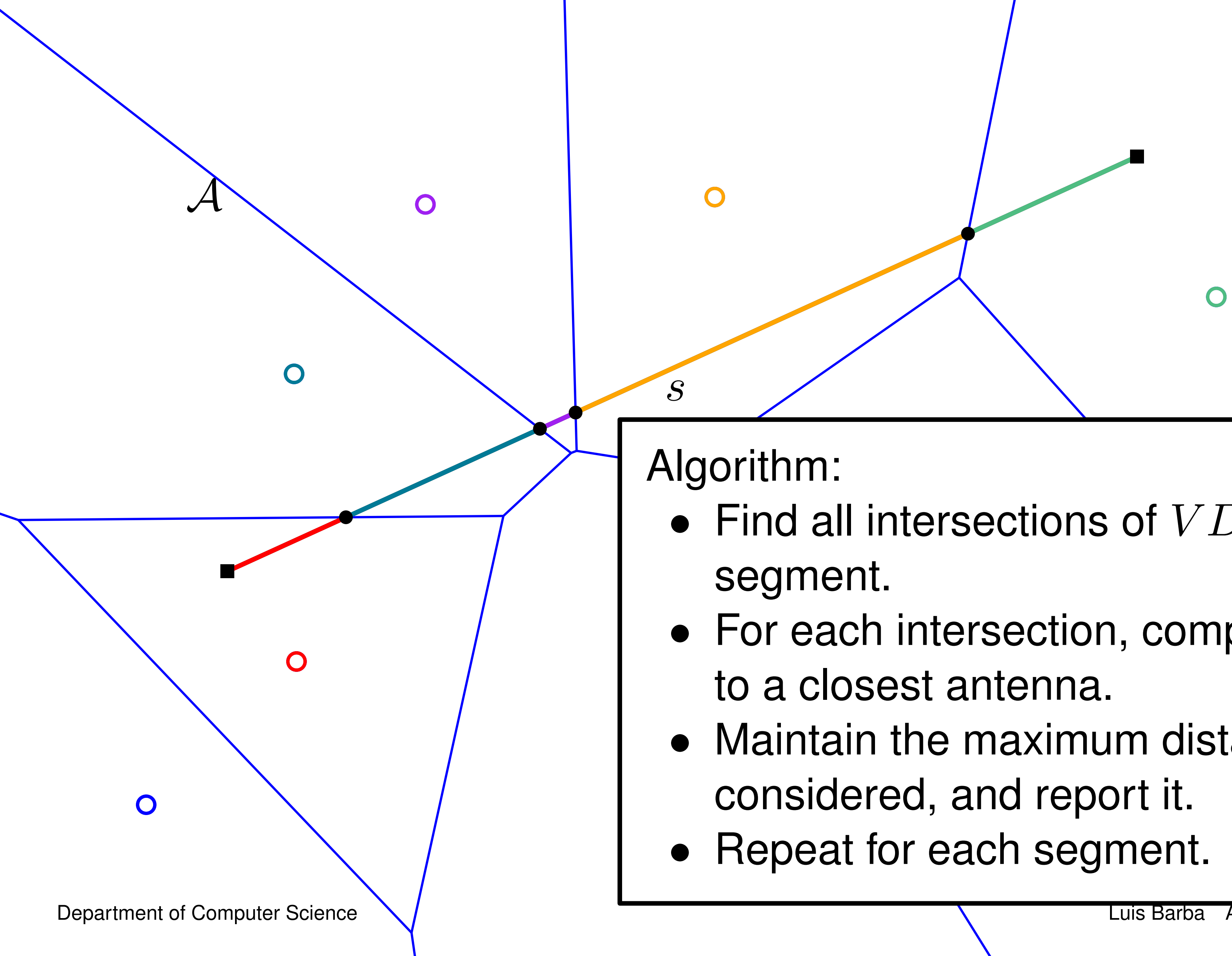
Working with a single segment

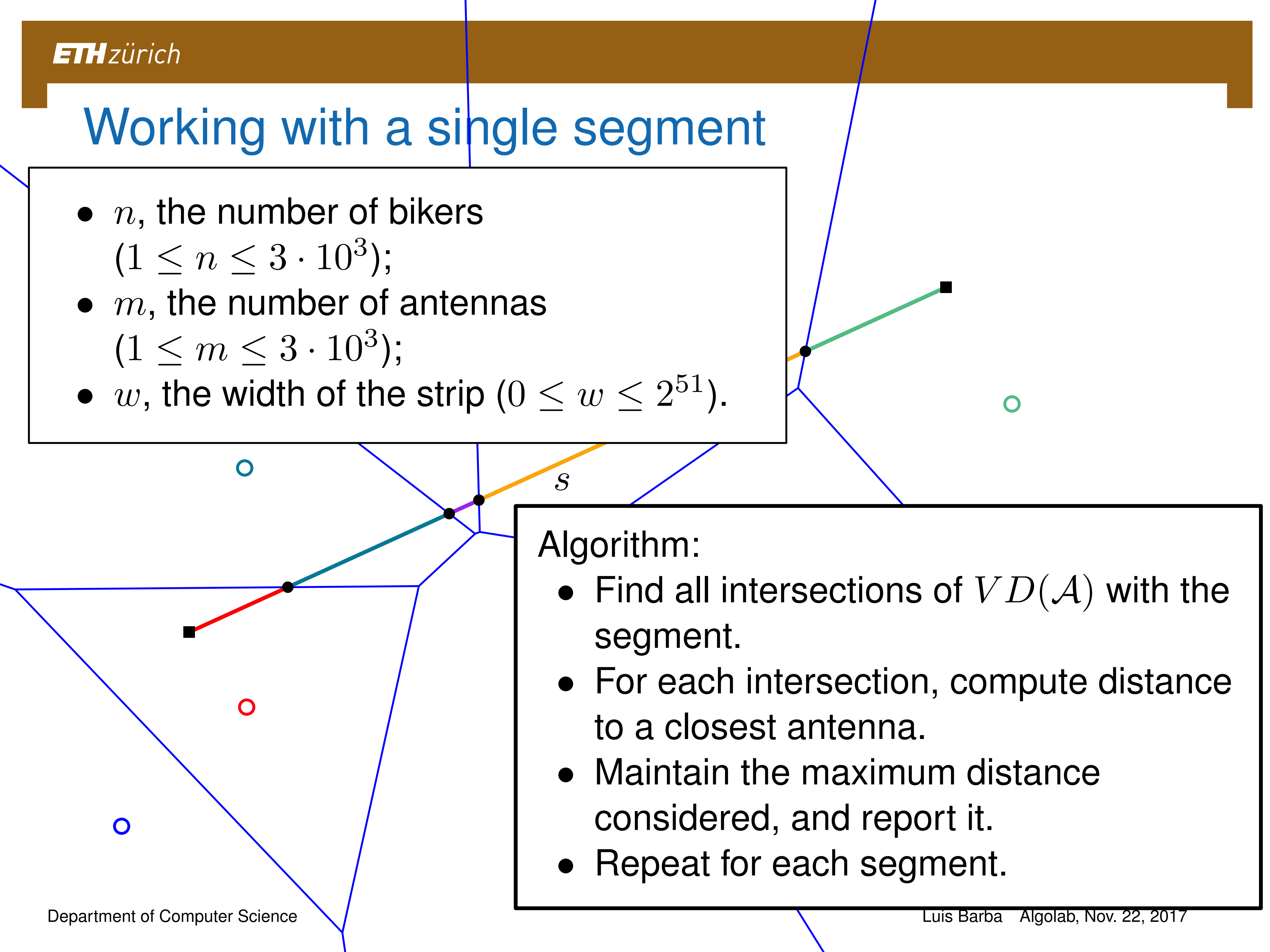


Algorithm:

- Find all intersections of $VD(\mathcal{A})$ with the segment.
- For each intersection, compute distance to a closest antenna.
- Maintain the maximum distance considered, and report it.
- Repeat for each segment.

Working with a single segment

- n, the number of bikers $(1 \leq n \leq 3 \cdot 10^3)$;
- m, the number of antennas $(1 \leq m \leq 3 \cdot 10^3)$;
- w, the width of the strip $(0 \leq w \leq 2^{51})$.



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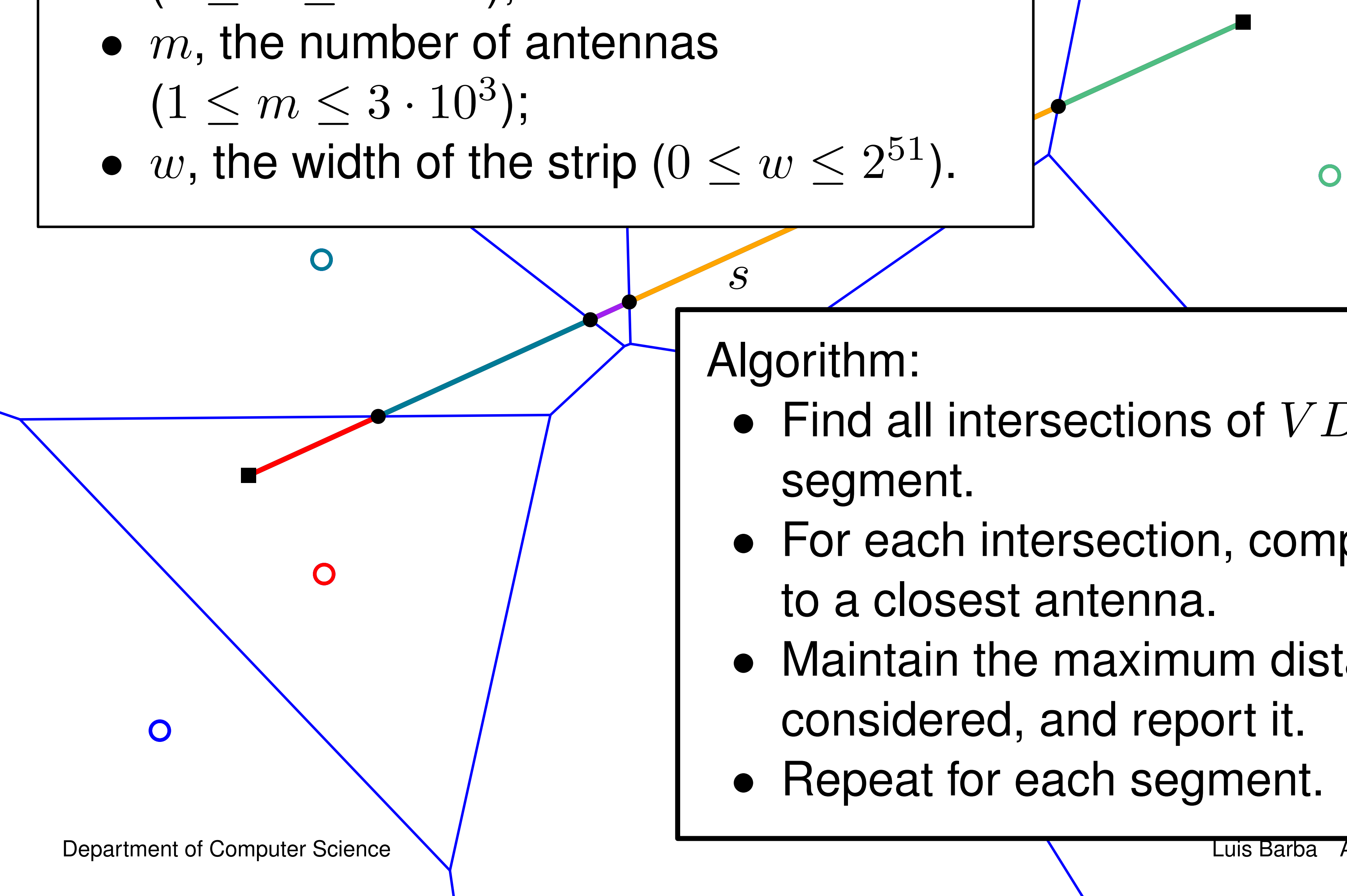
- $O(m \log m)$ time to Compute $VD(\mathcal{A})$.
- $O(m)$ time per segment.
- $O(nm)$ time in total.



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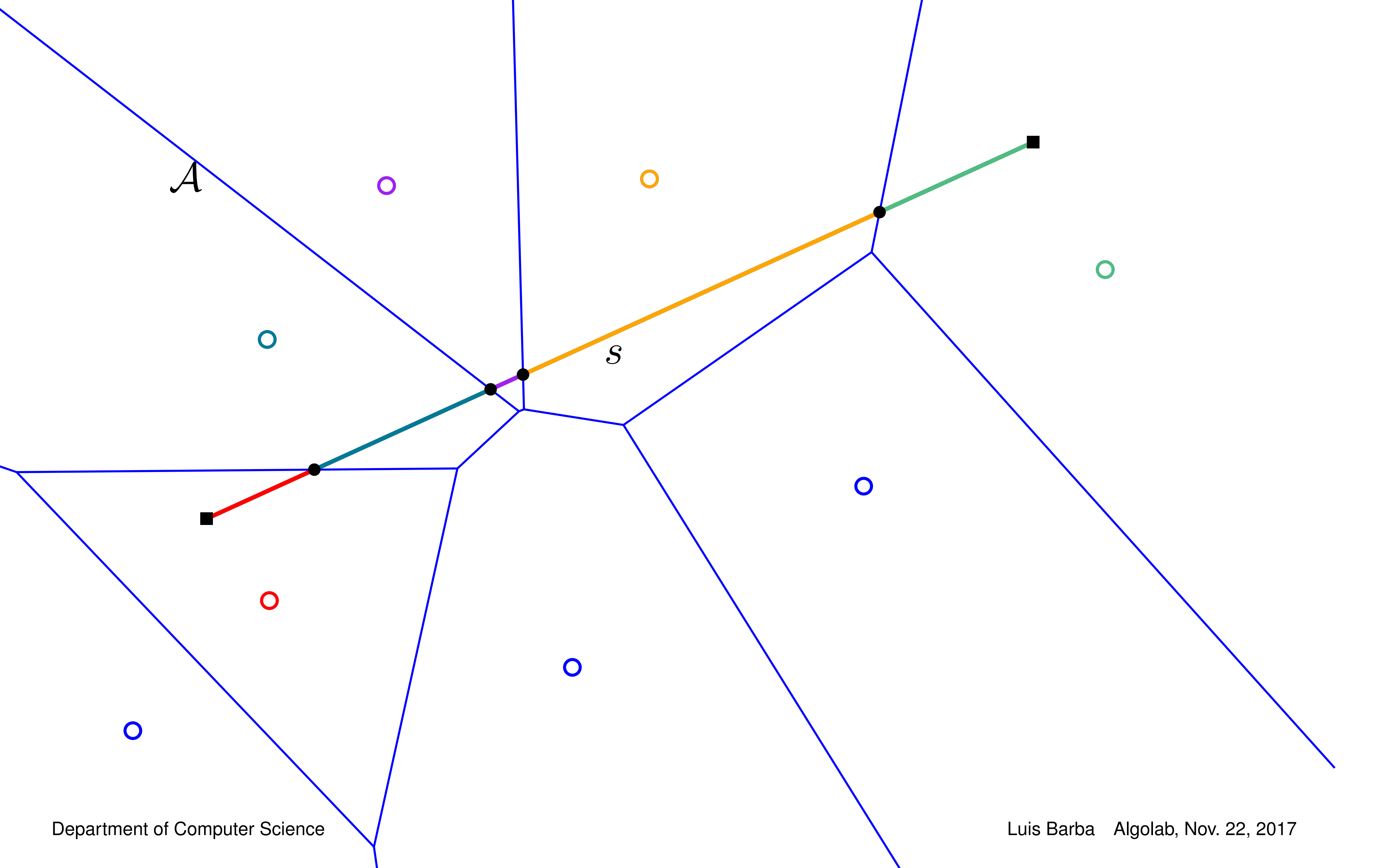
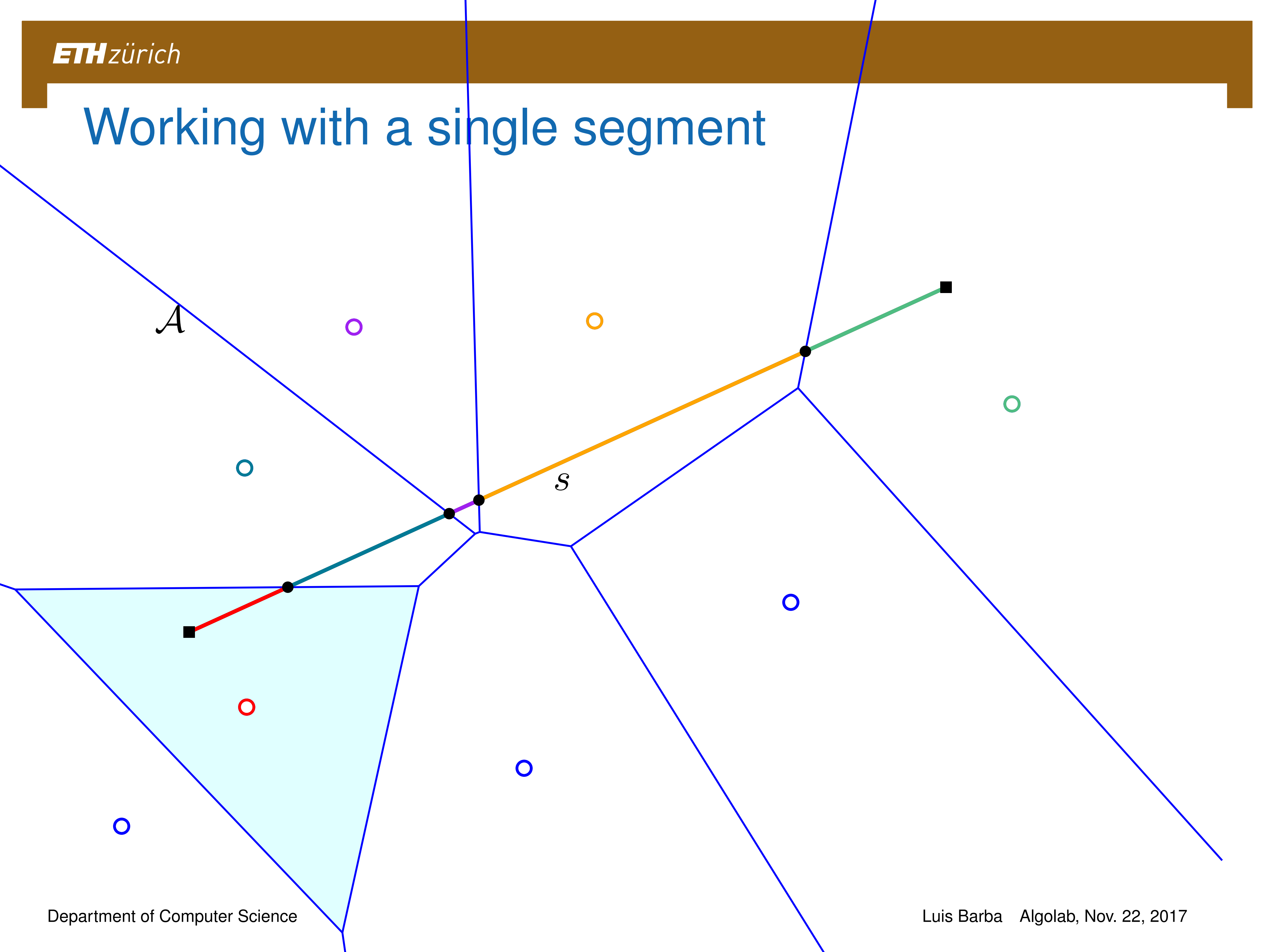


Working with a single segment



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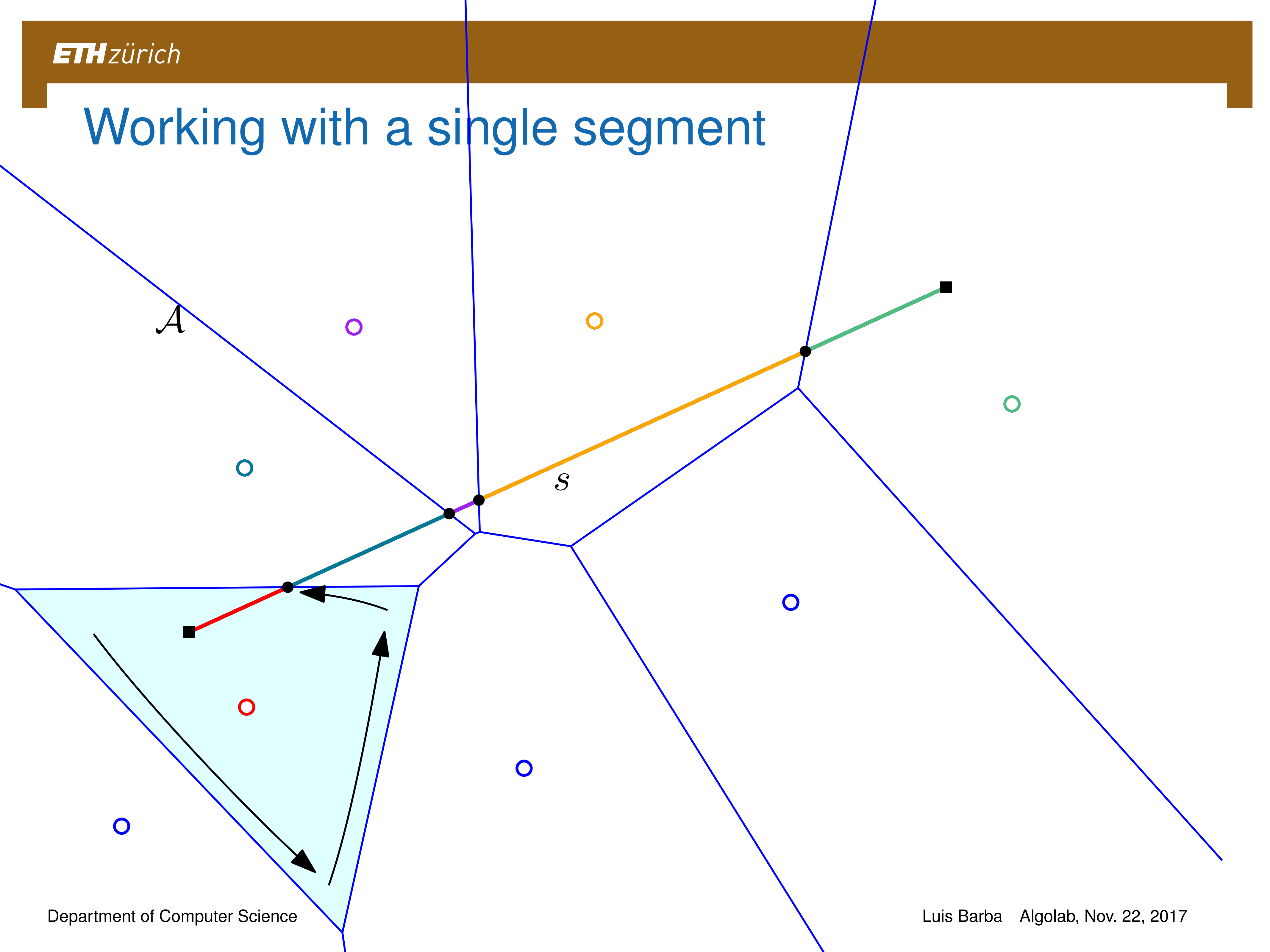

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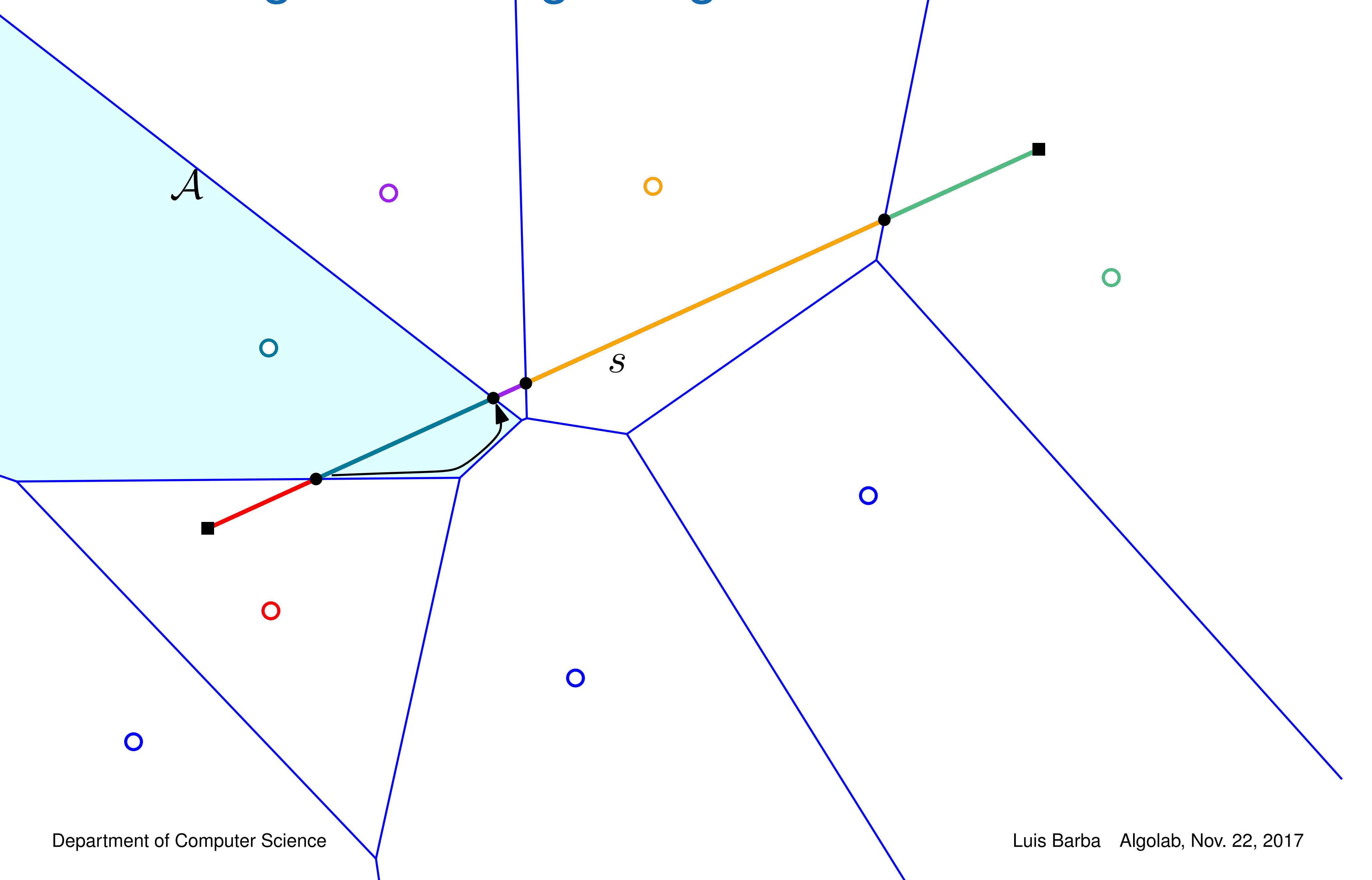

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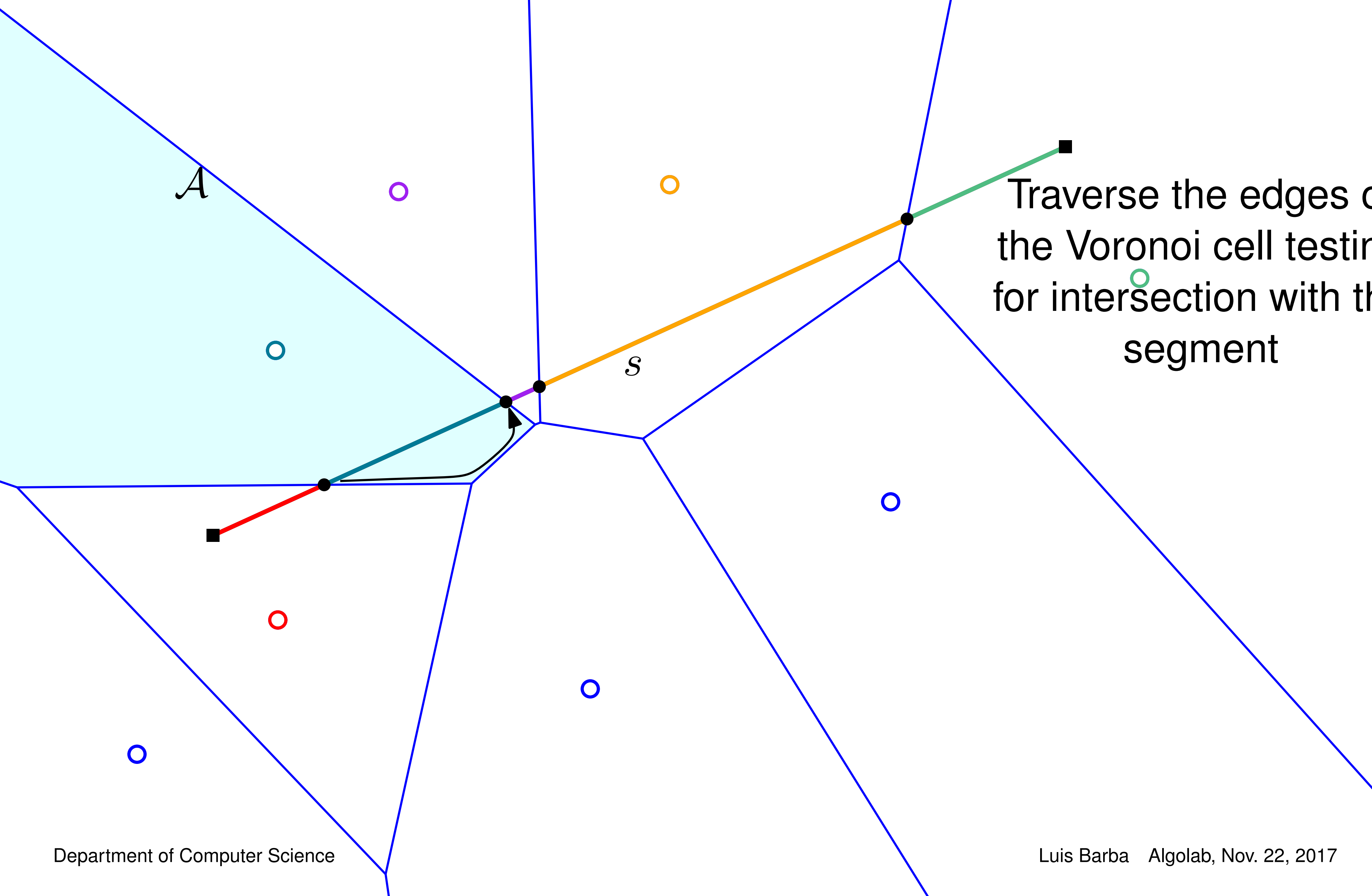
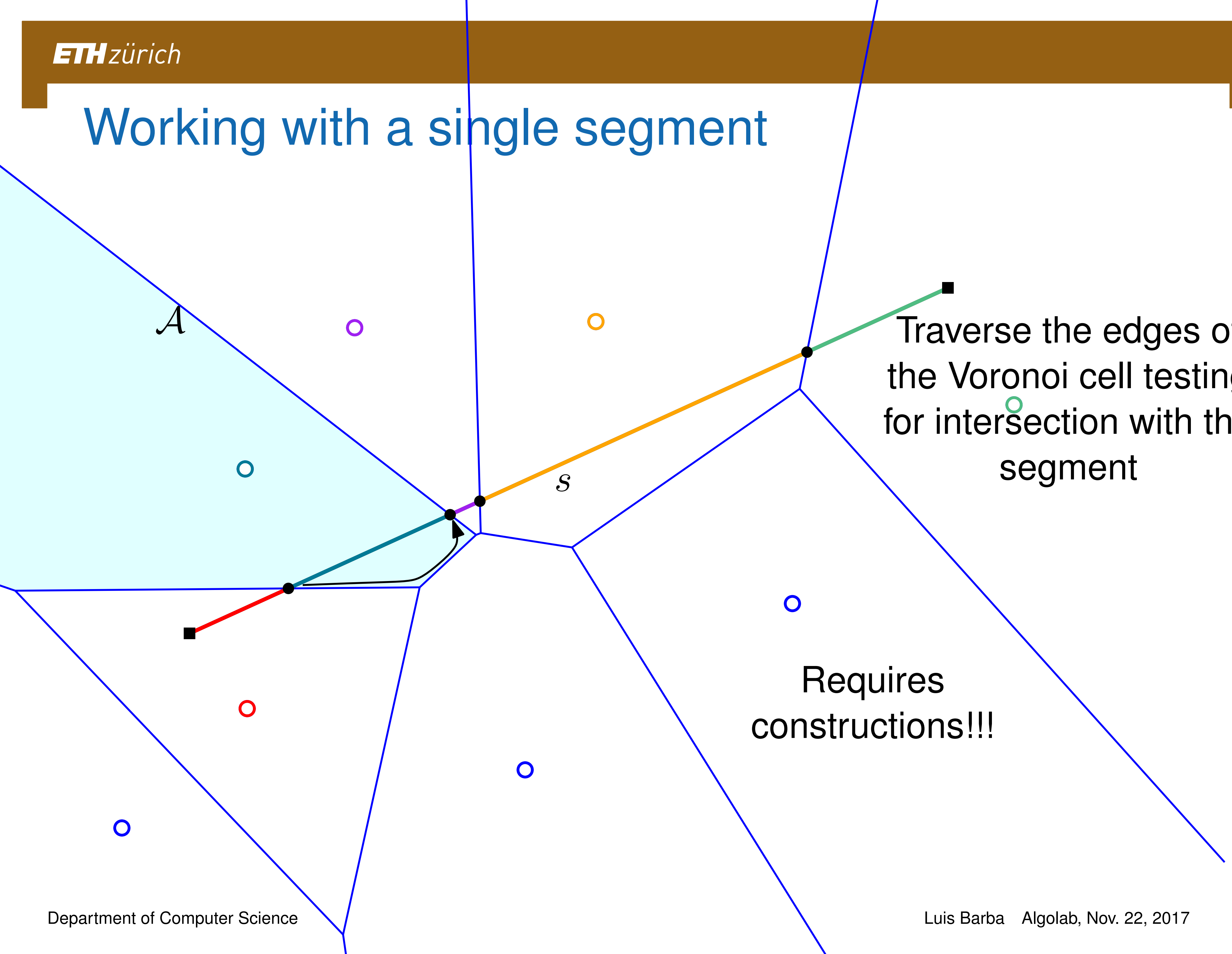


Traverse the edges of the Voronoi cell testing for intersection with the segment

Working with a single segment



Traverse the edges of the Voronoi cell testing for intersection with the segment

Requires constructions!!!

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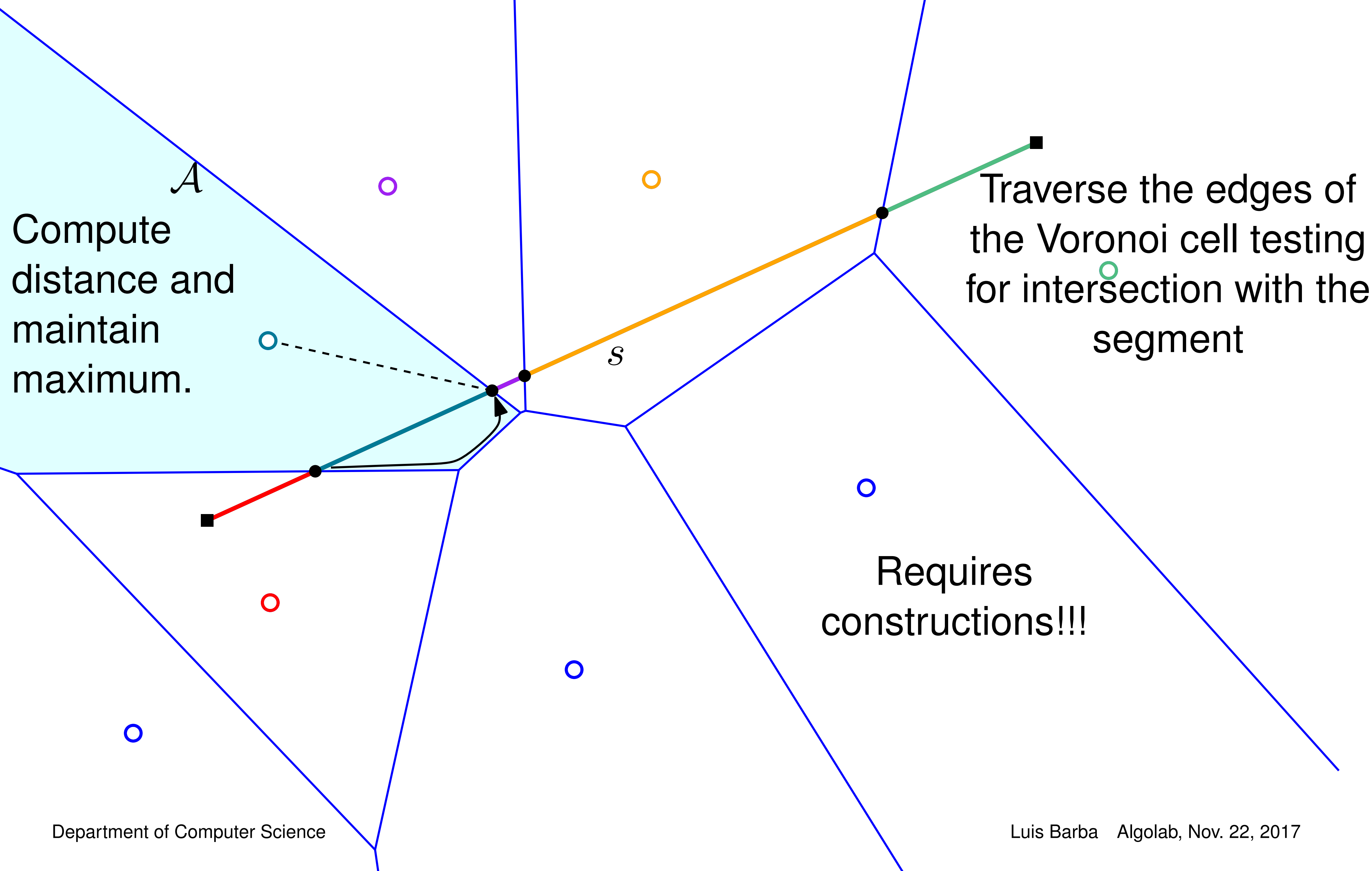
Working with a single segment



Compute distance and maintain maximum.

Traverse the edges of the Voronoi cell testing for intersection with the segment

Requires constructions!!!

Working with a single segment