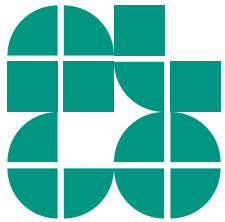
Vorlesung Algorithmische Kartografie

Beschriftung in dynamischen Karten: Rotieren

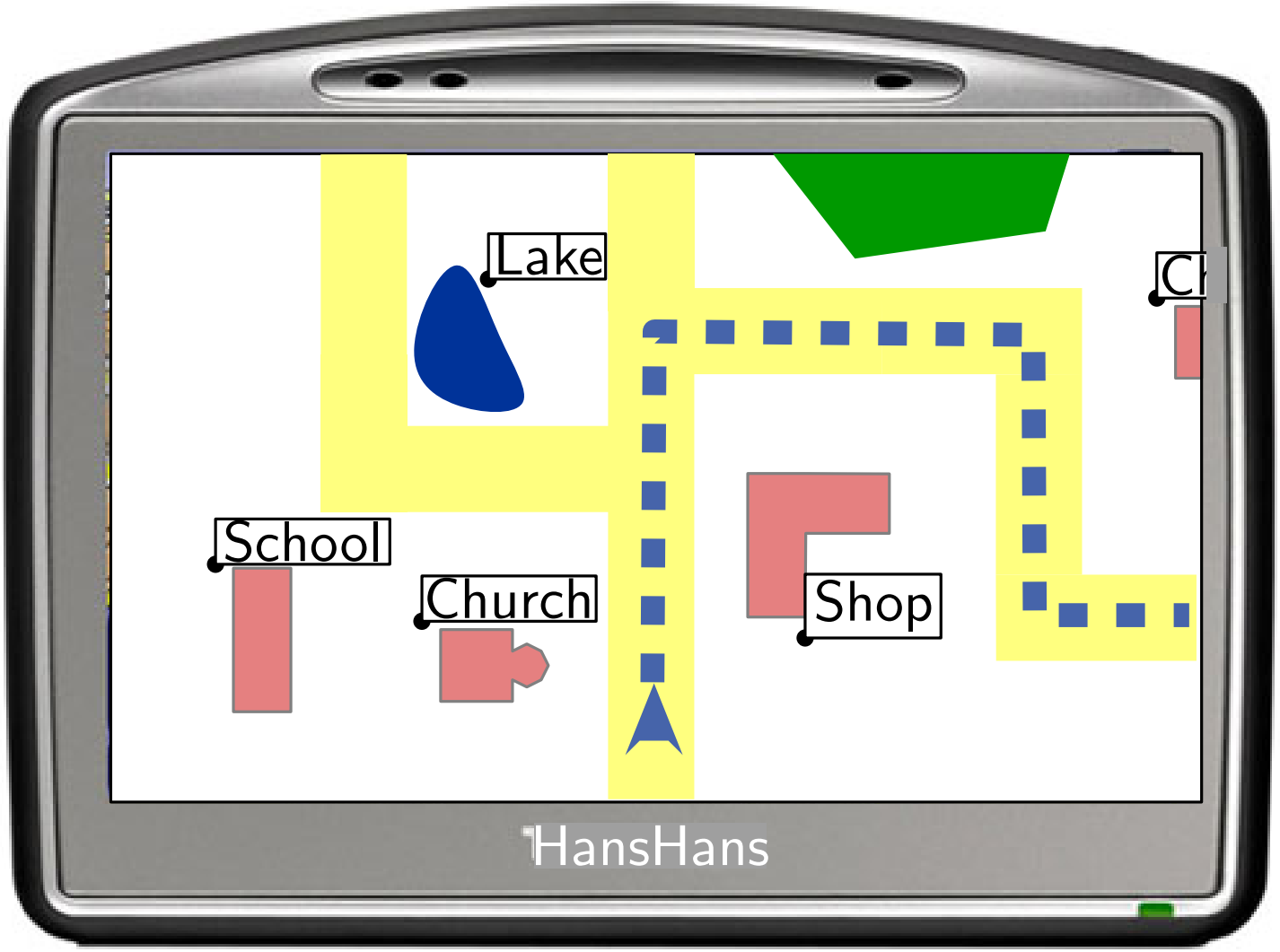
LEHRSTUHL FÜR ALGORITHMIK I · INSTITUT FÜR THEORETISCHE INFORMATIK · FAKULTÄT FÜR INFORMATIK

Andreas Gemsa

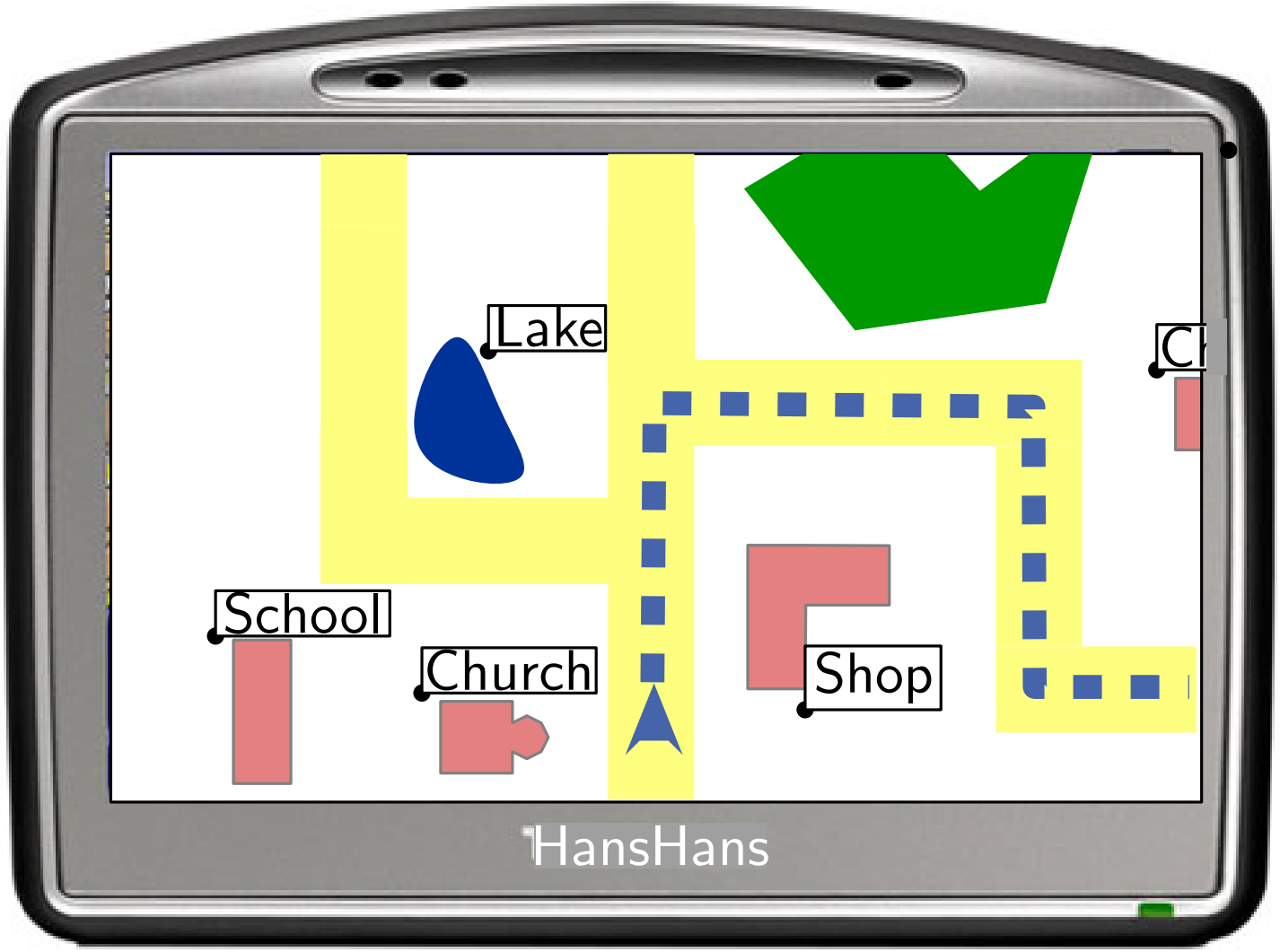
11.06.2013



Motivation



Motivation



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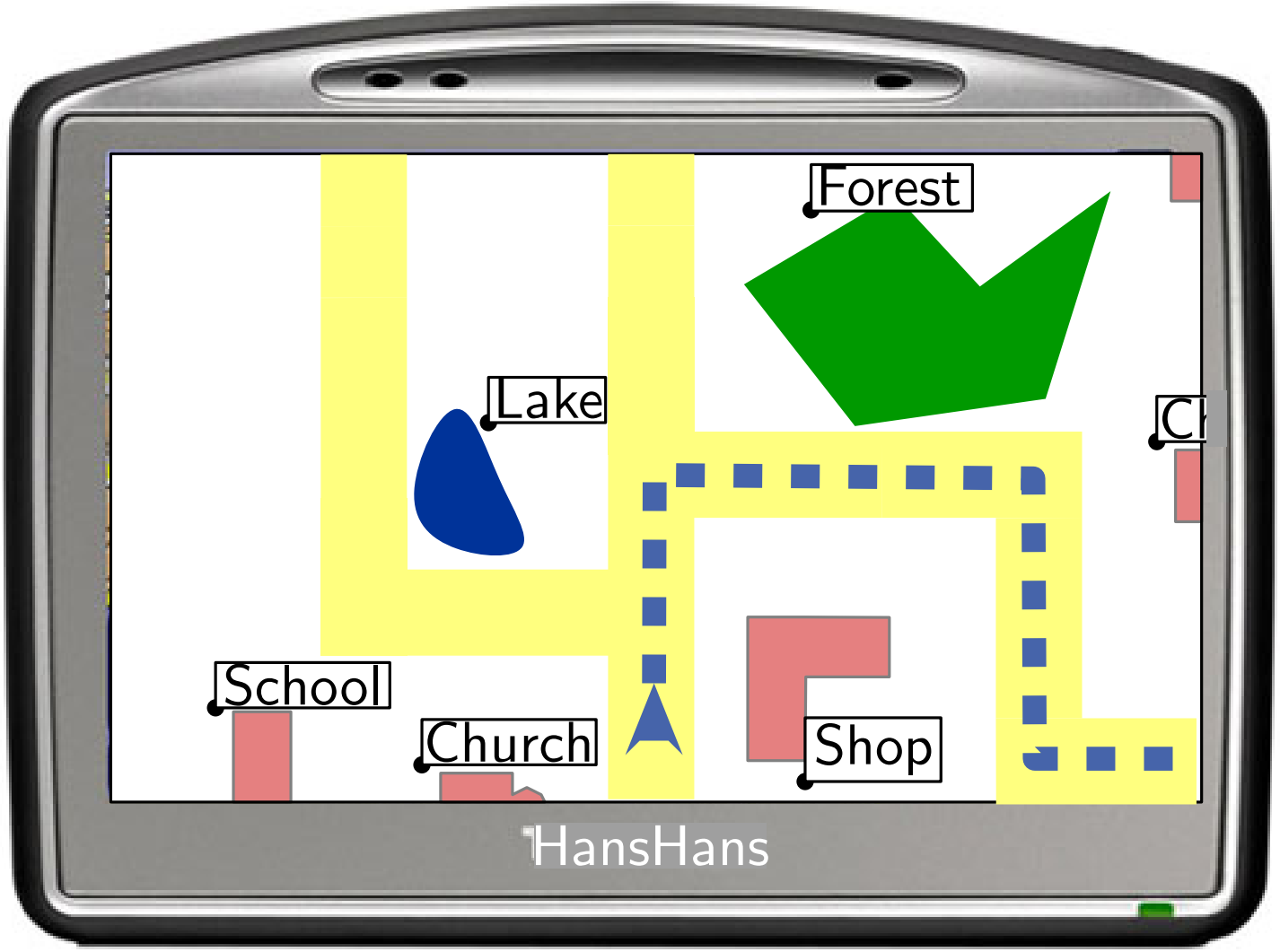
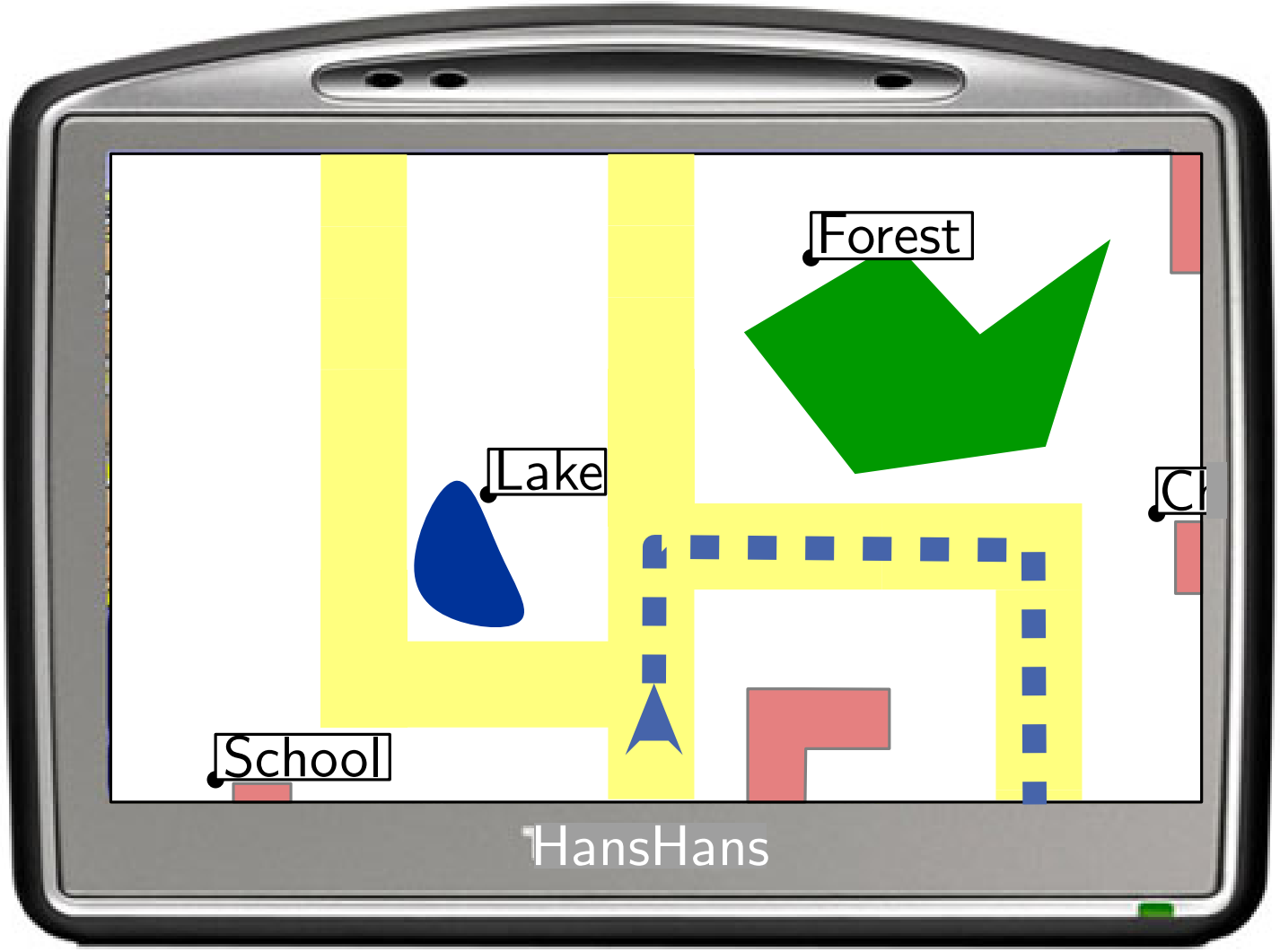
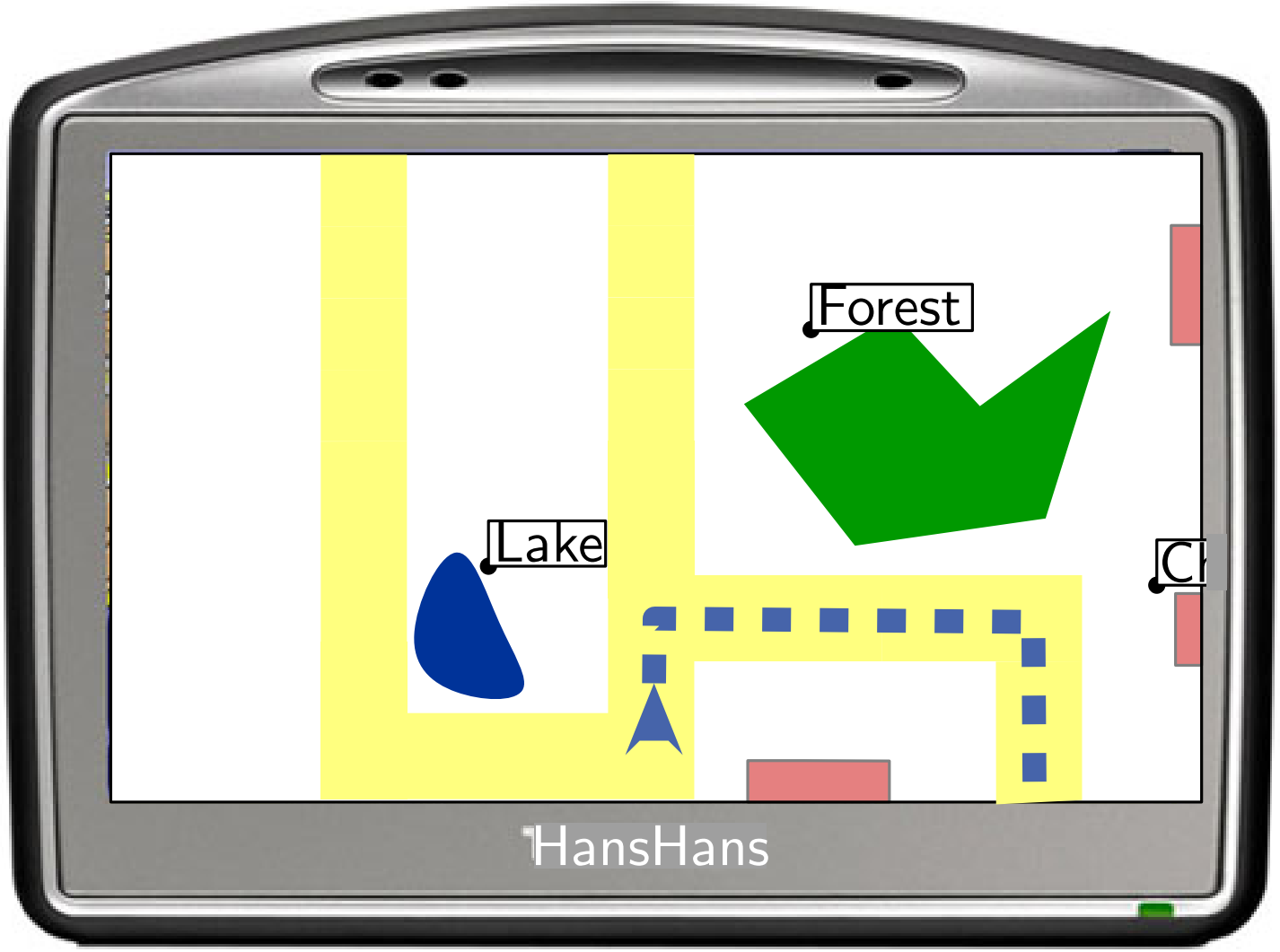


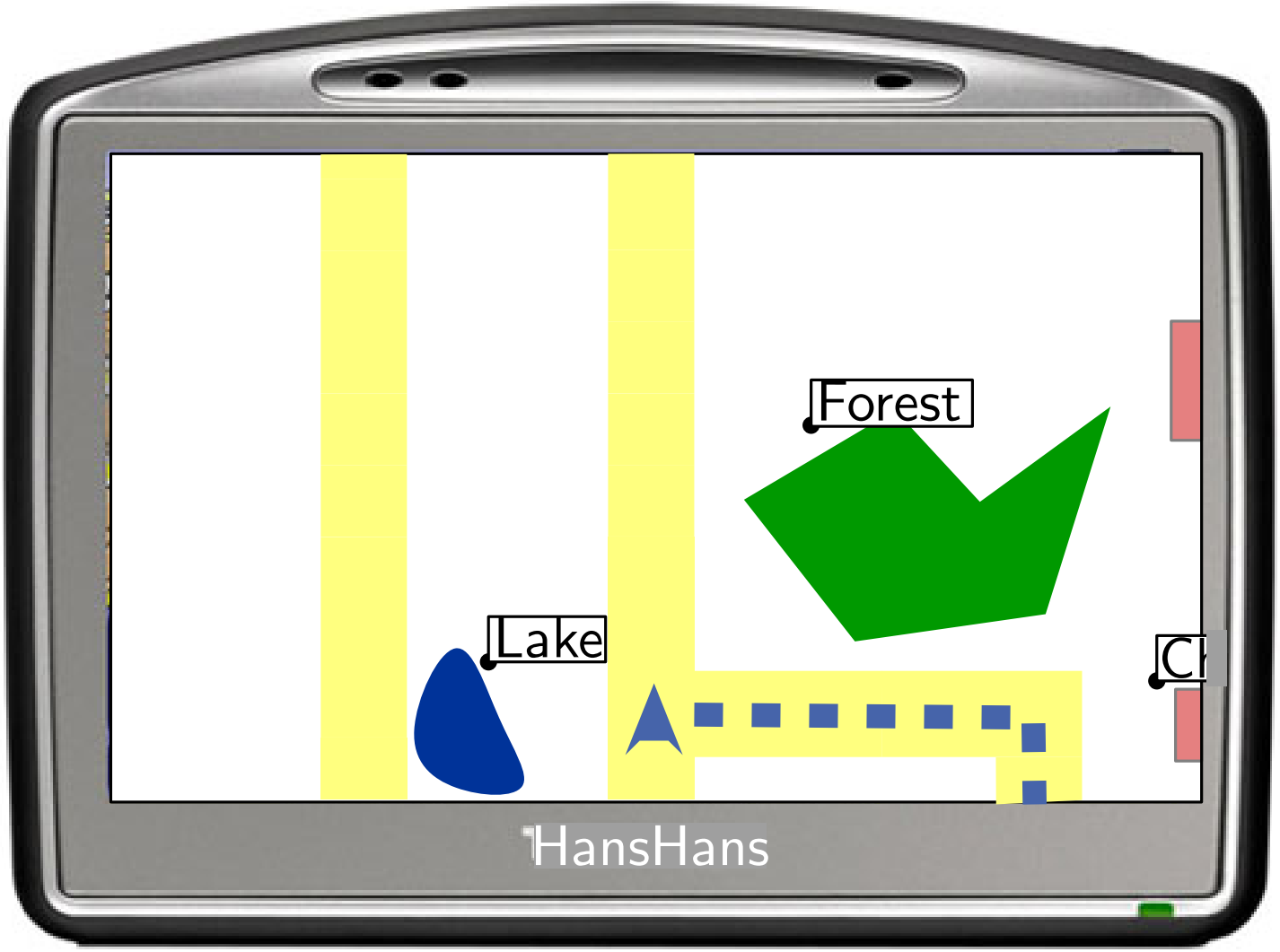
Motivation



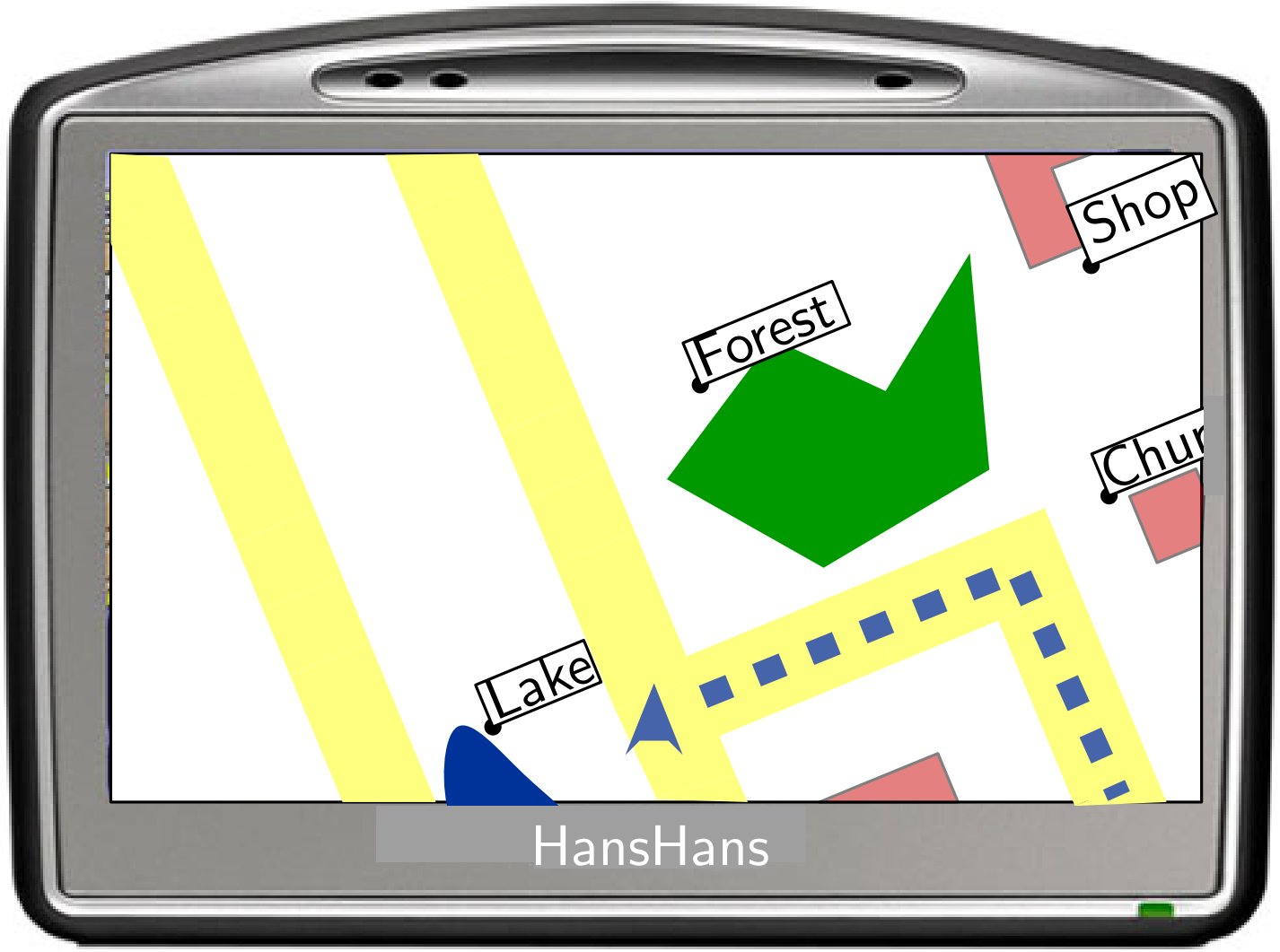
Motivation



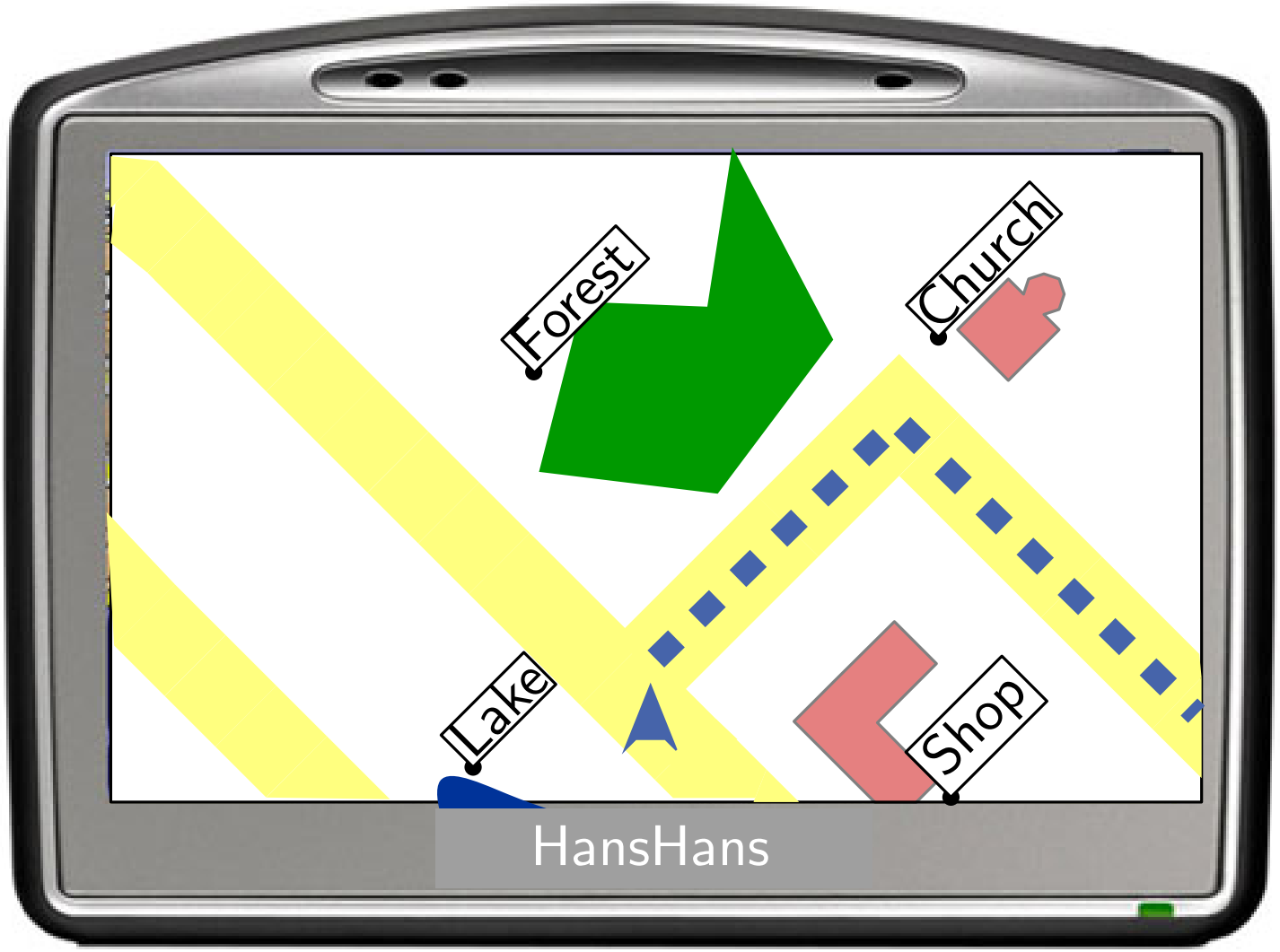
Motivation



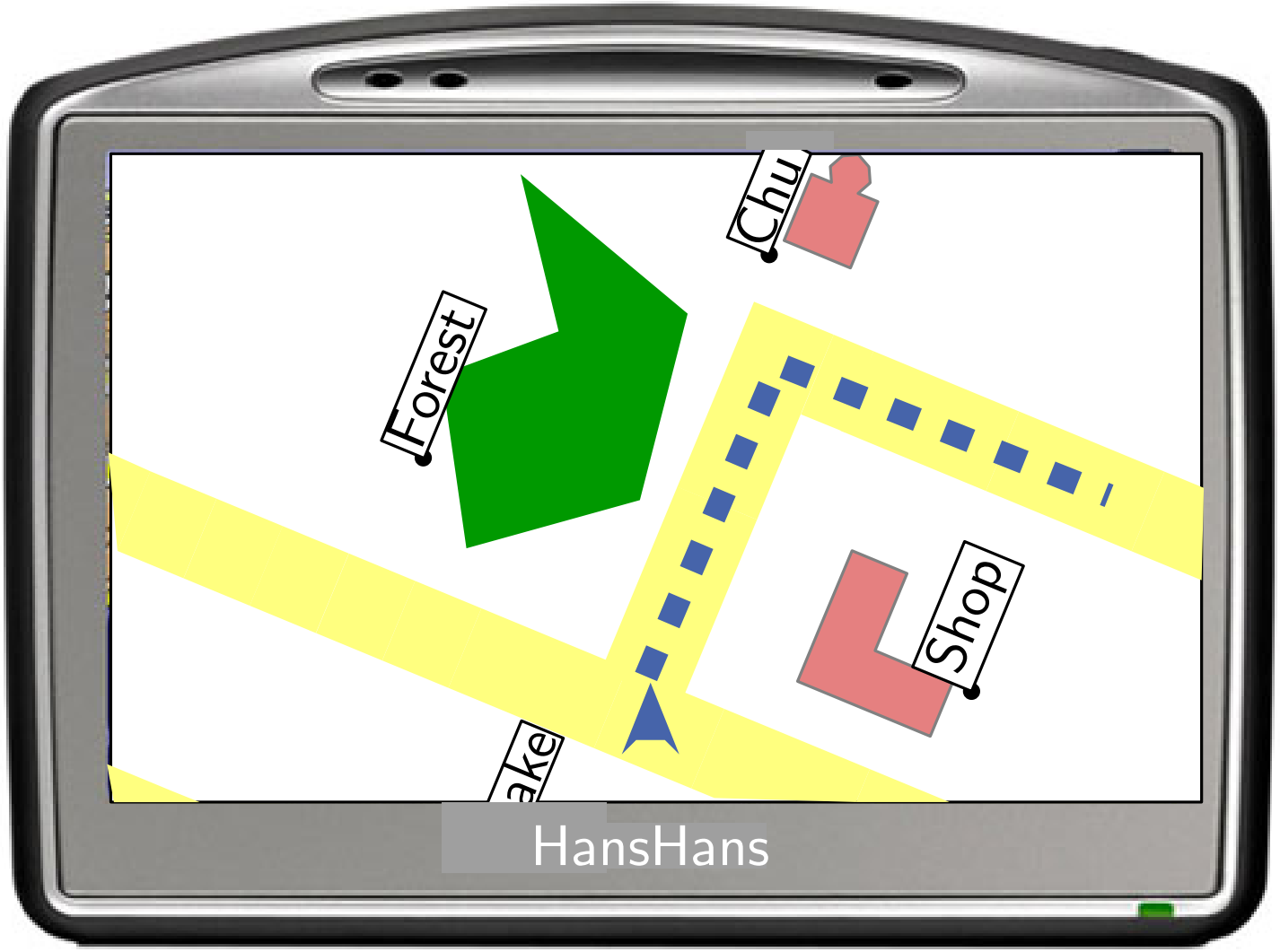
Motivation



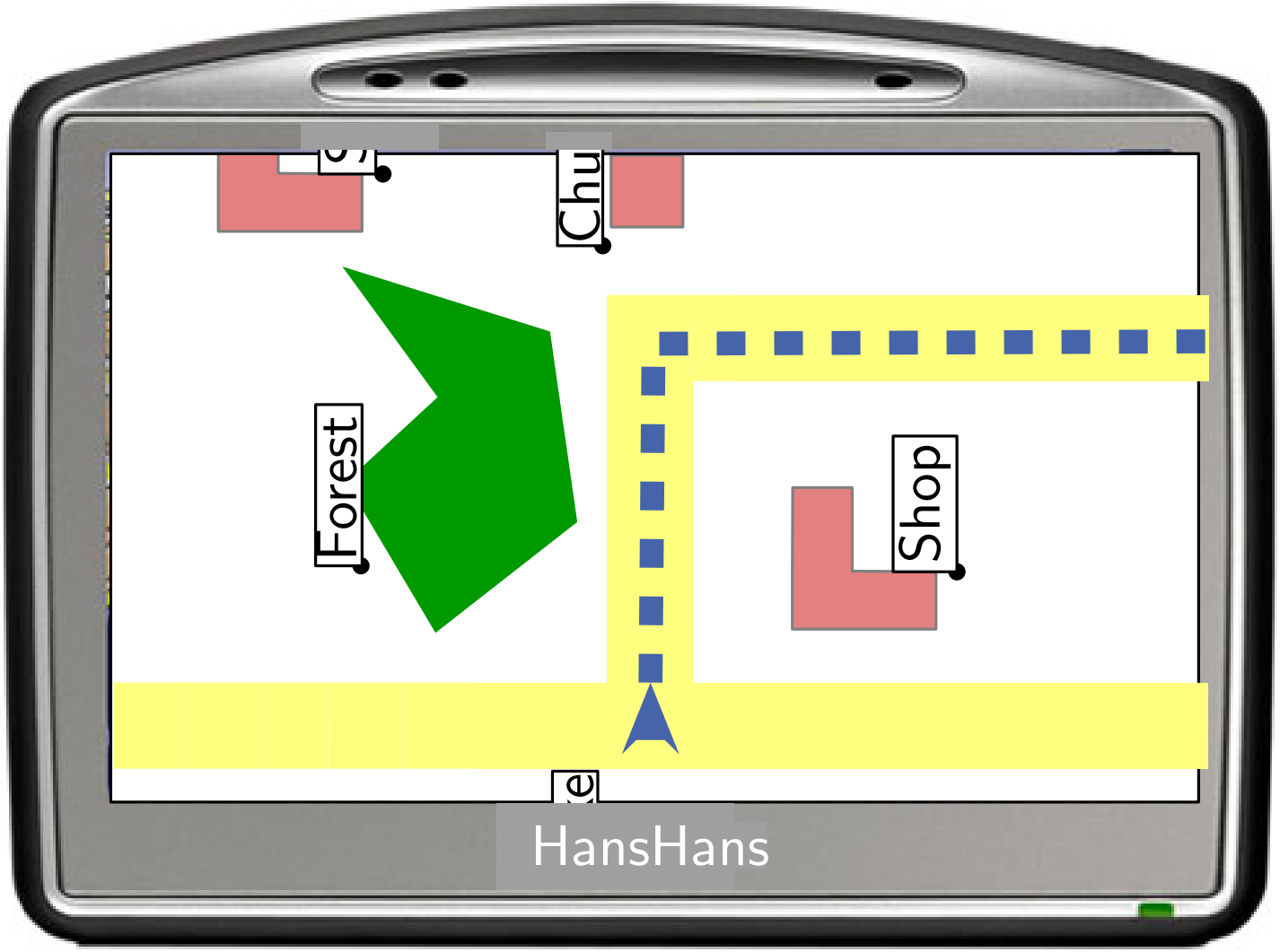
Motivation



Motivation



Motivation



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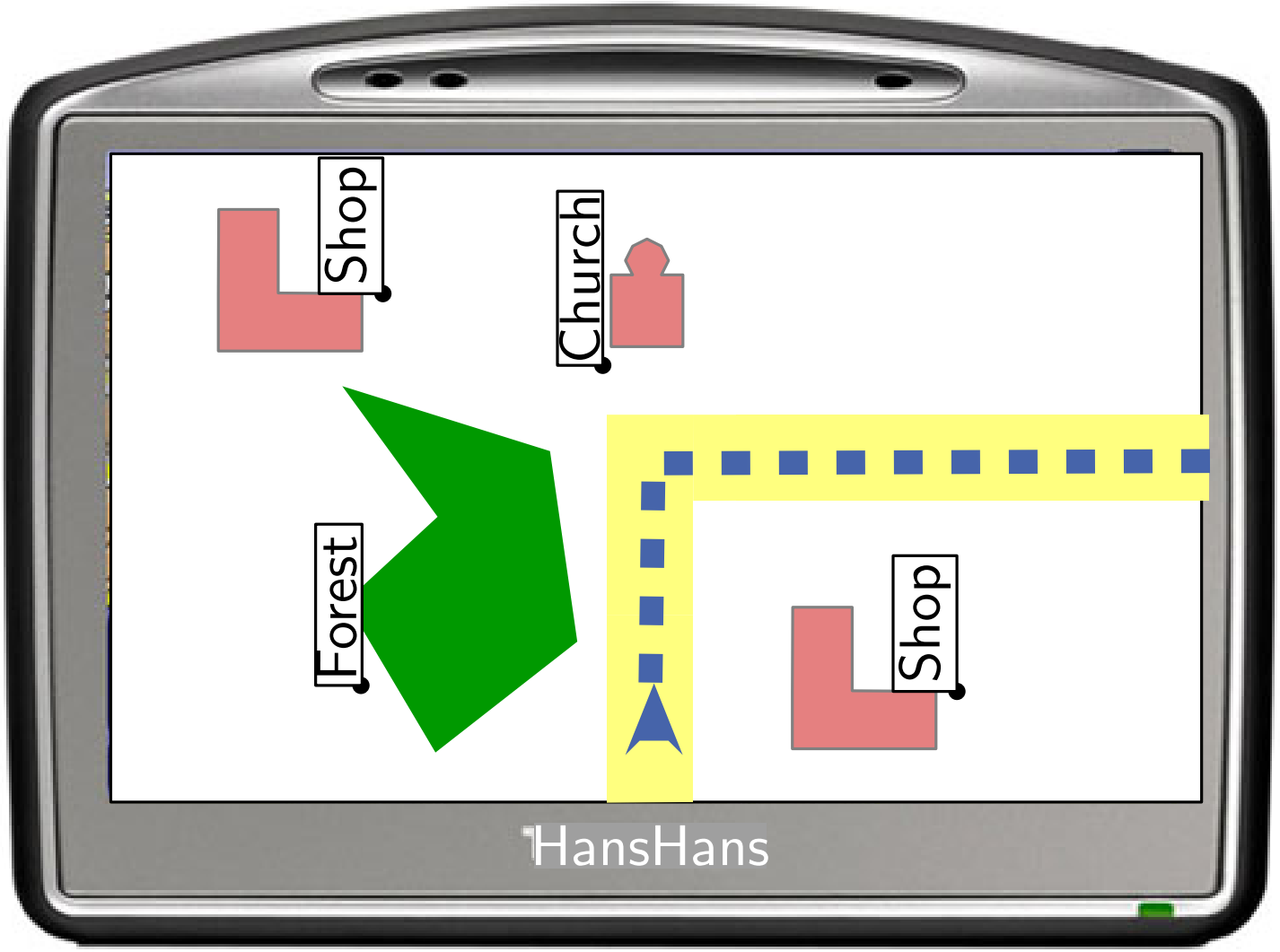

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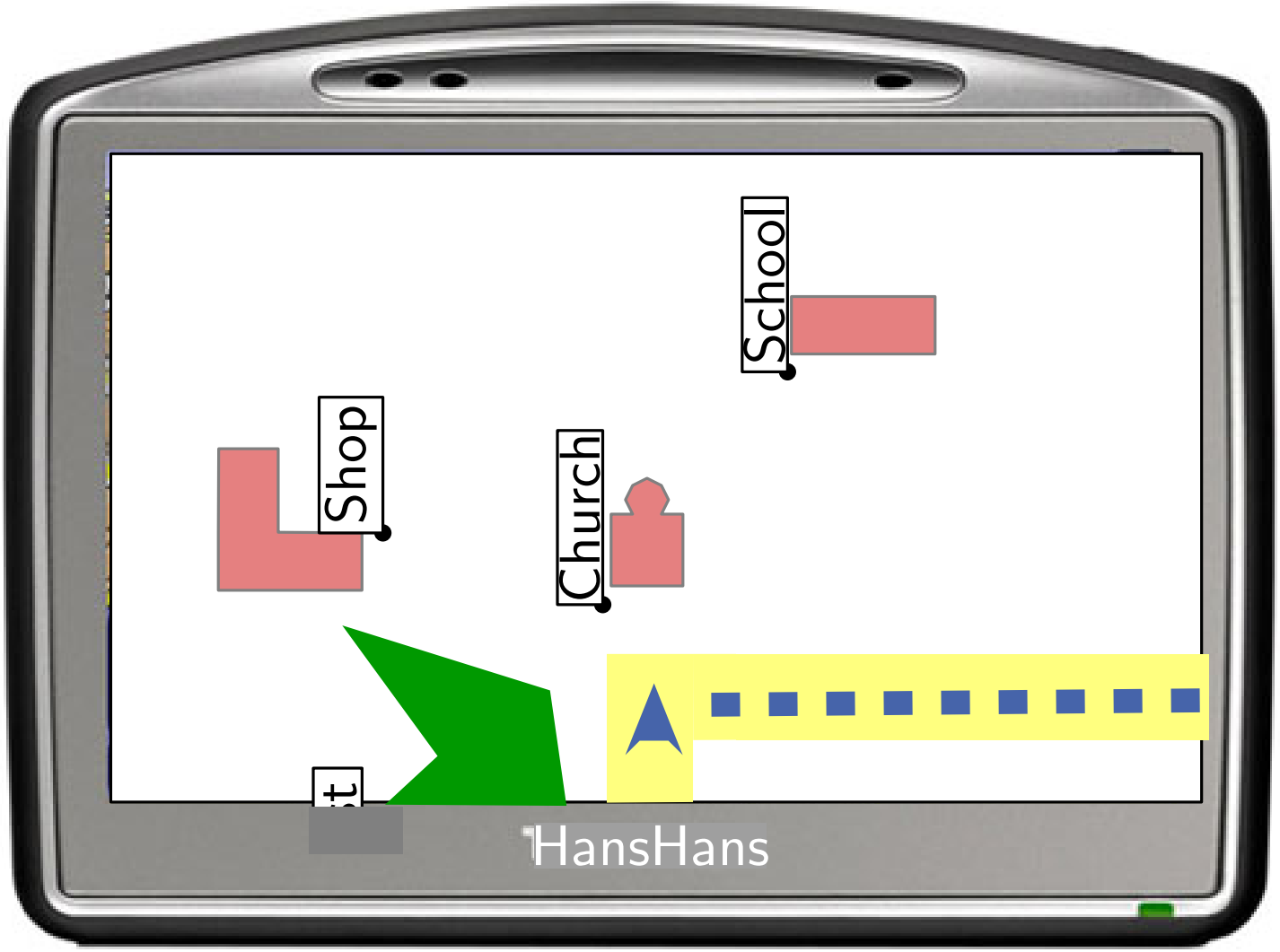

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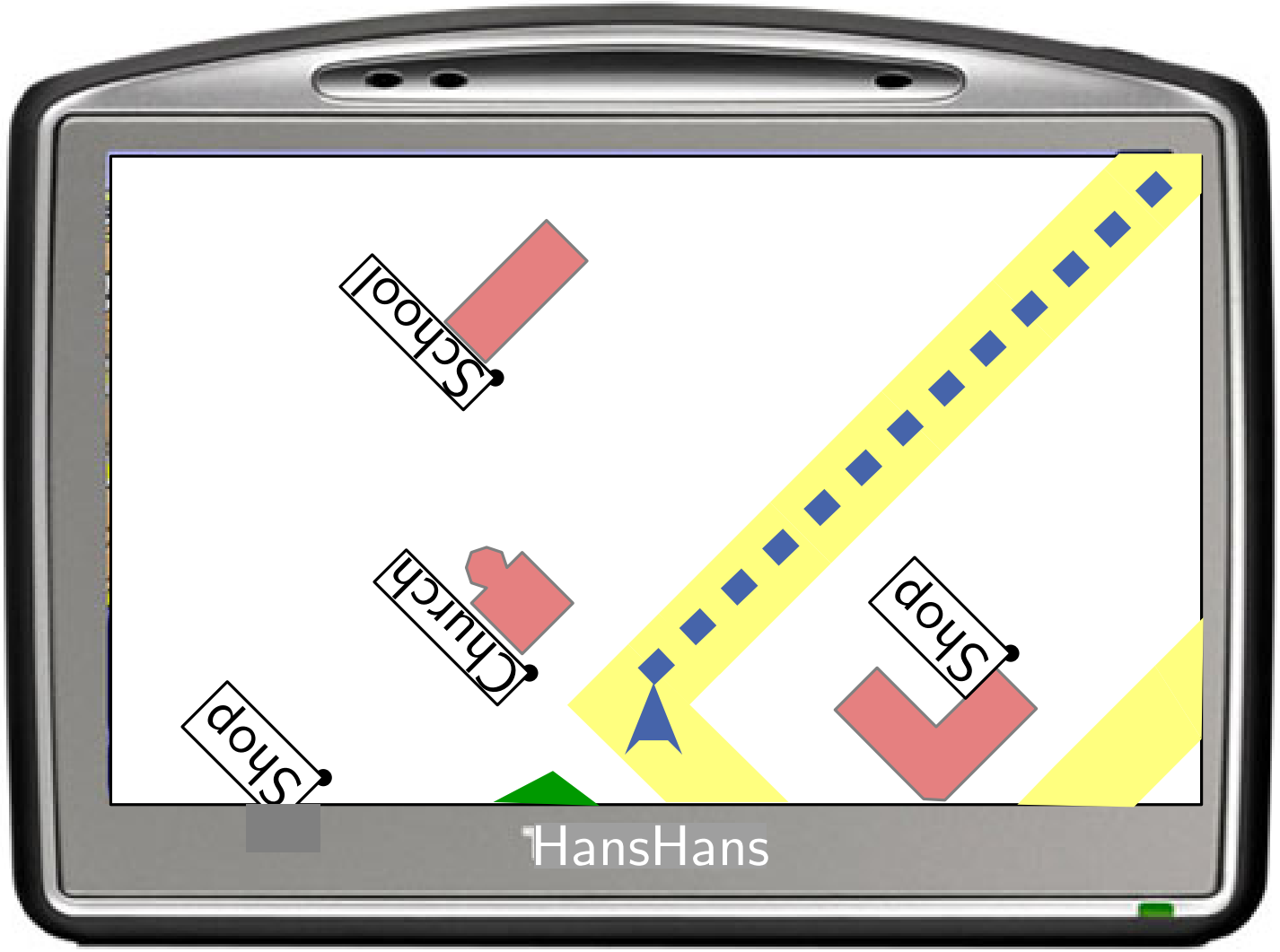

Motivation

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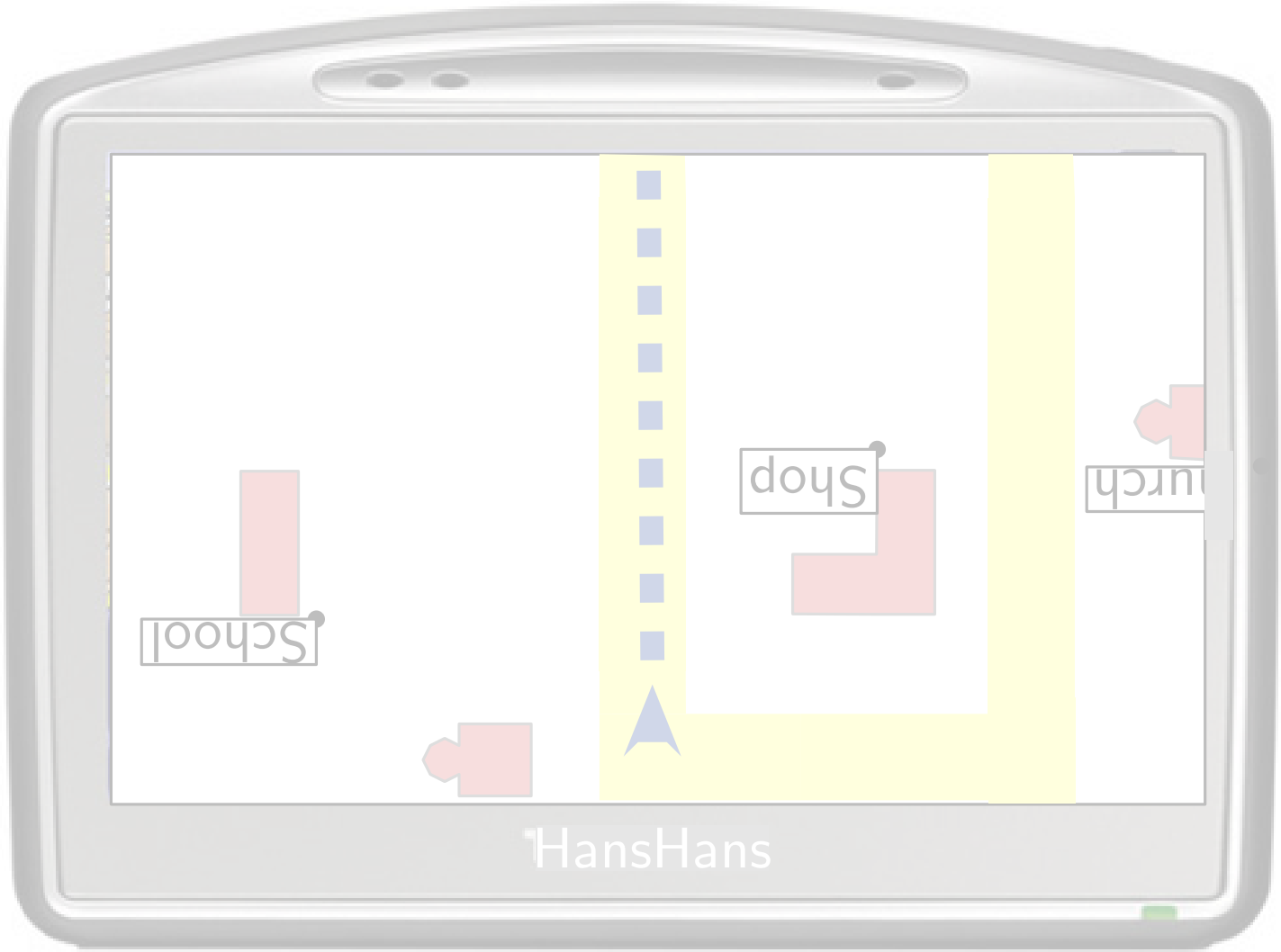

Motivation

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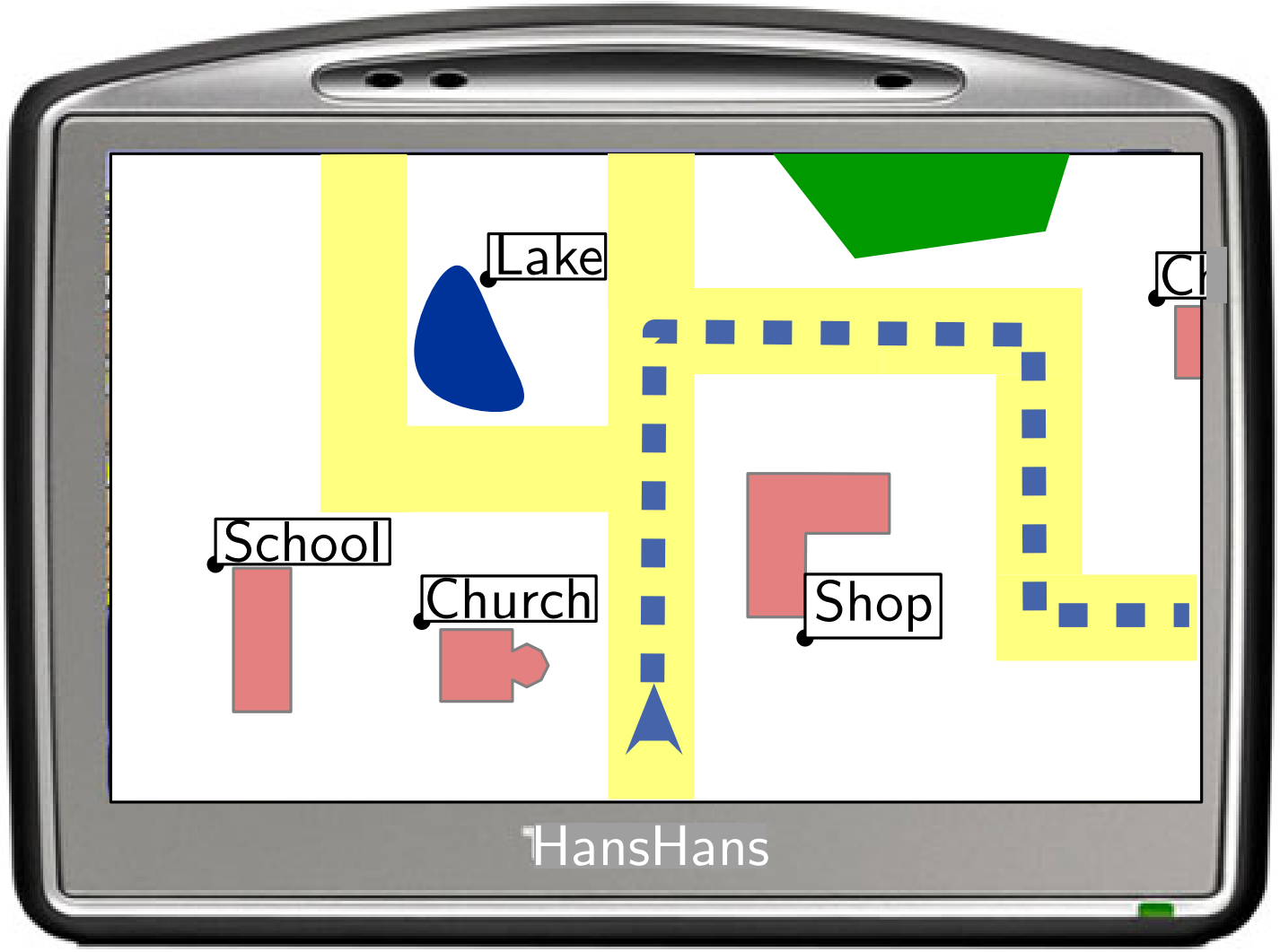
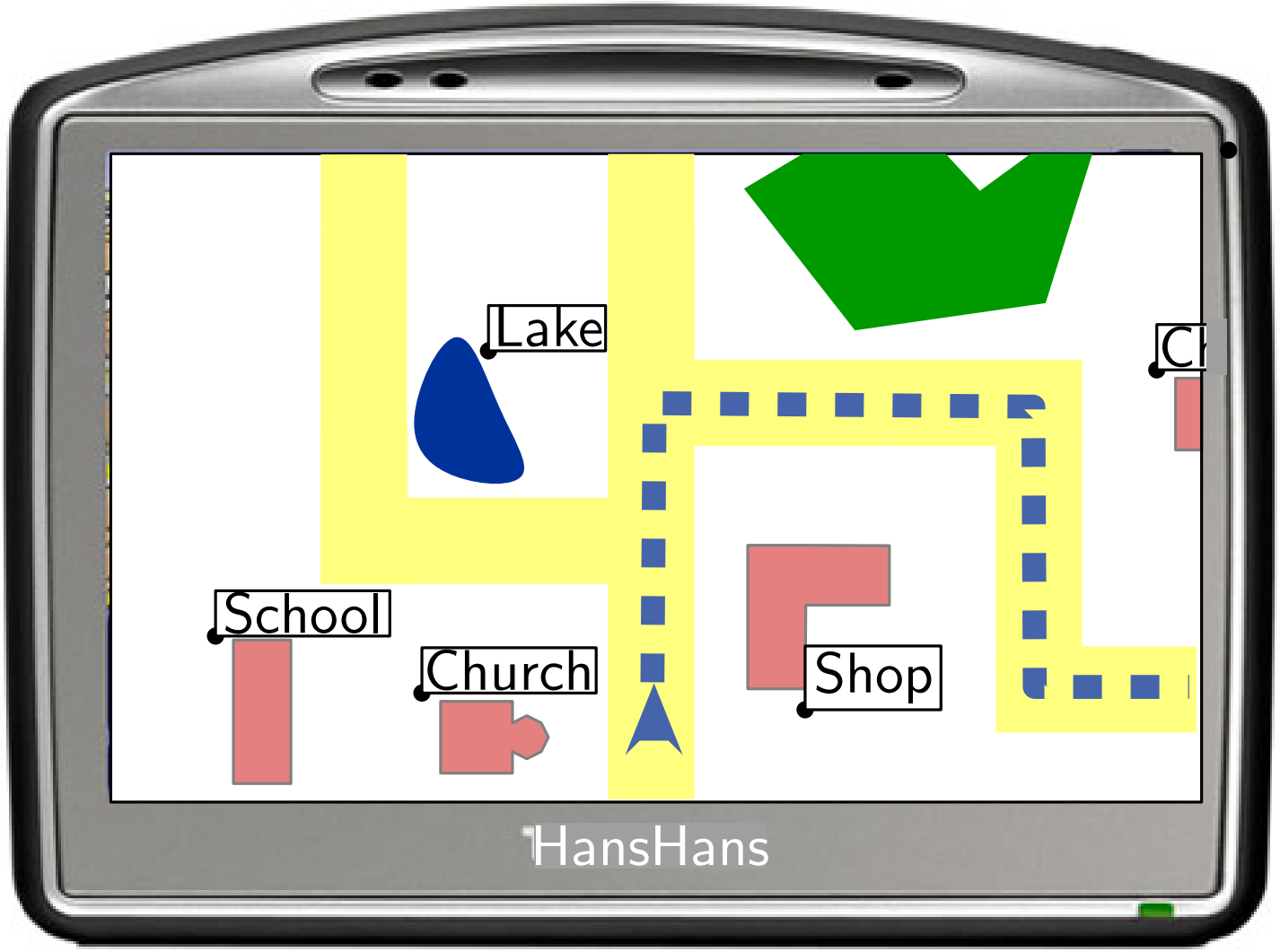
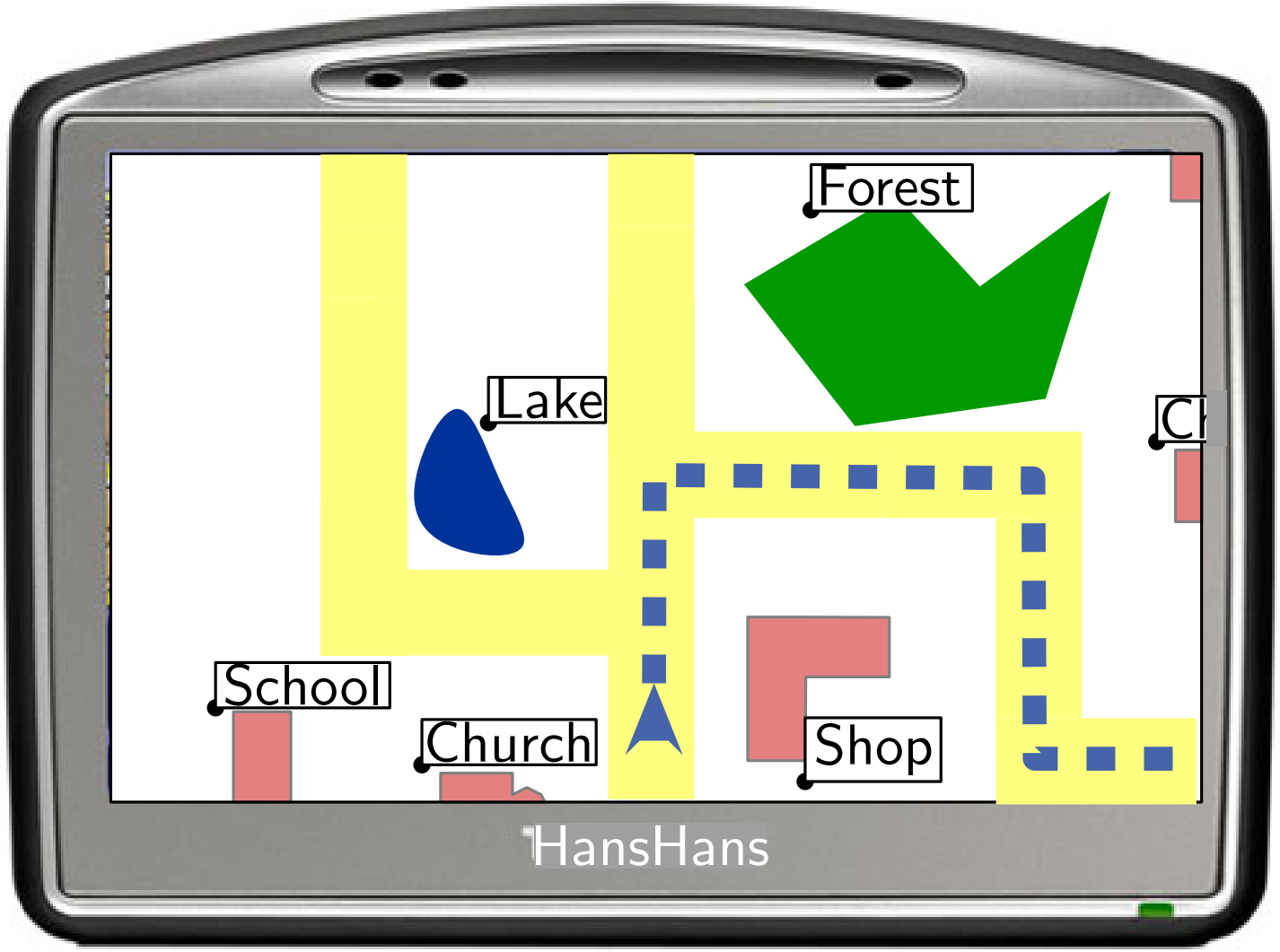


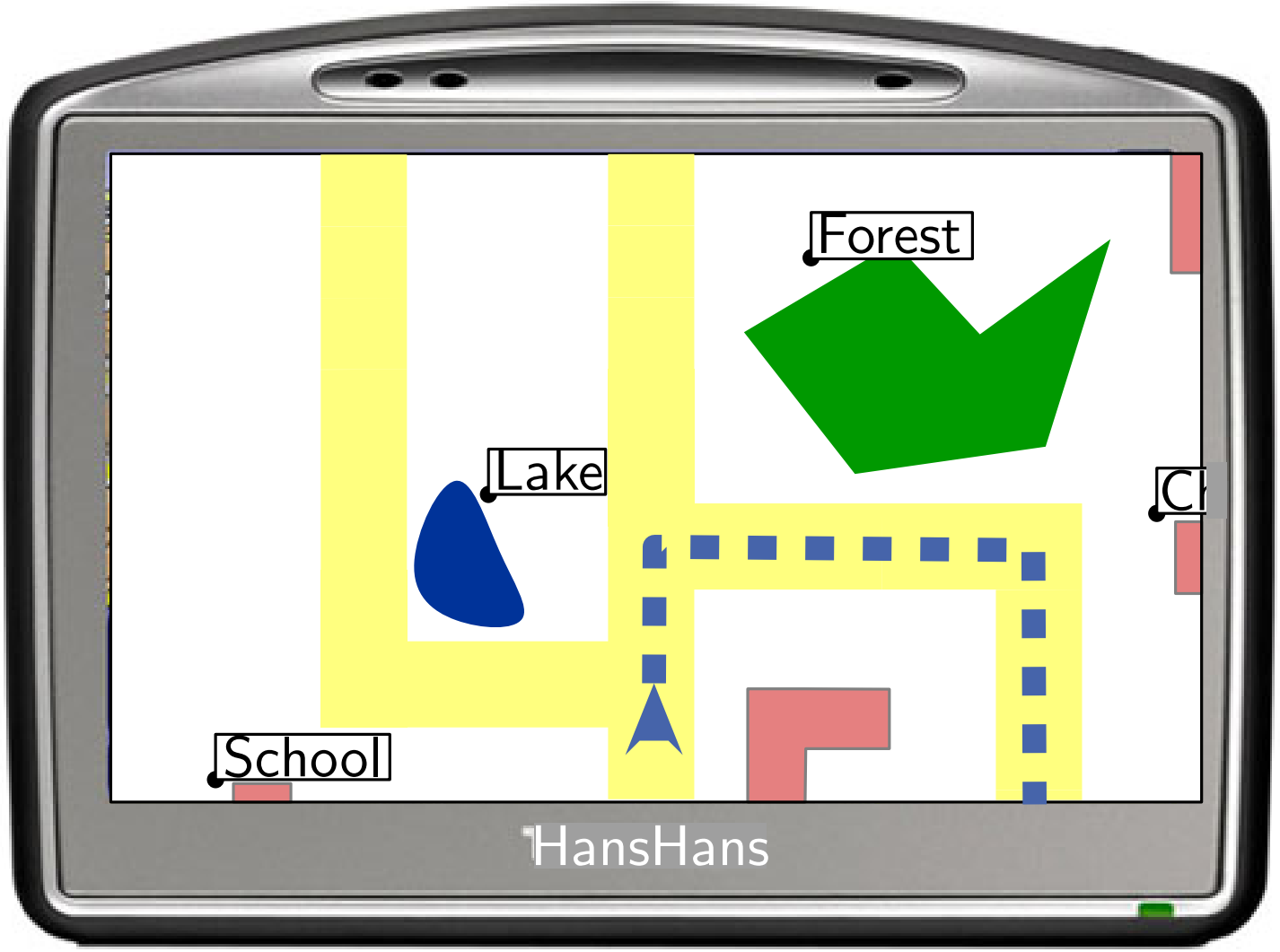
Motivation



Motivation



Motivation



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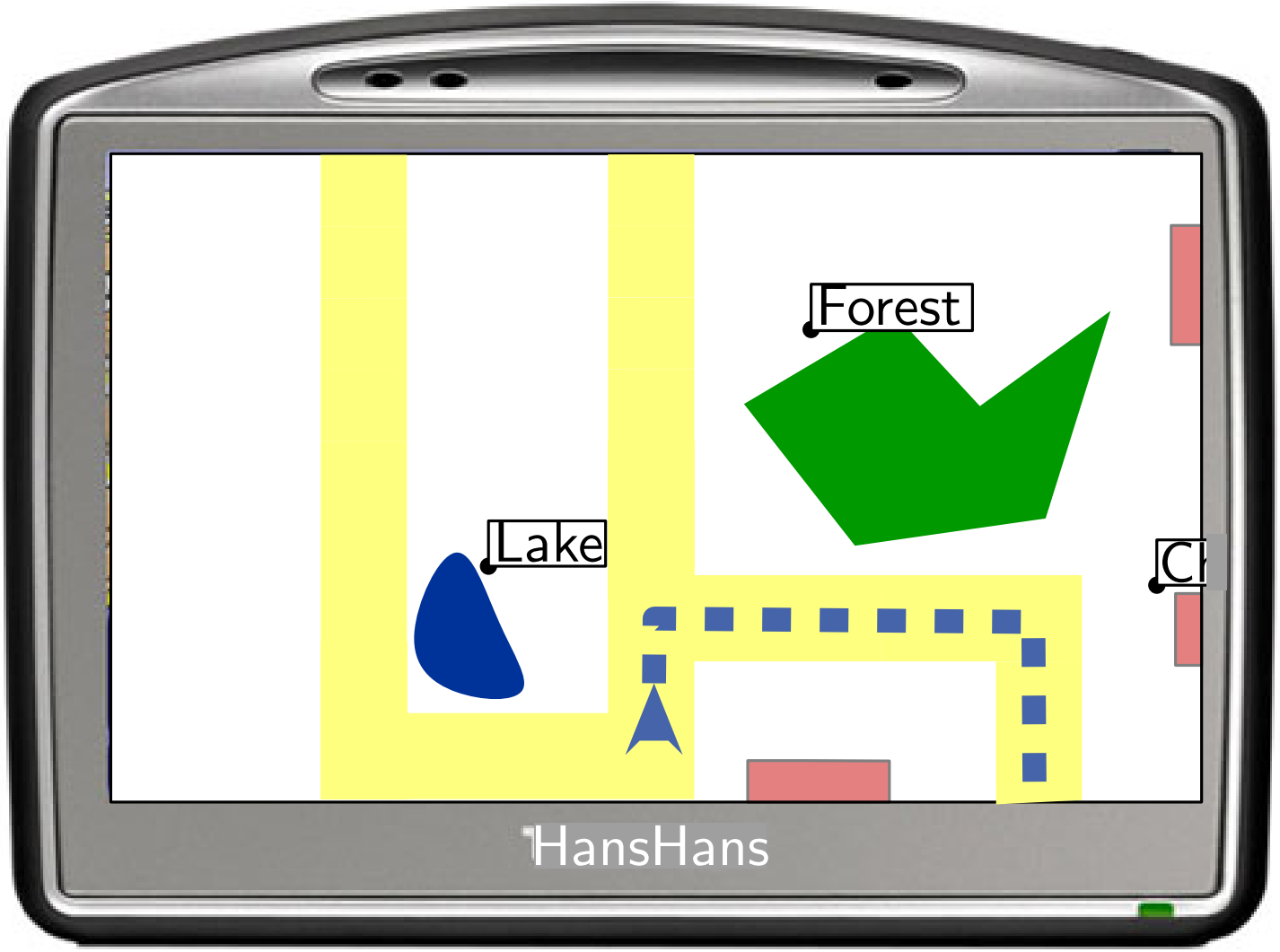

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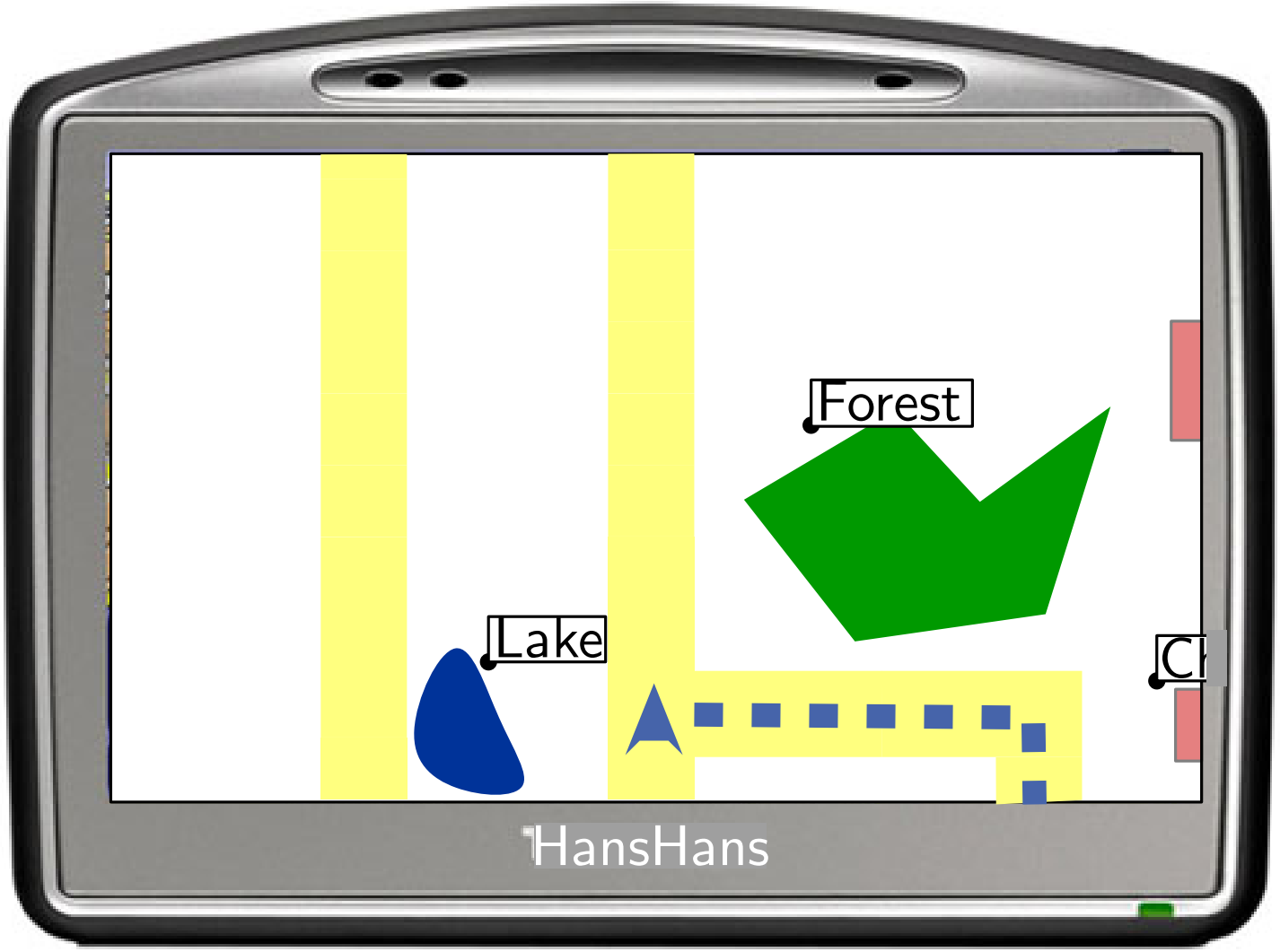

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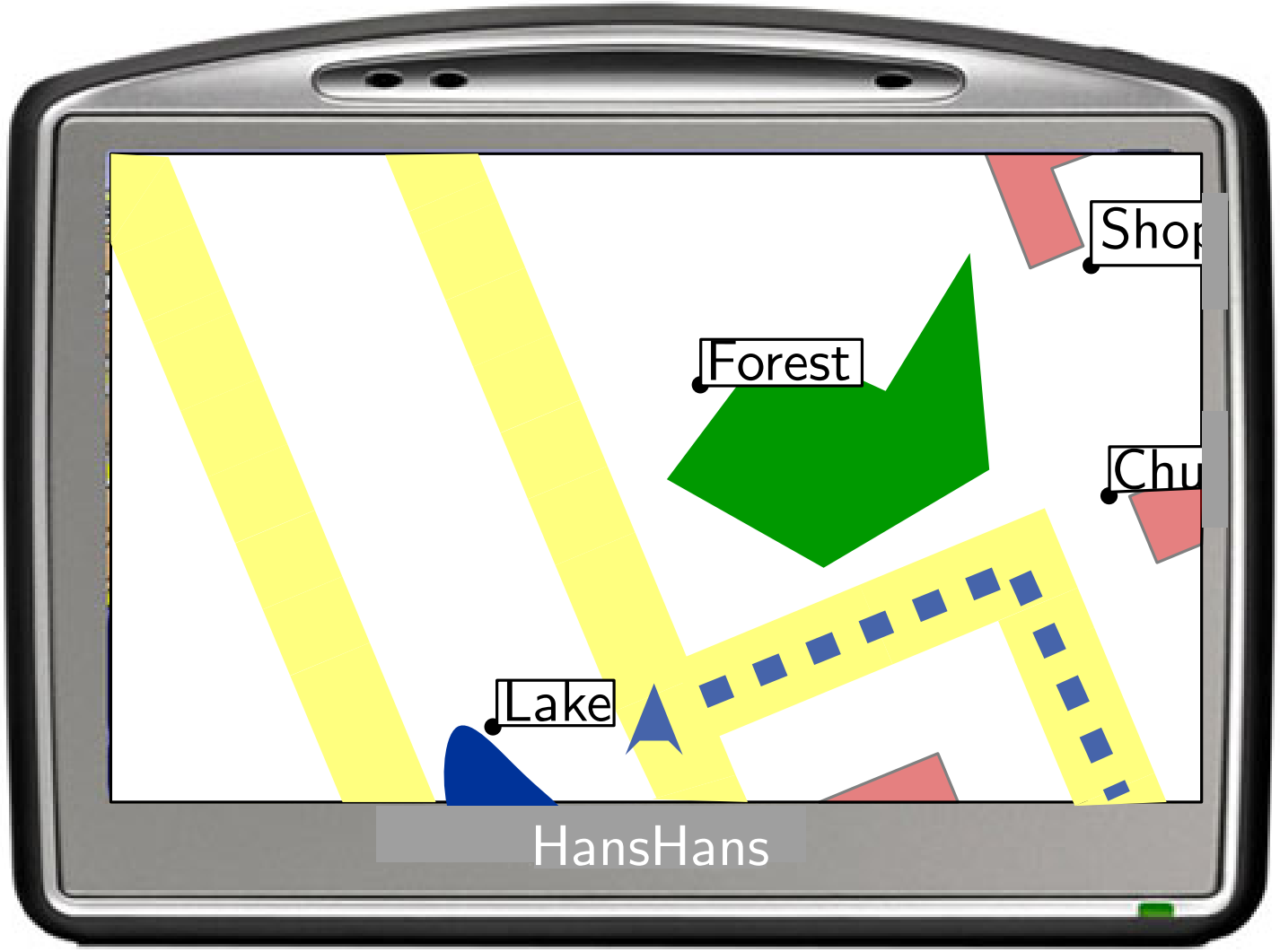

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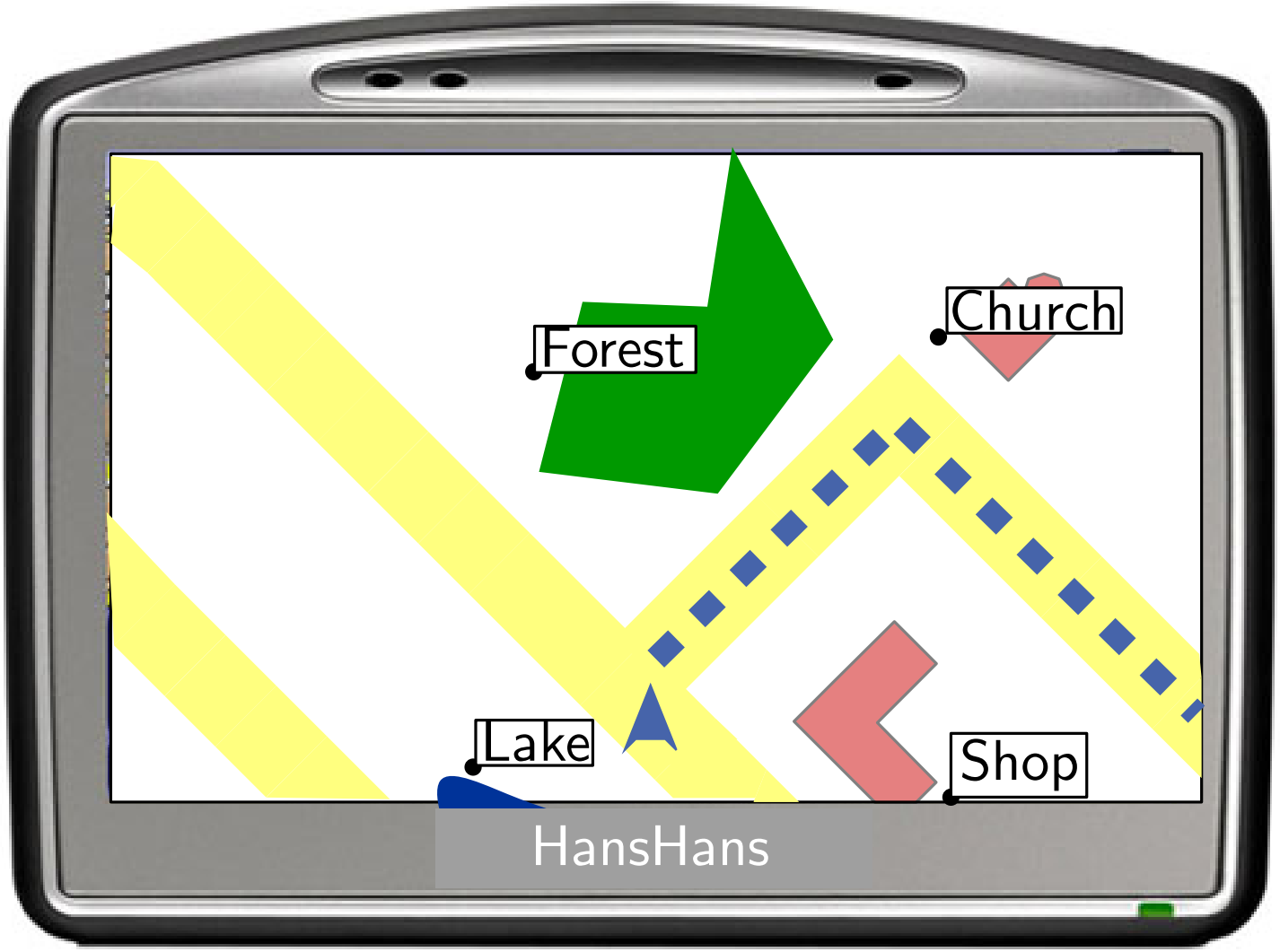

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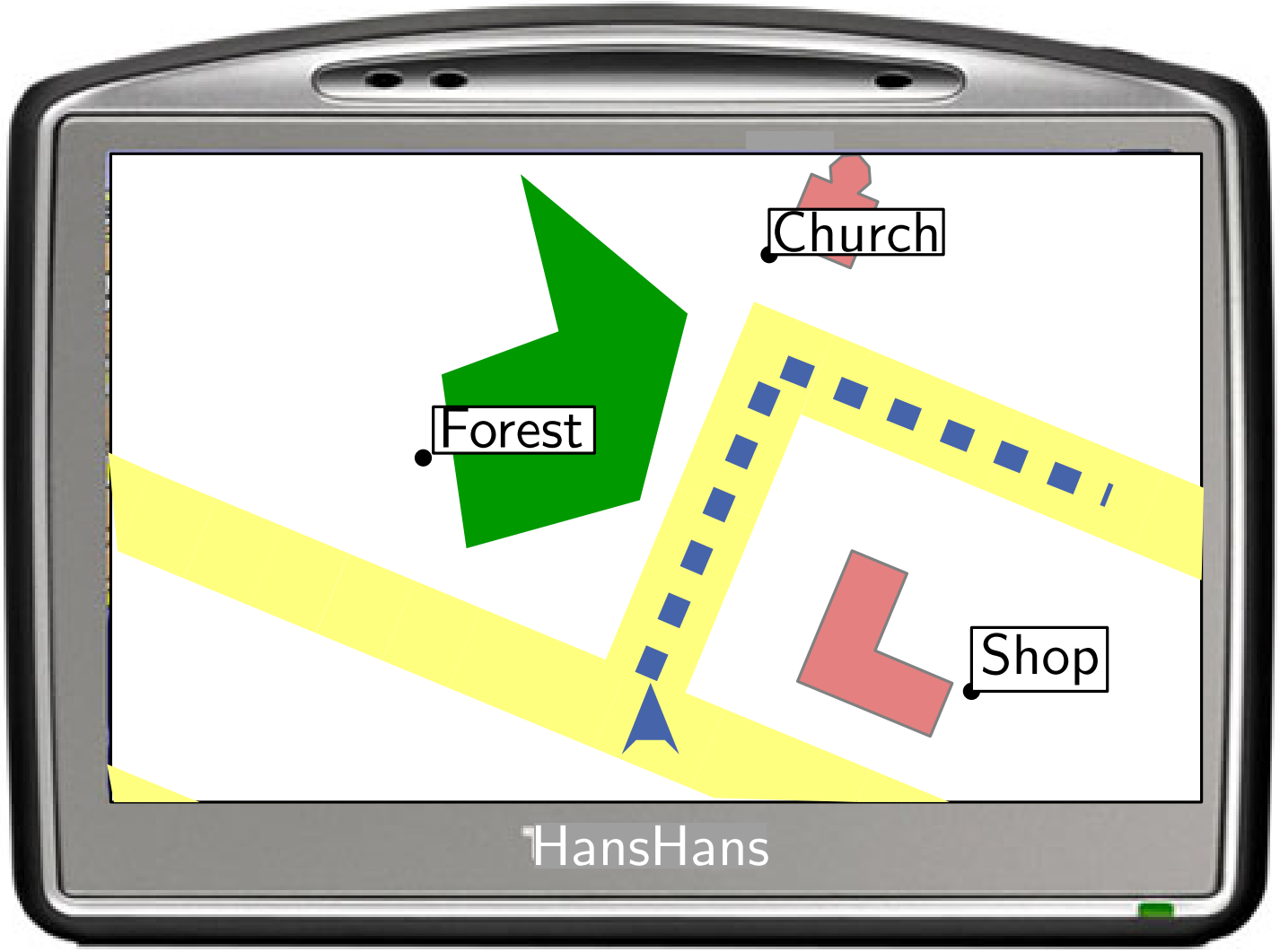

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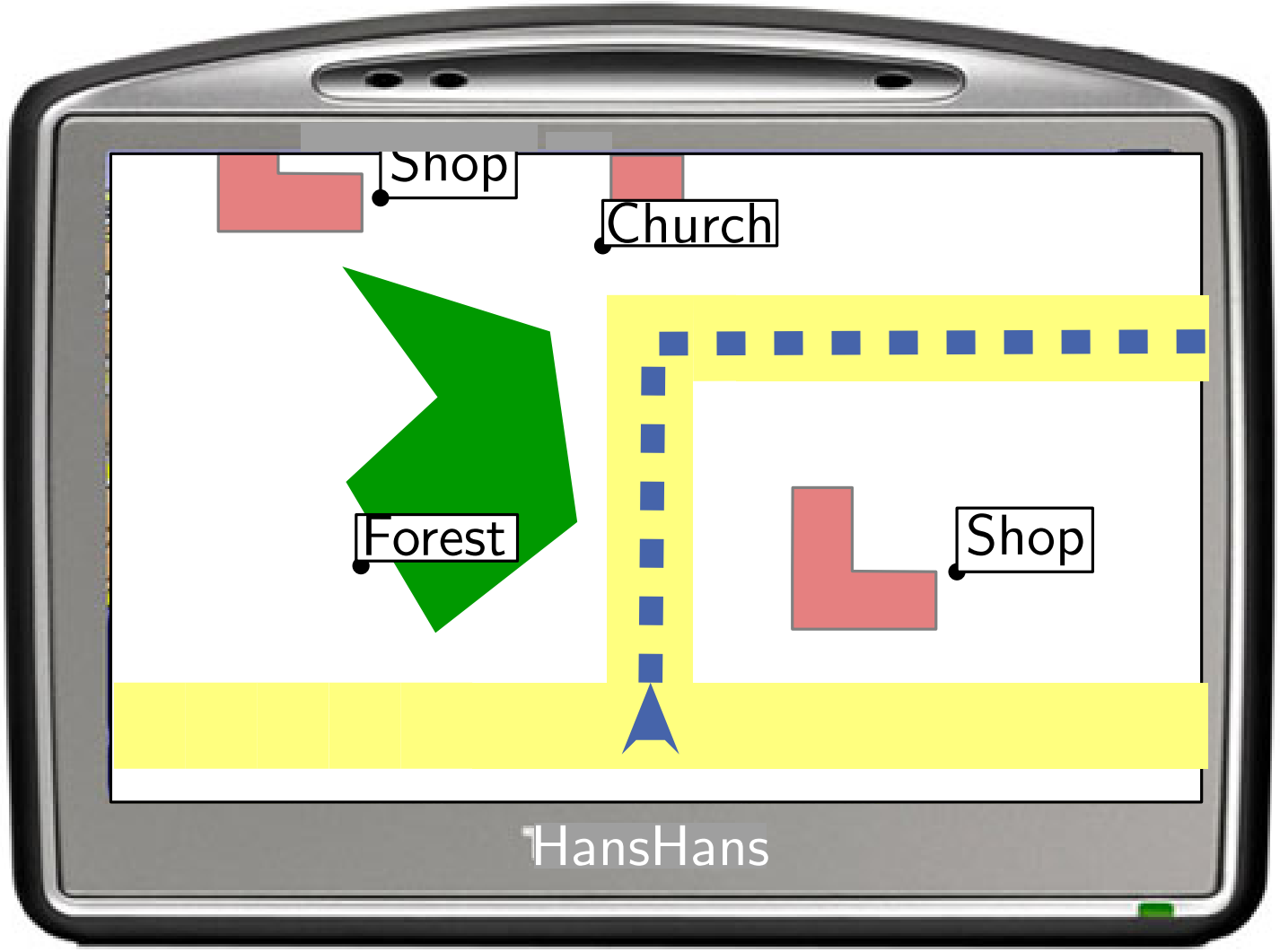

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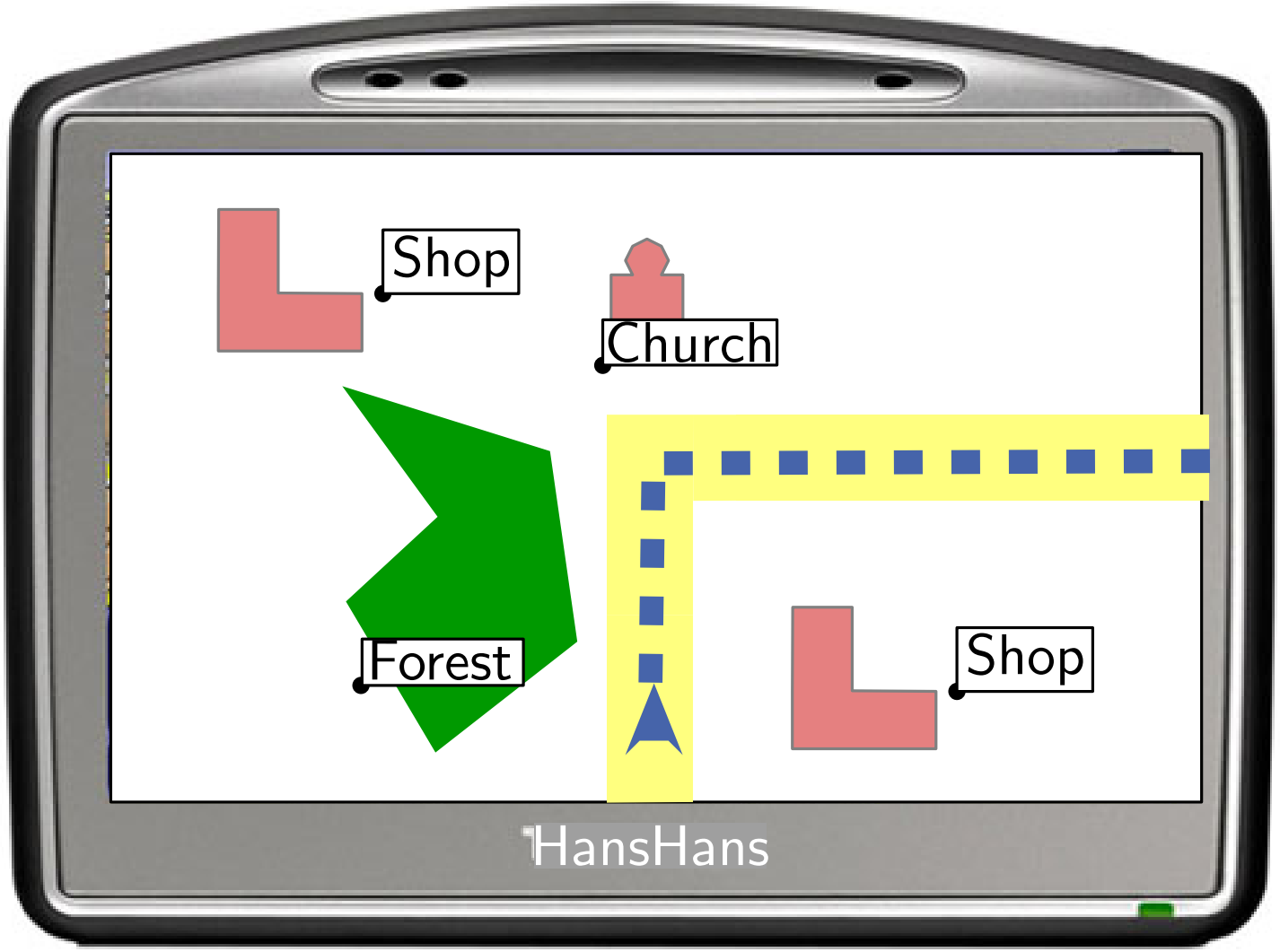

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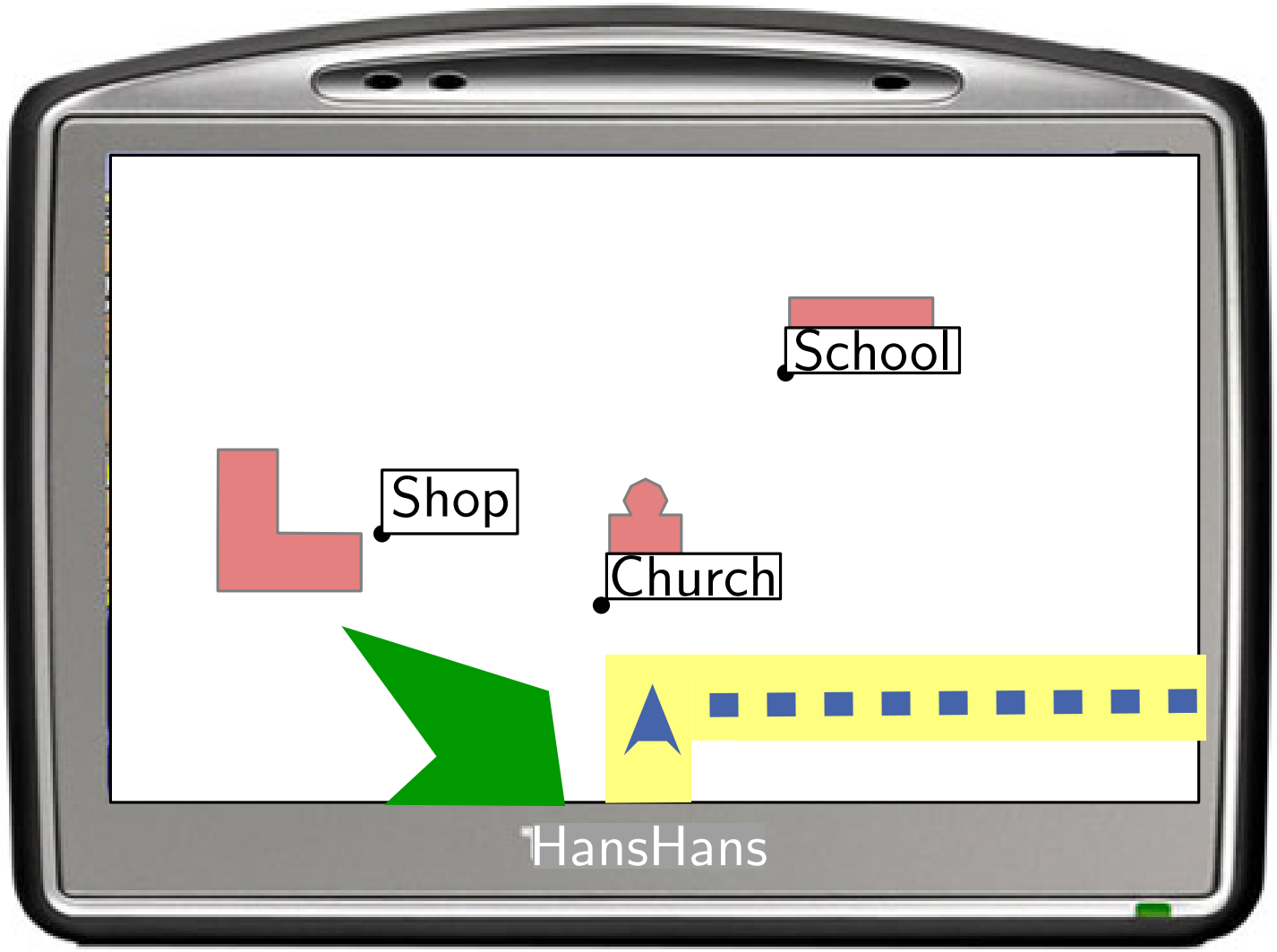

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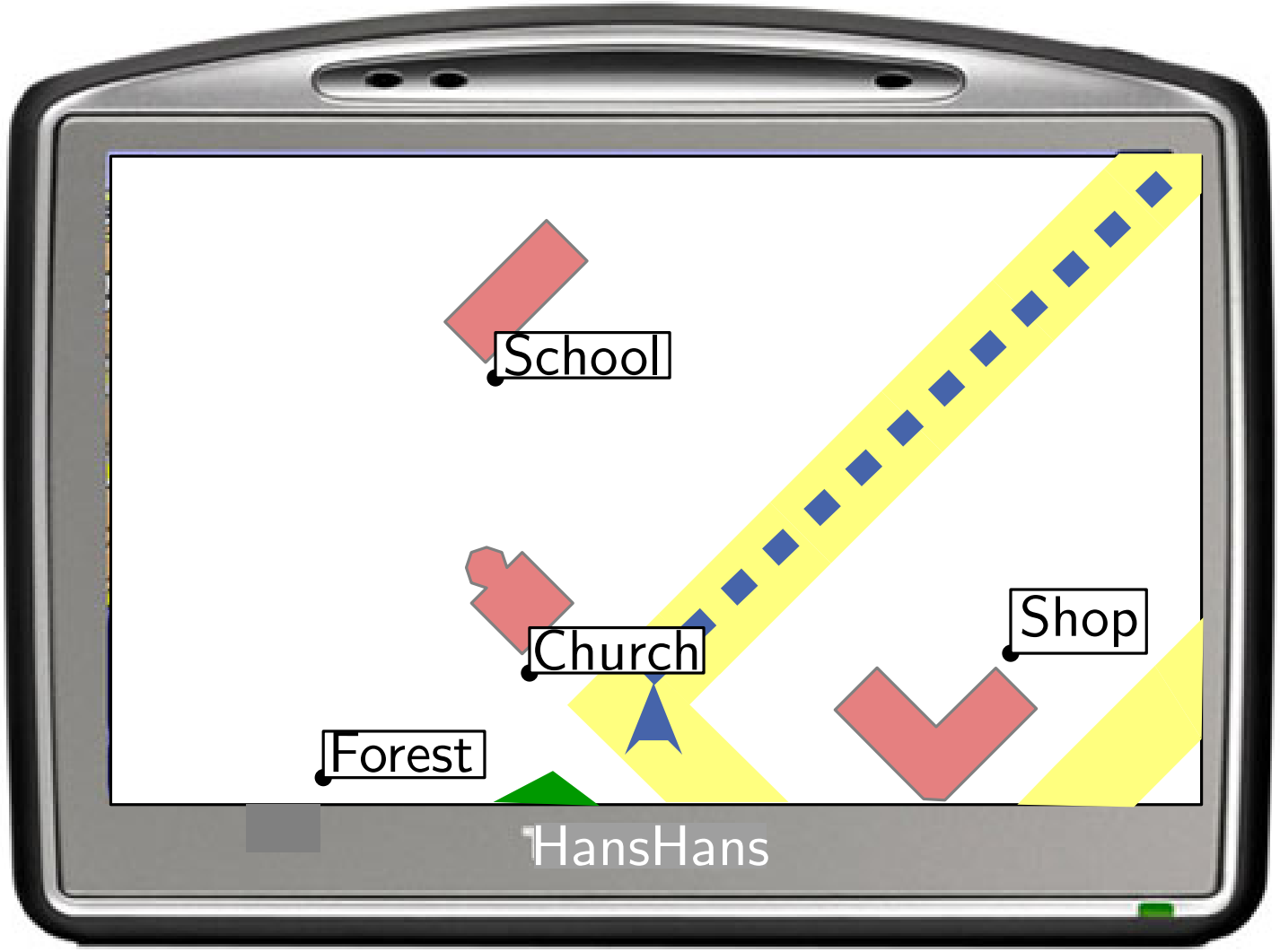

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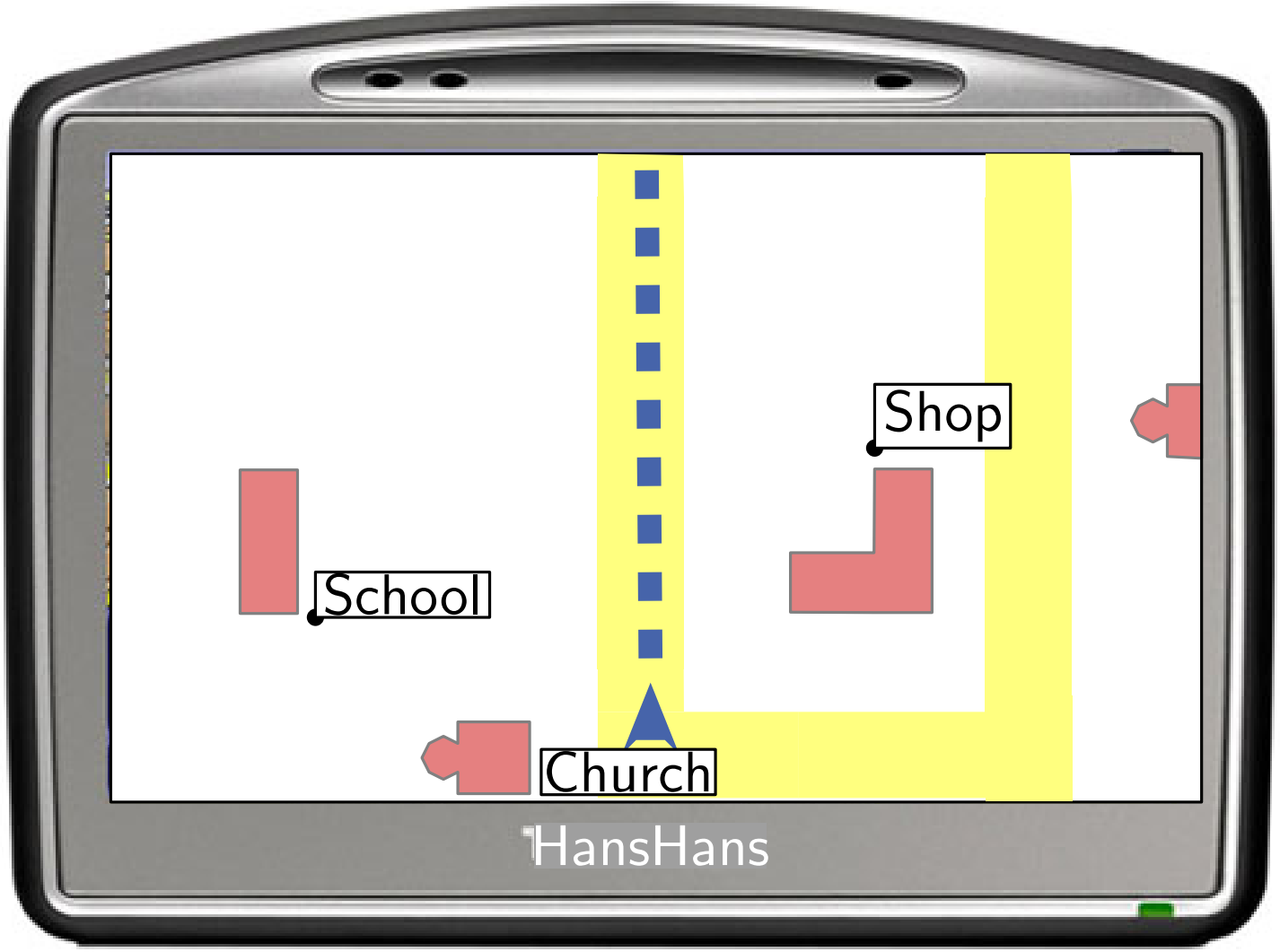

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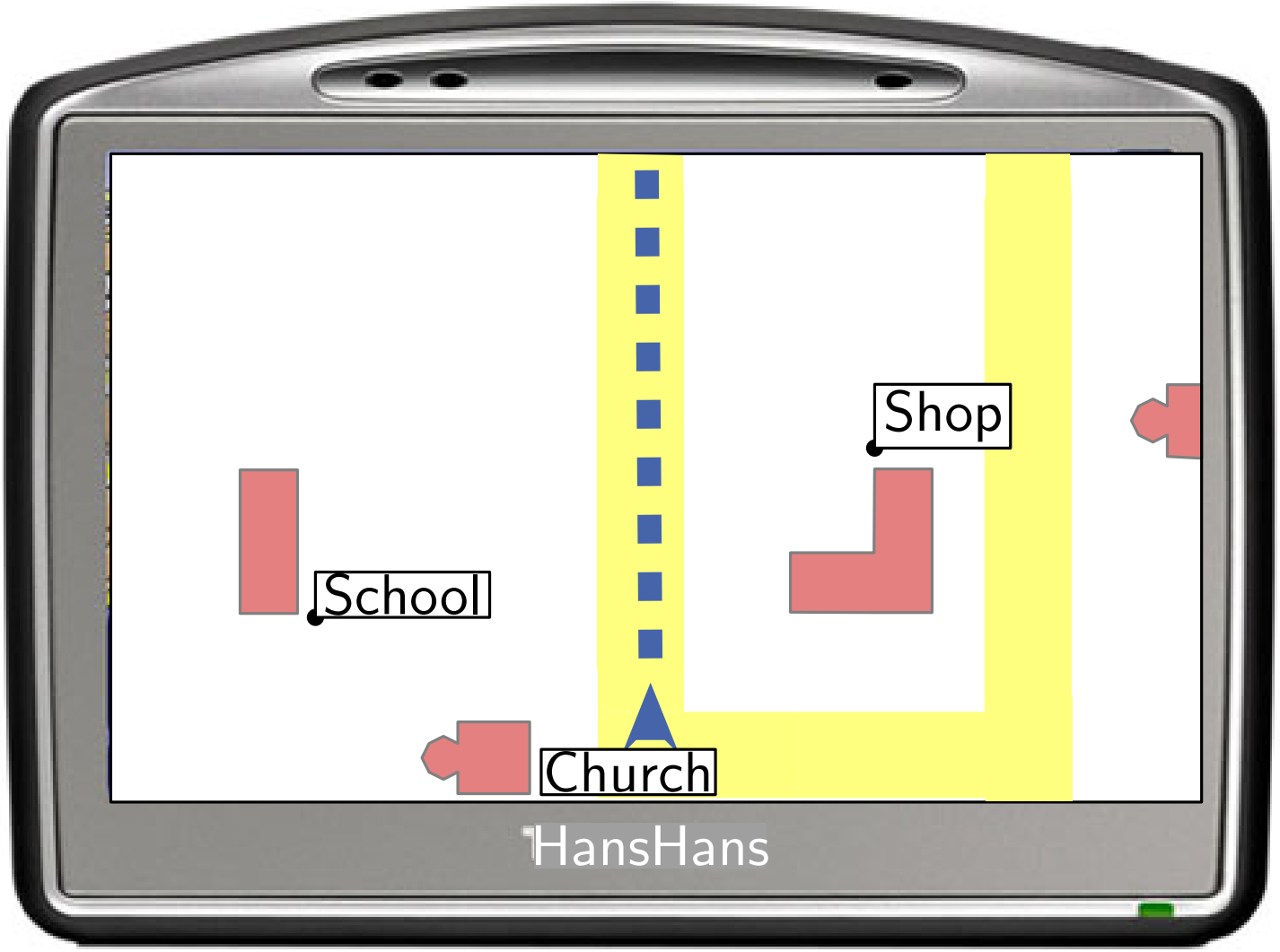
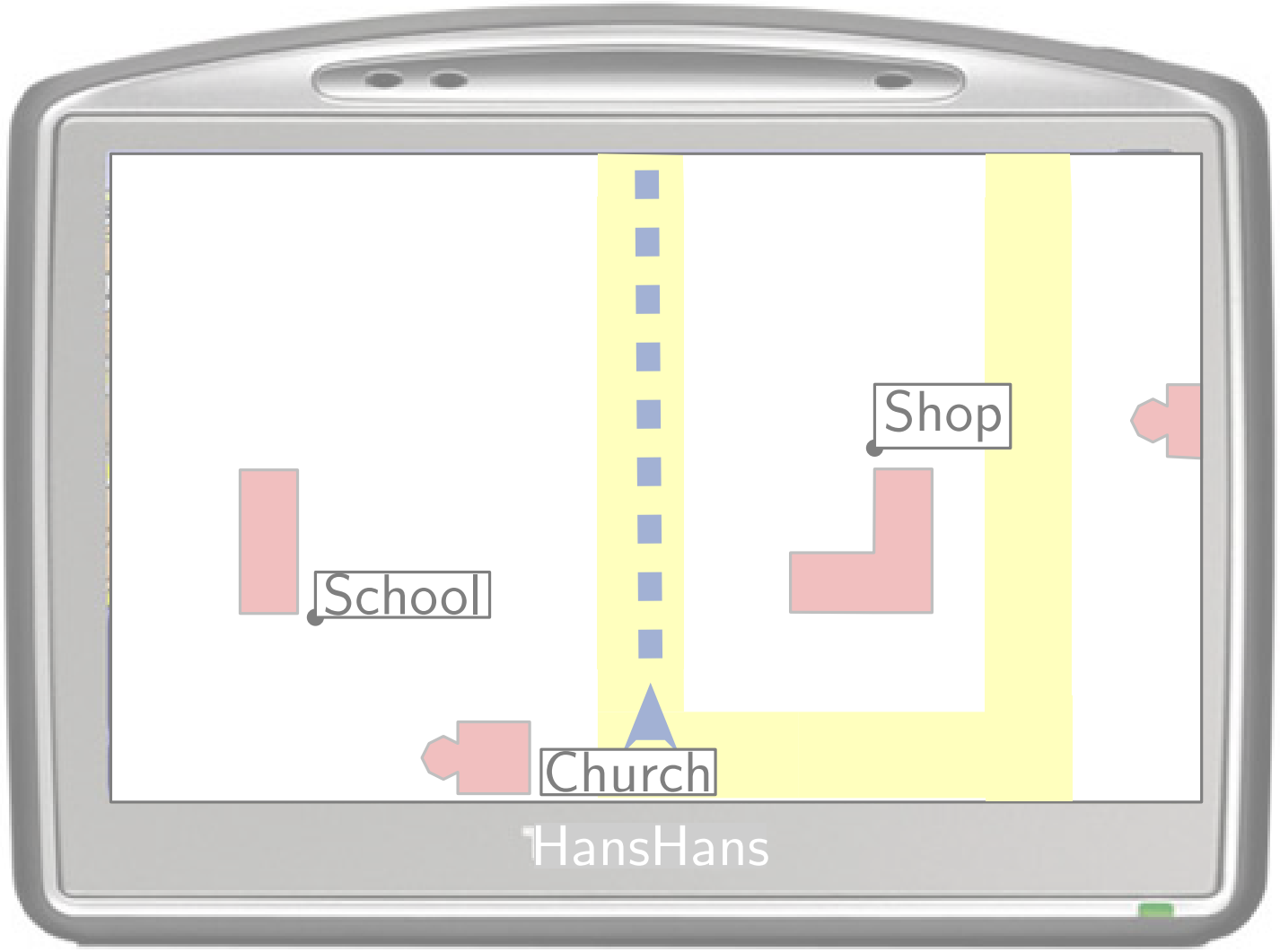
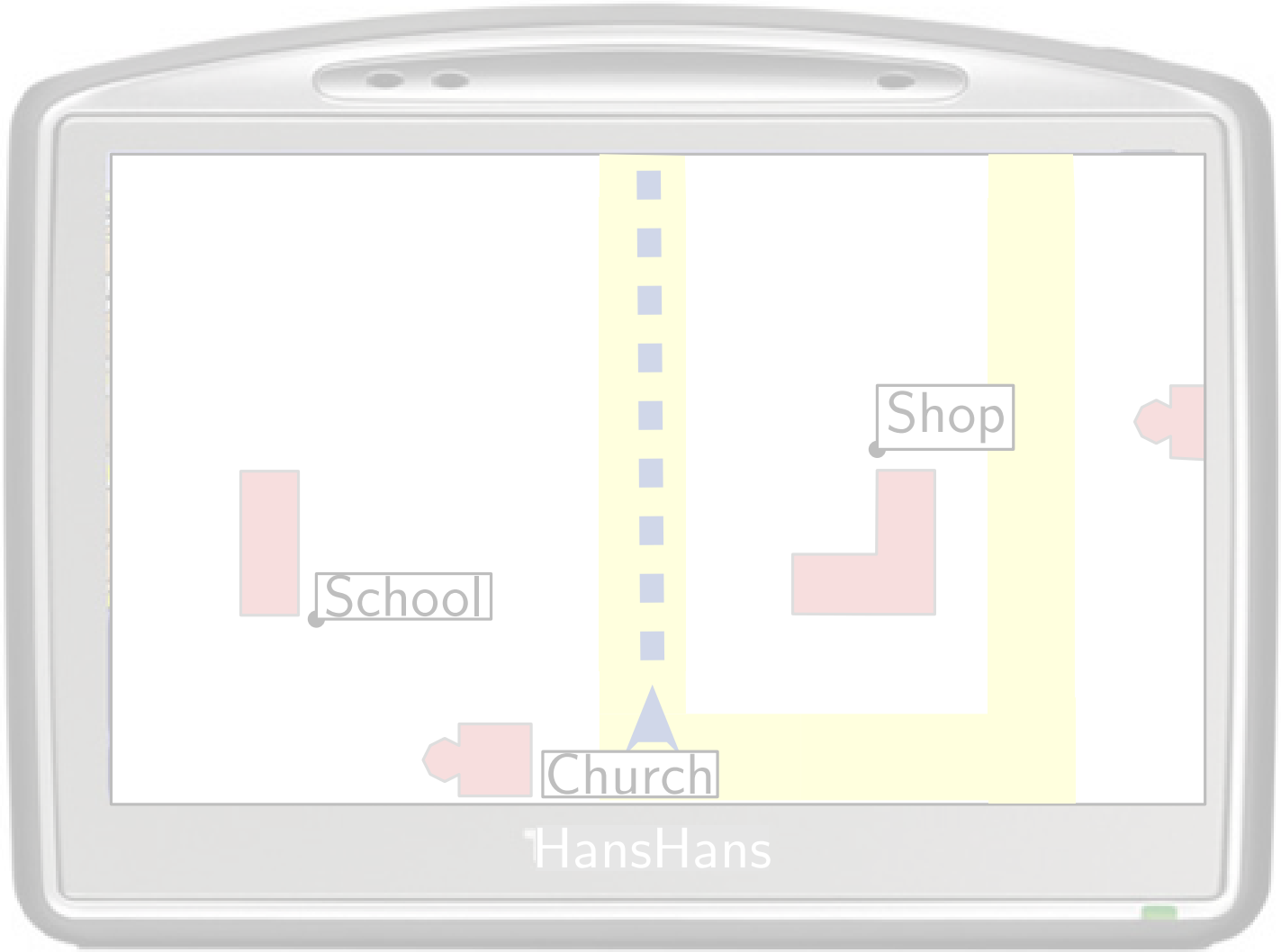


Motivation



Motivation

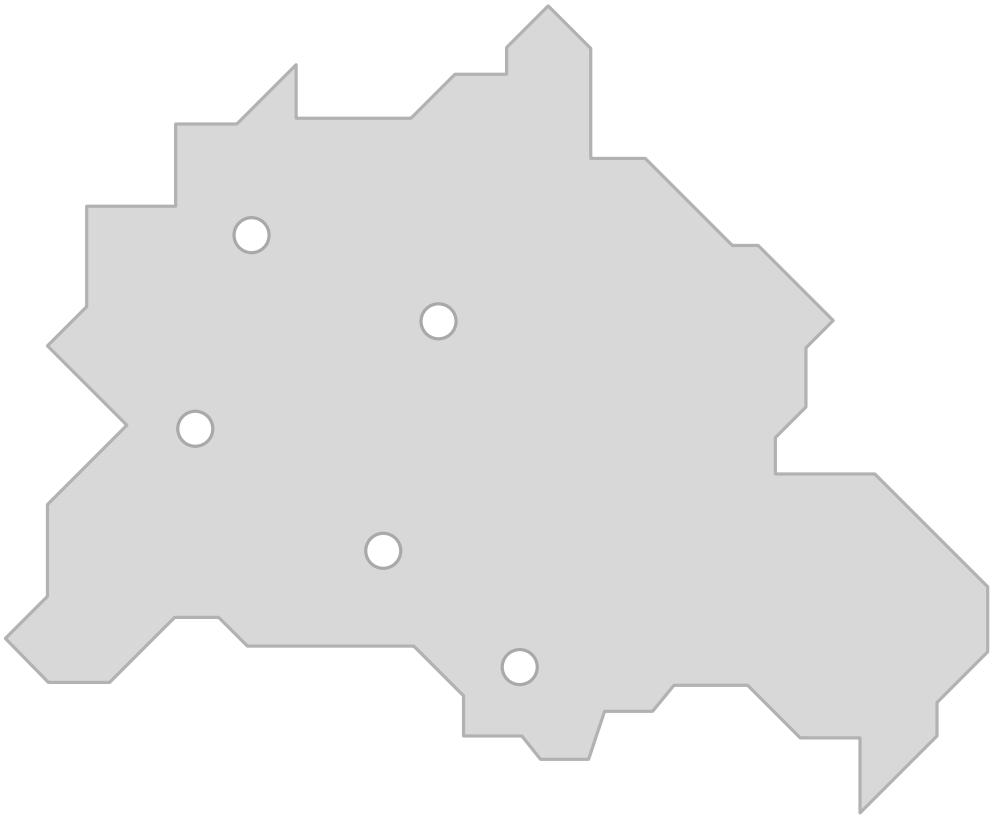


Motivation

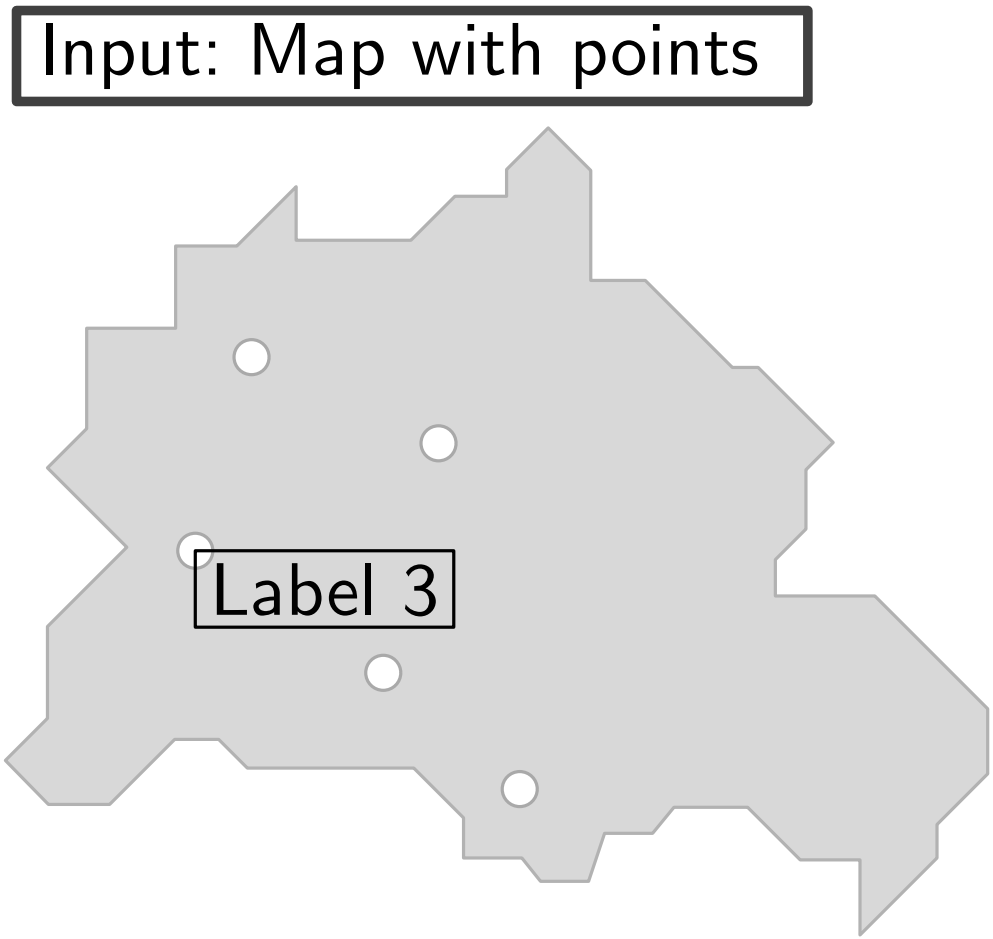
Problem Definition

Static Labeling

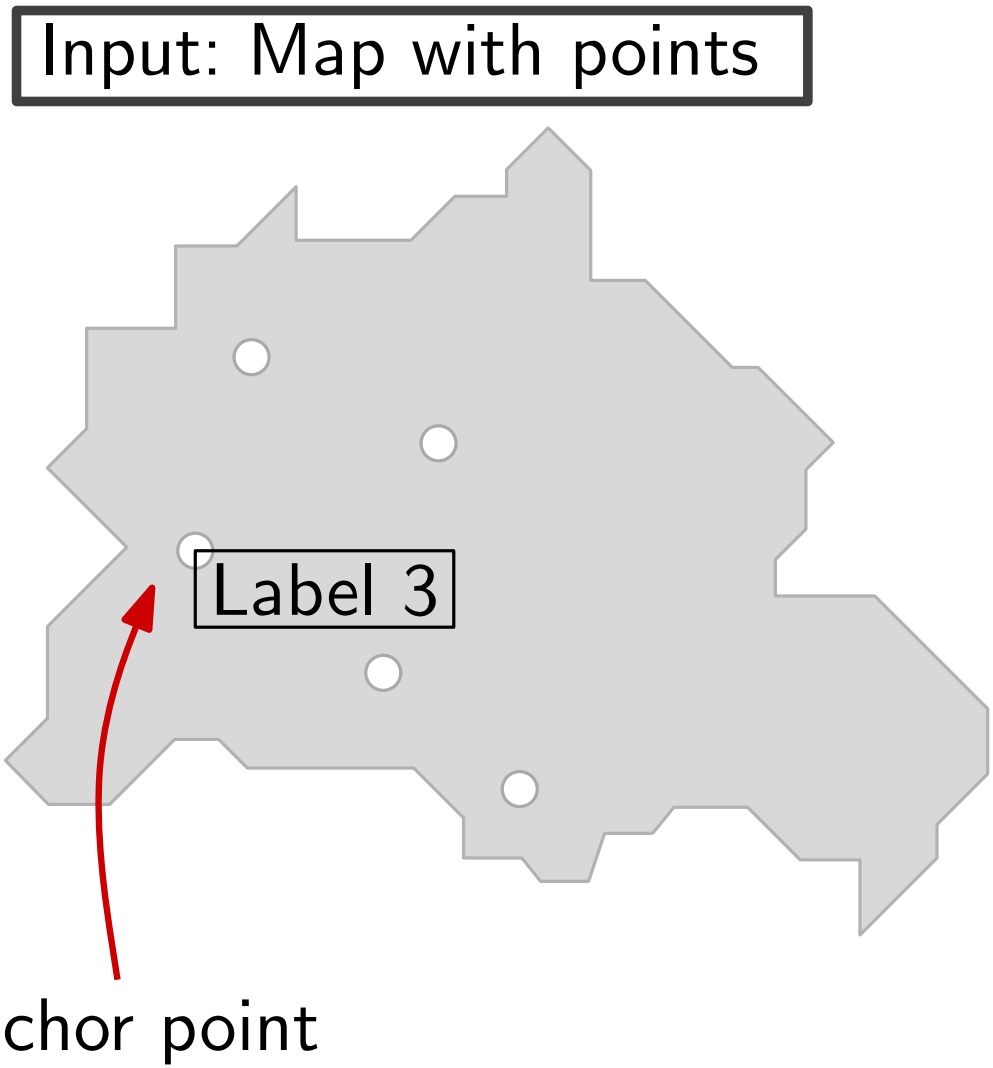
Input: Map with points



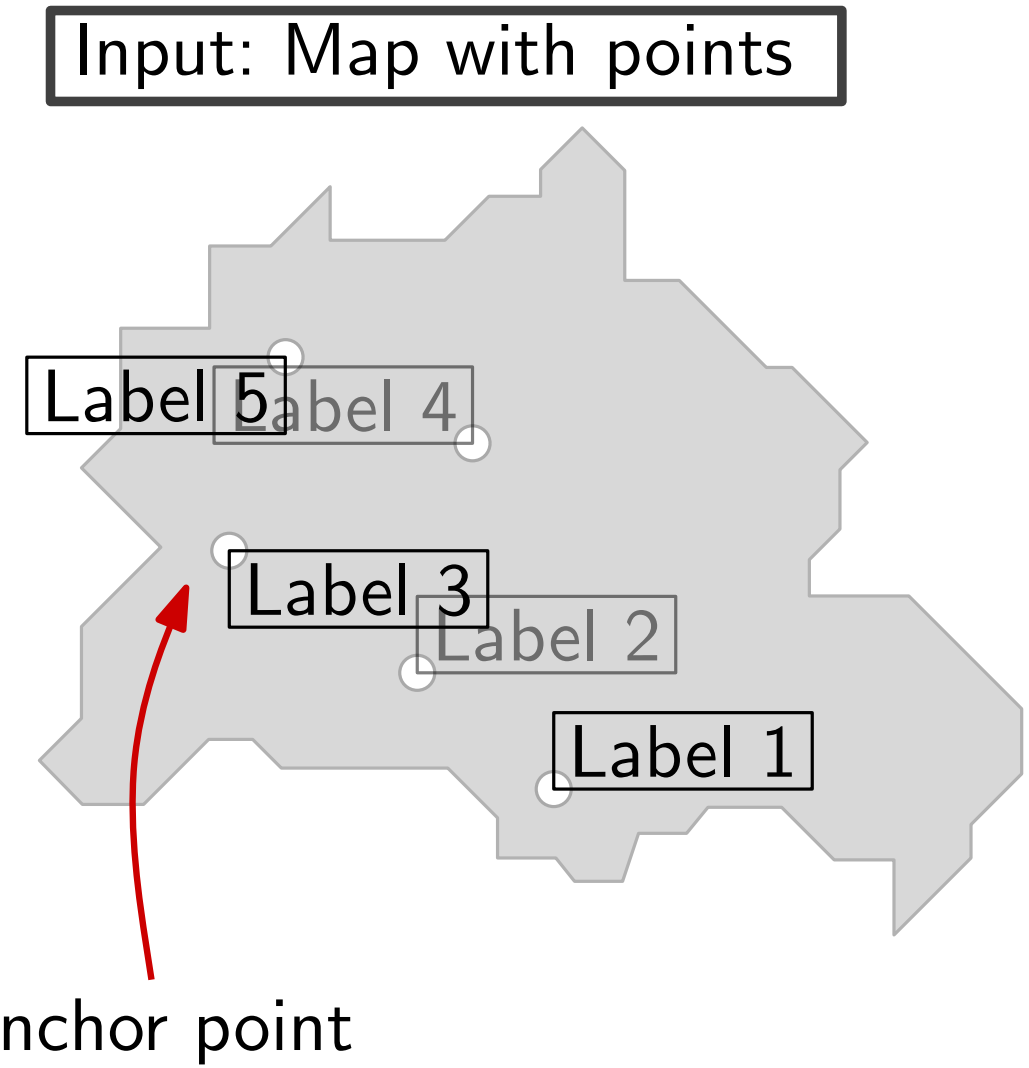
Static Labeling



Static Labeling



Static Labeling



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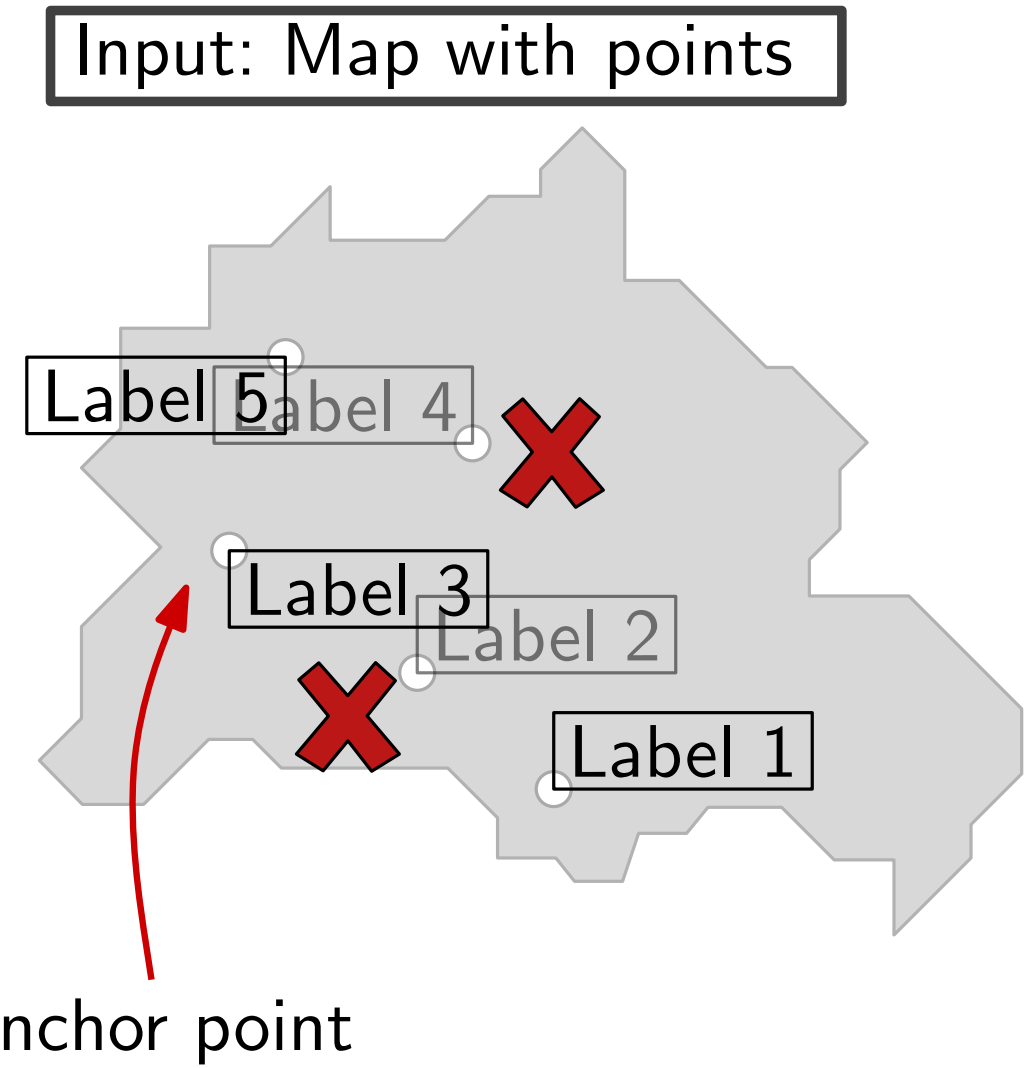

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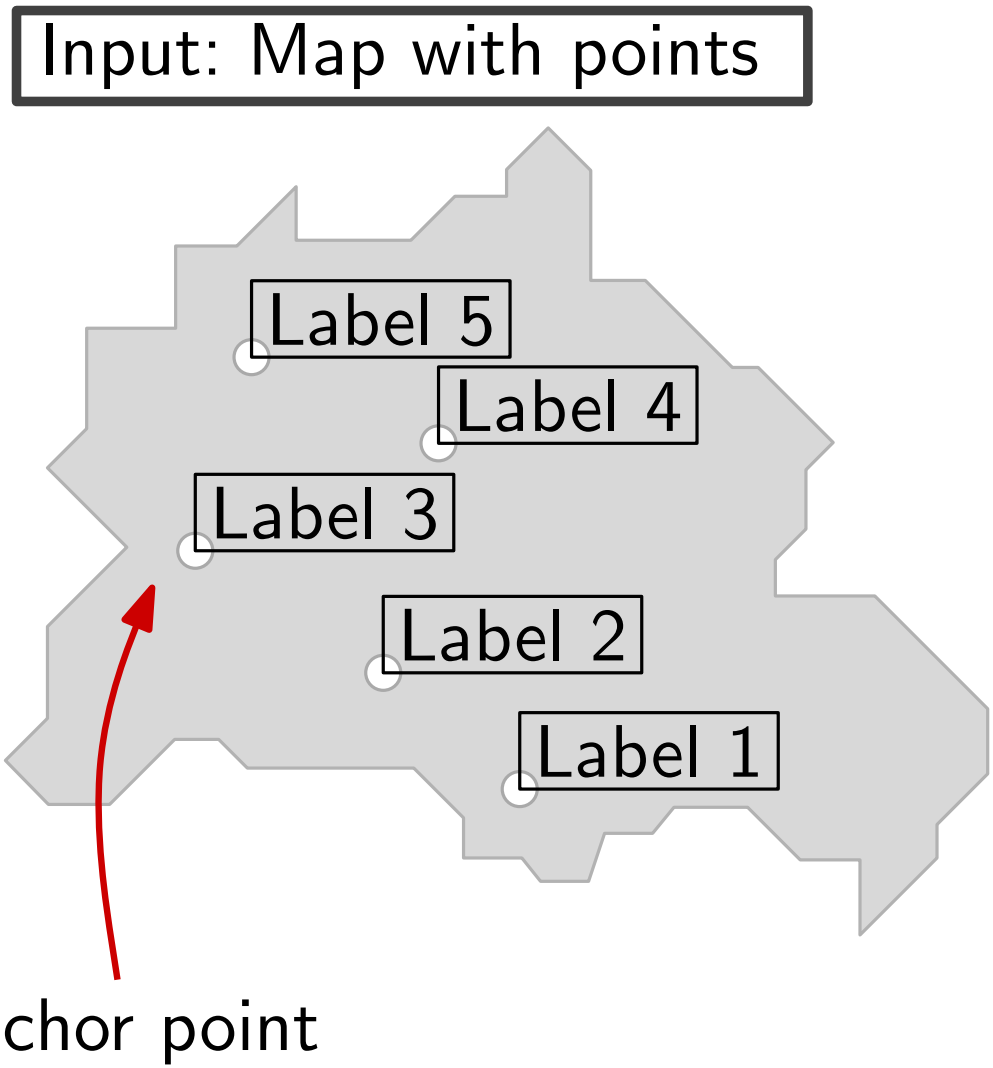
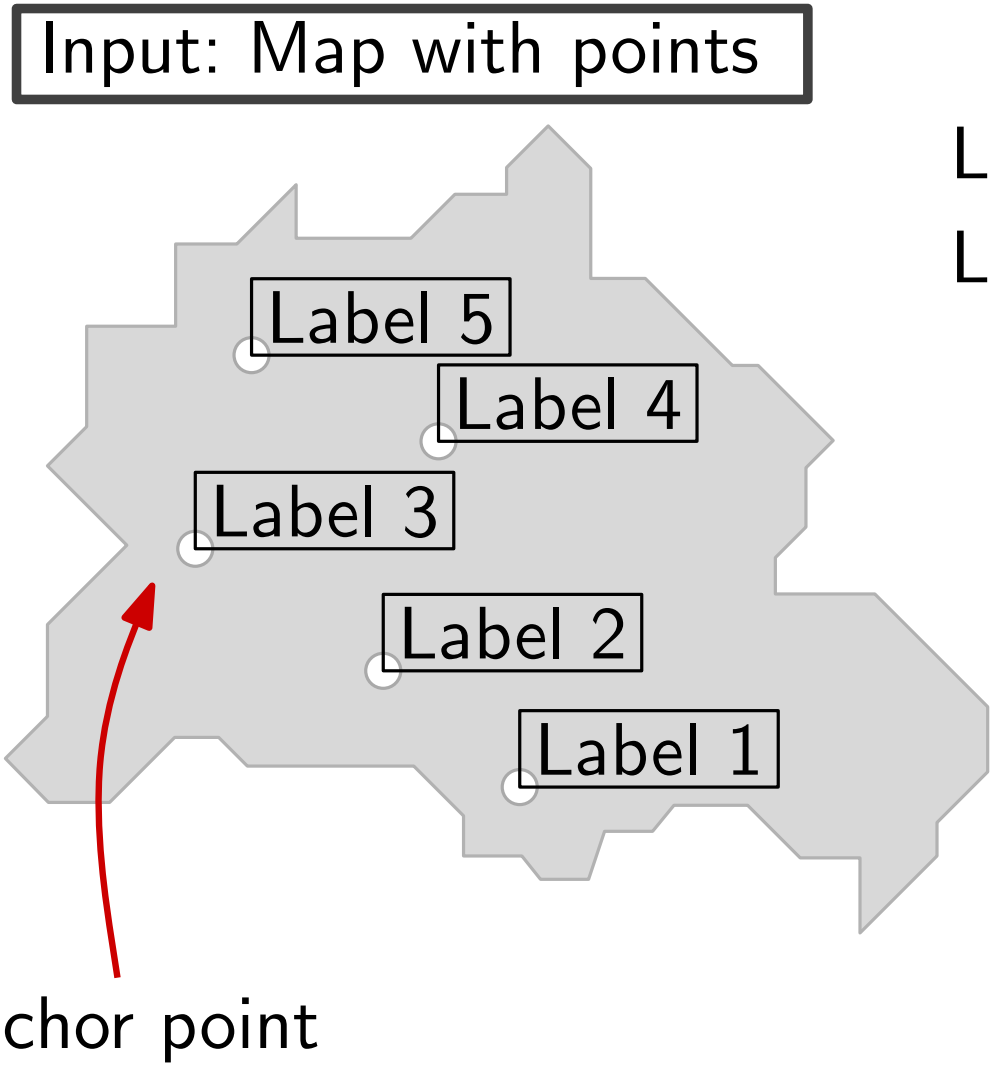


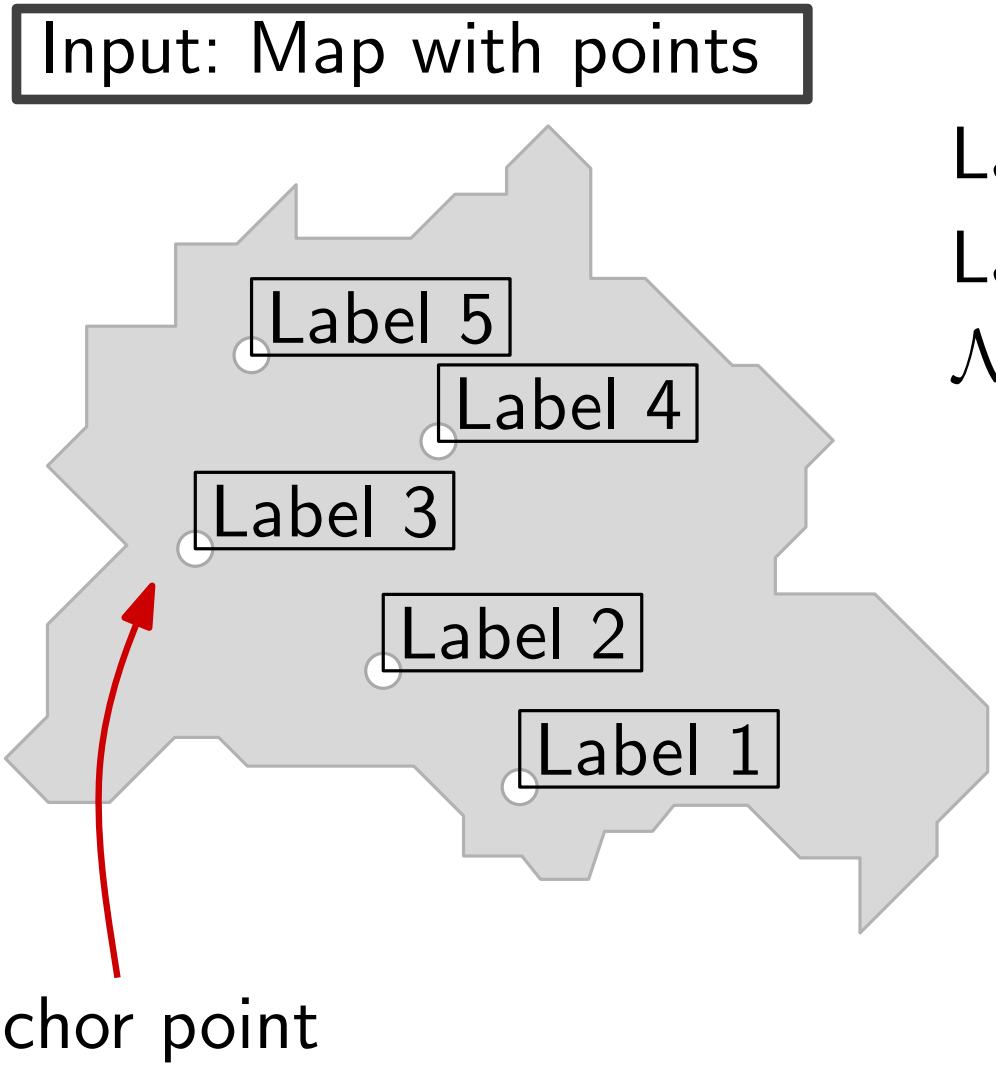
Static Labeling



Label Size Maximization

Label Number Maximization

Static Labeling

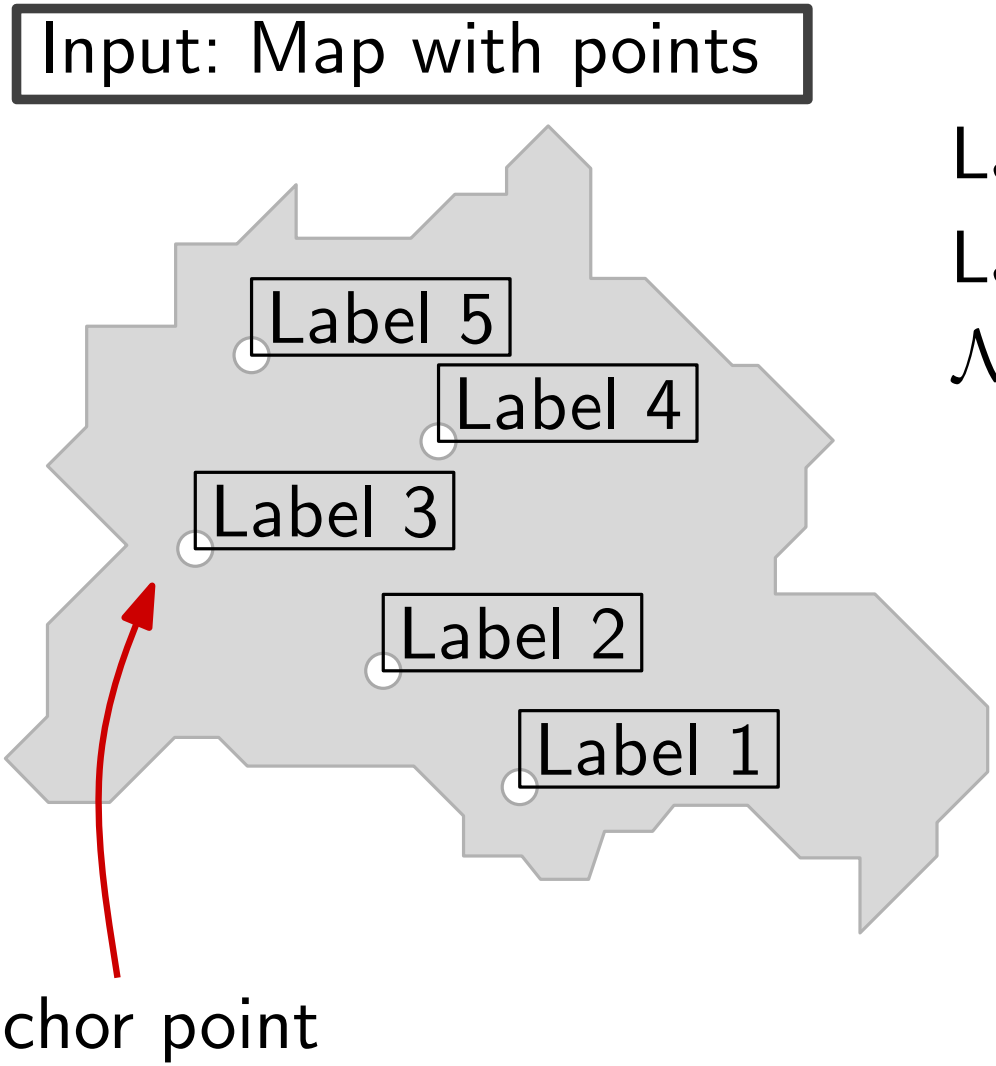


Label Size Maximization

Label Number Maximization

$\mathcal{NP}$–hard

Static Labeling

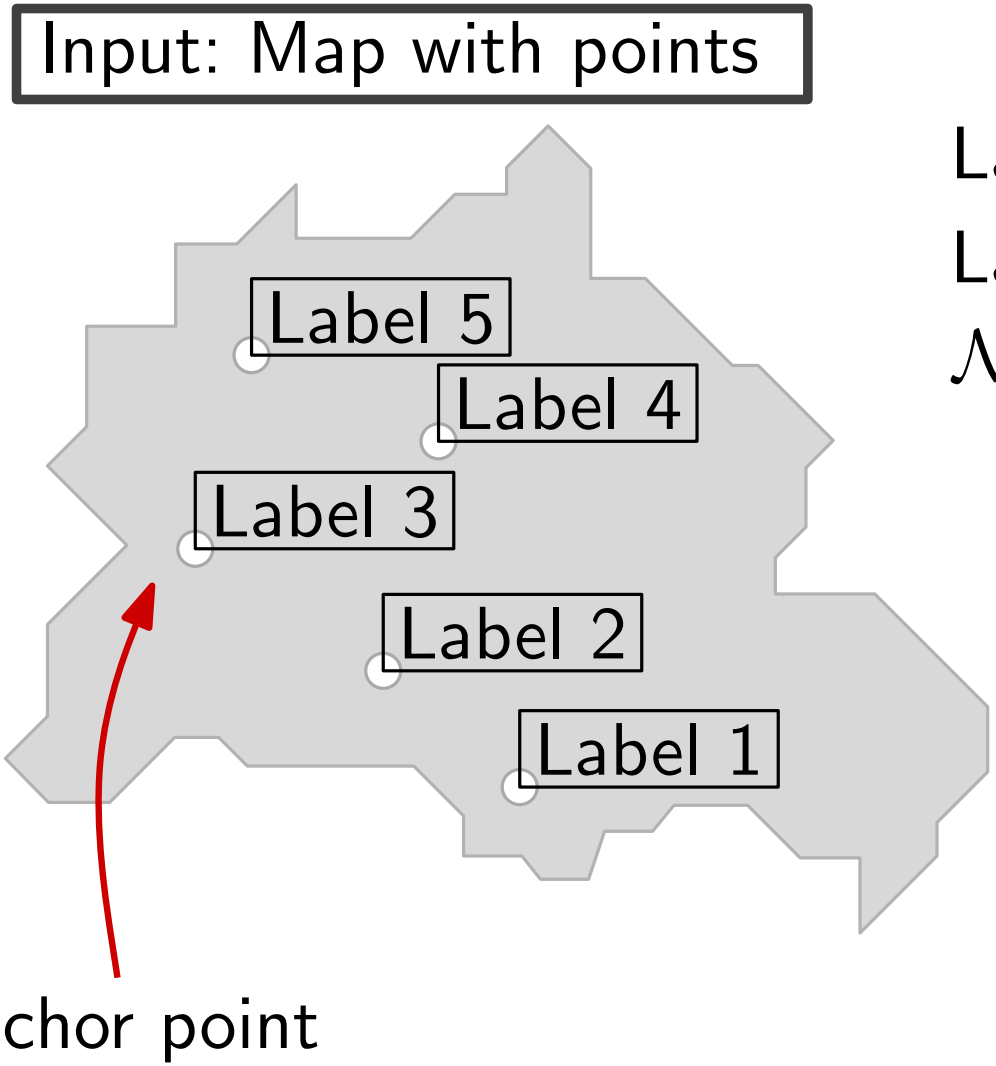


Label Size Maximization

Label Number Maximization

$\mathcal{NP}$–hard

Static Labeling



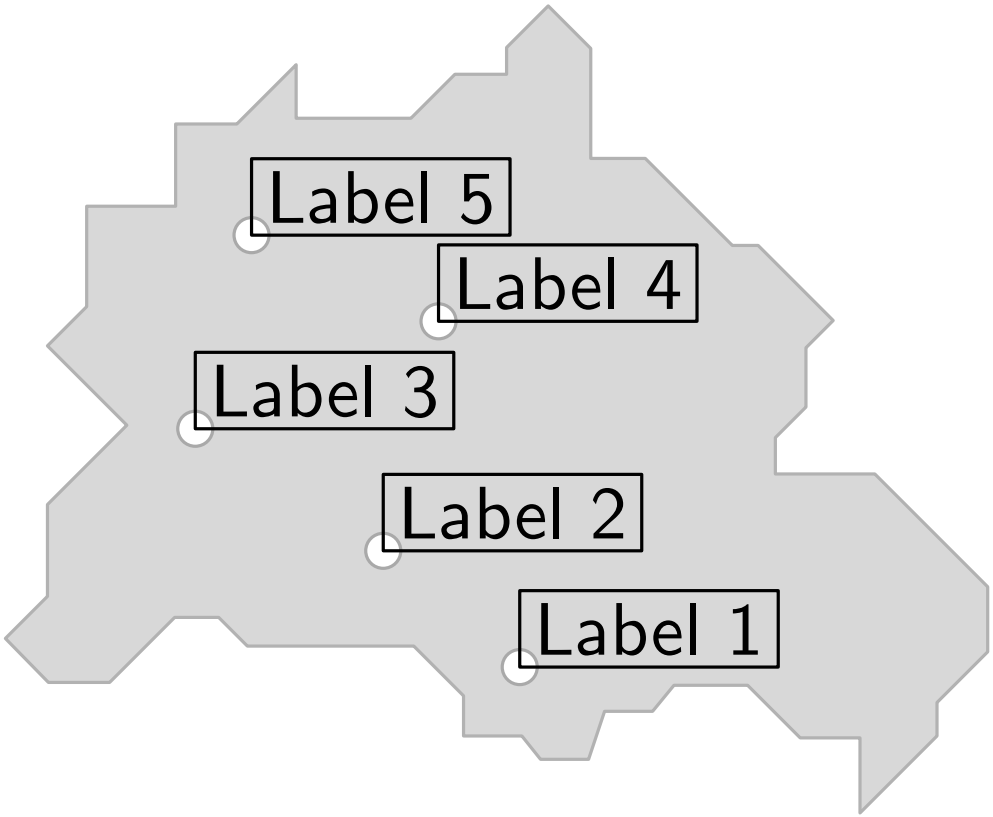
Label Size Maximization

Label Number Maximization

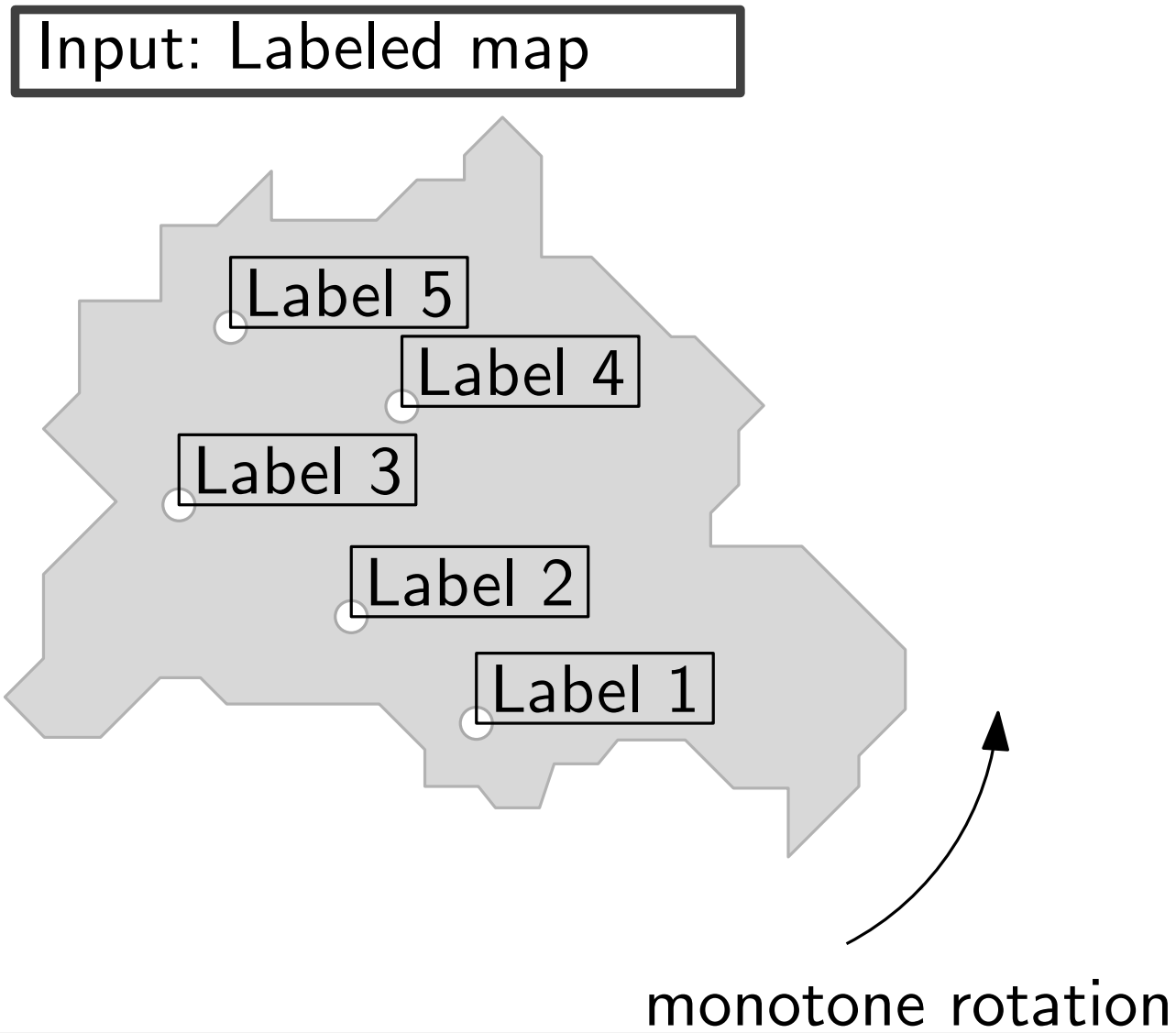
$\mathcal{NP}$–hard

Our Problem

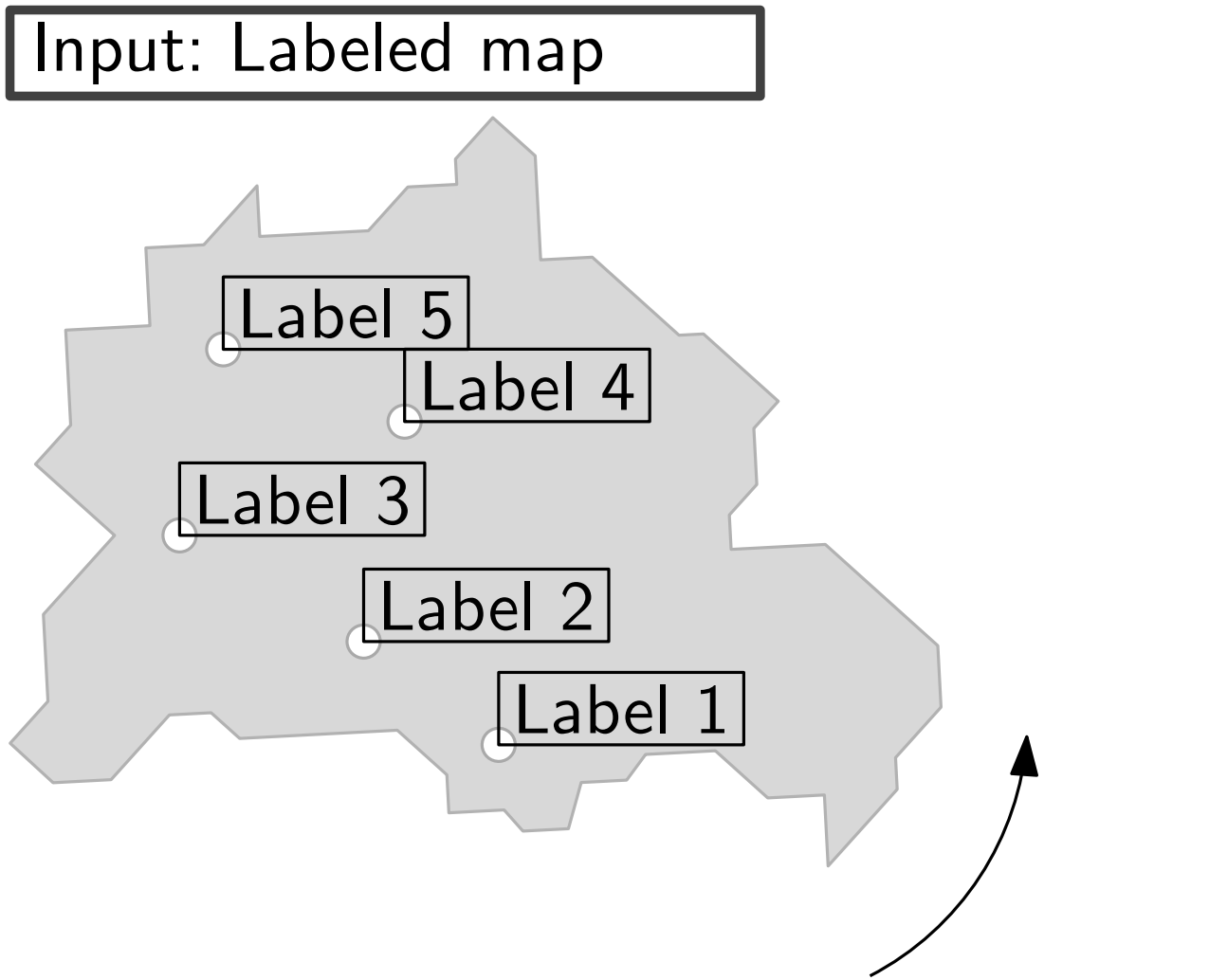
Input: Labeled map



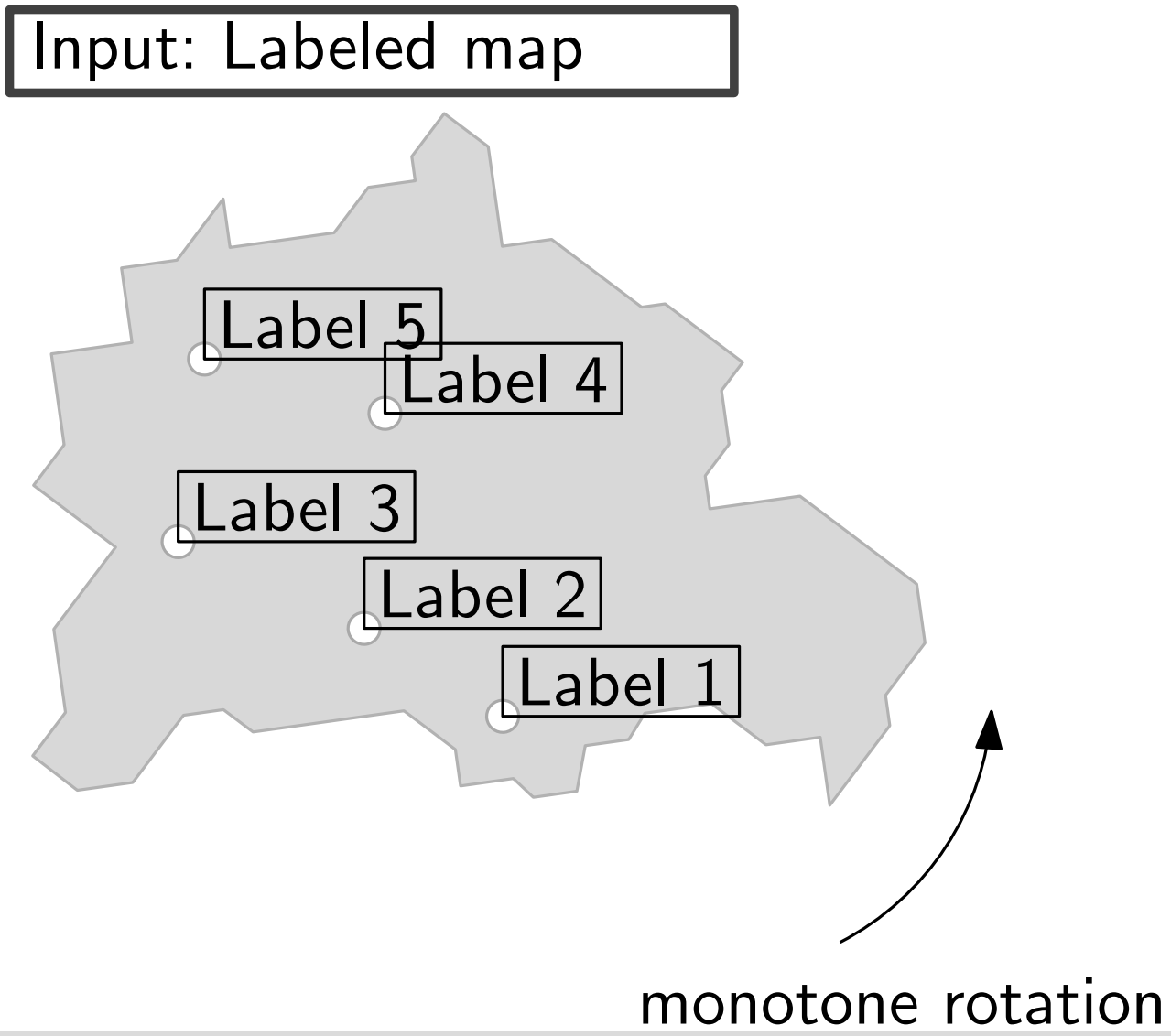
Our Problem


Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

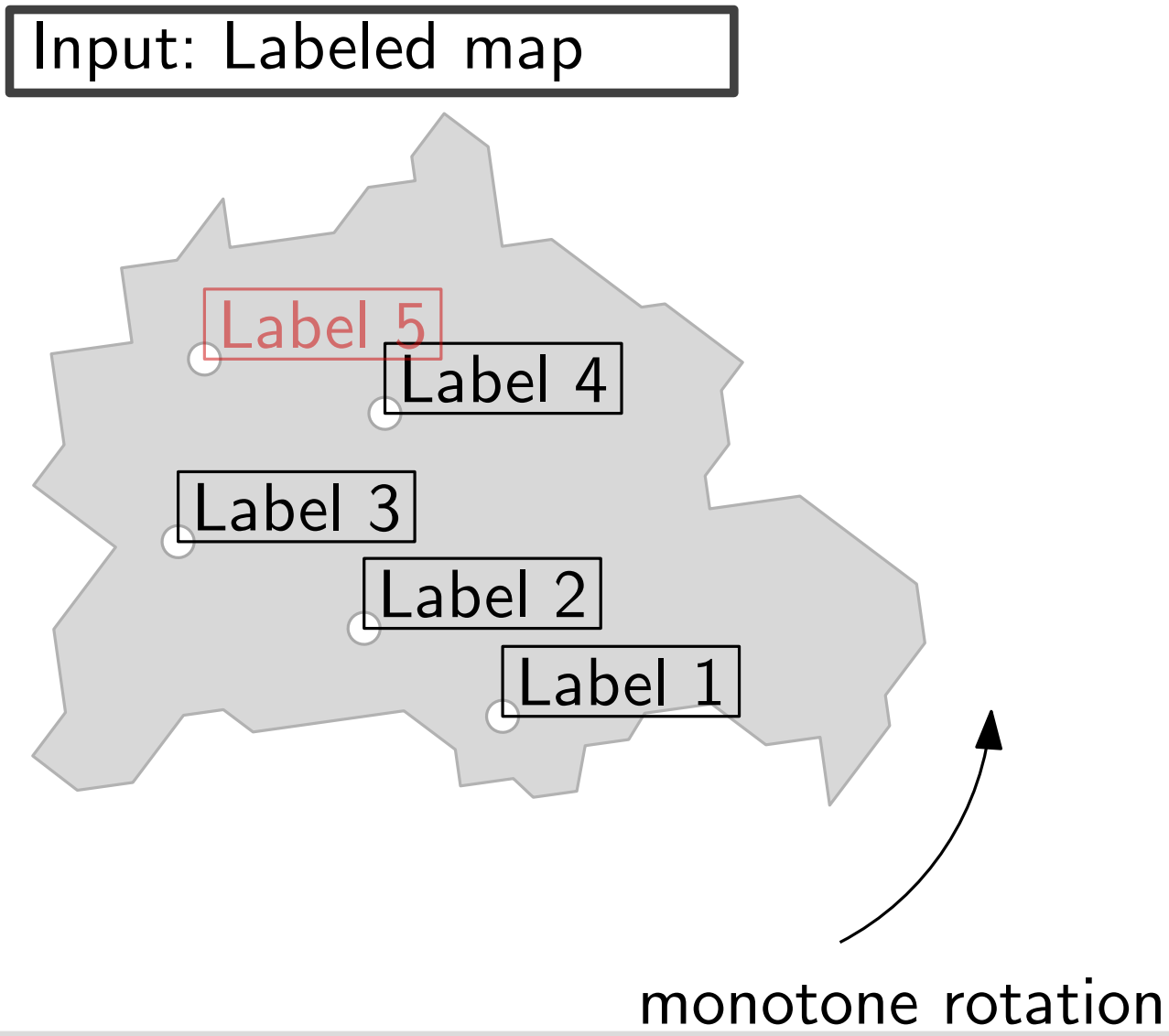
Our Problem


Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

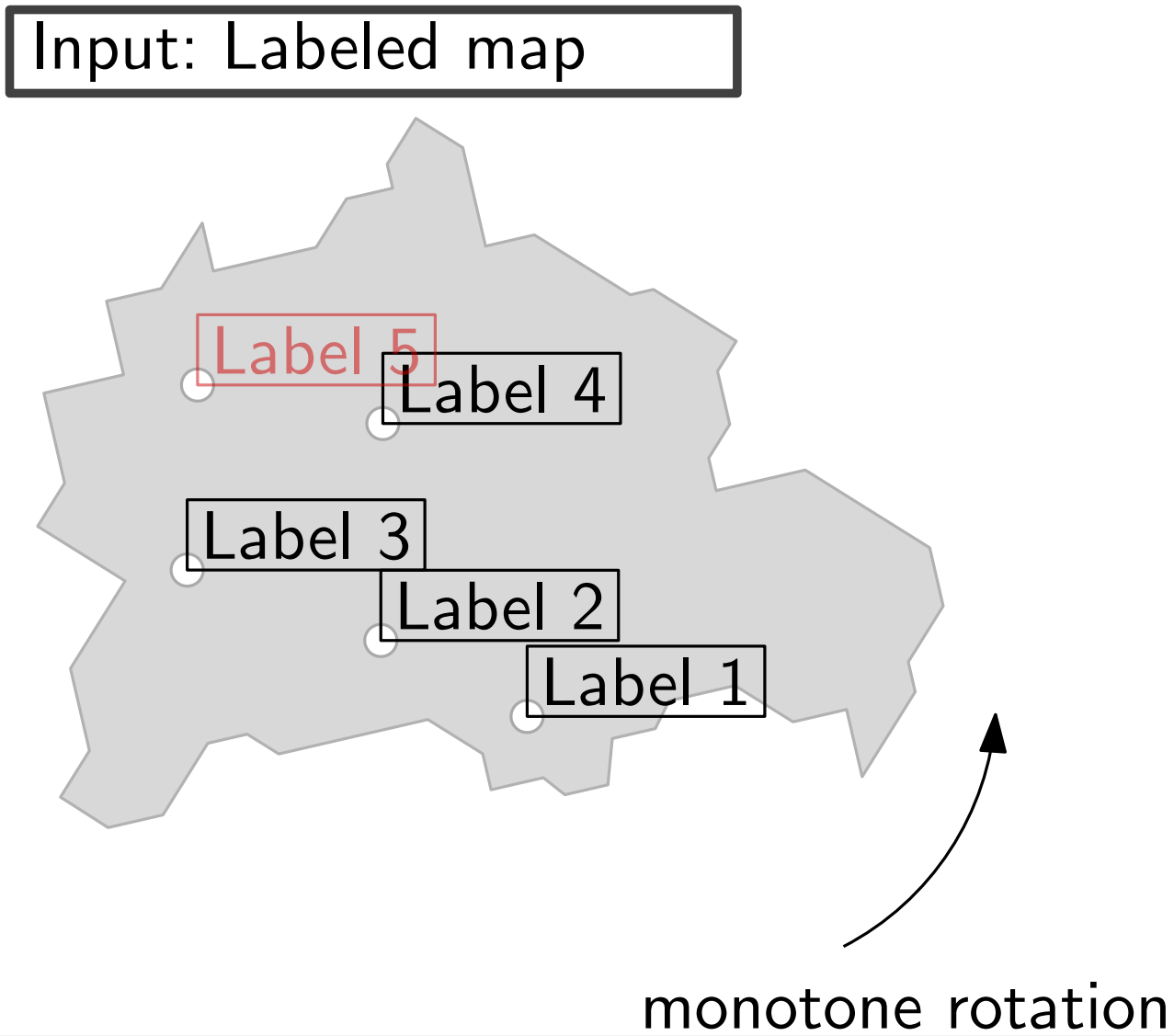
Our Problem


Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

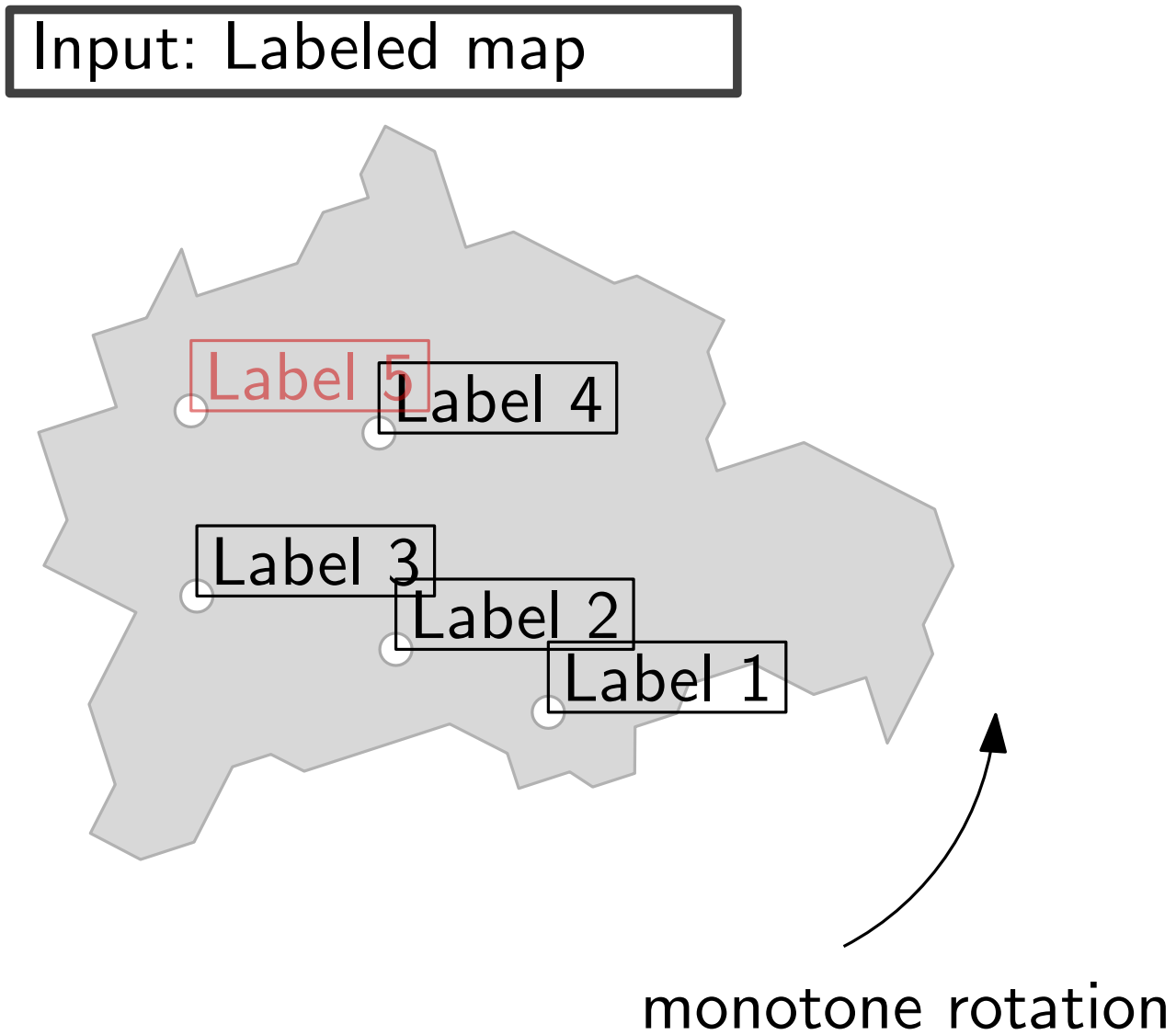
Our Problem


Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

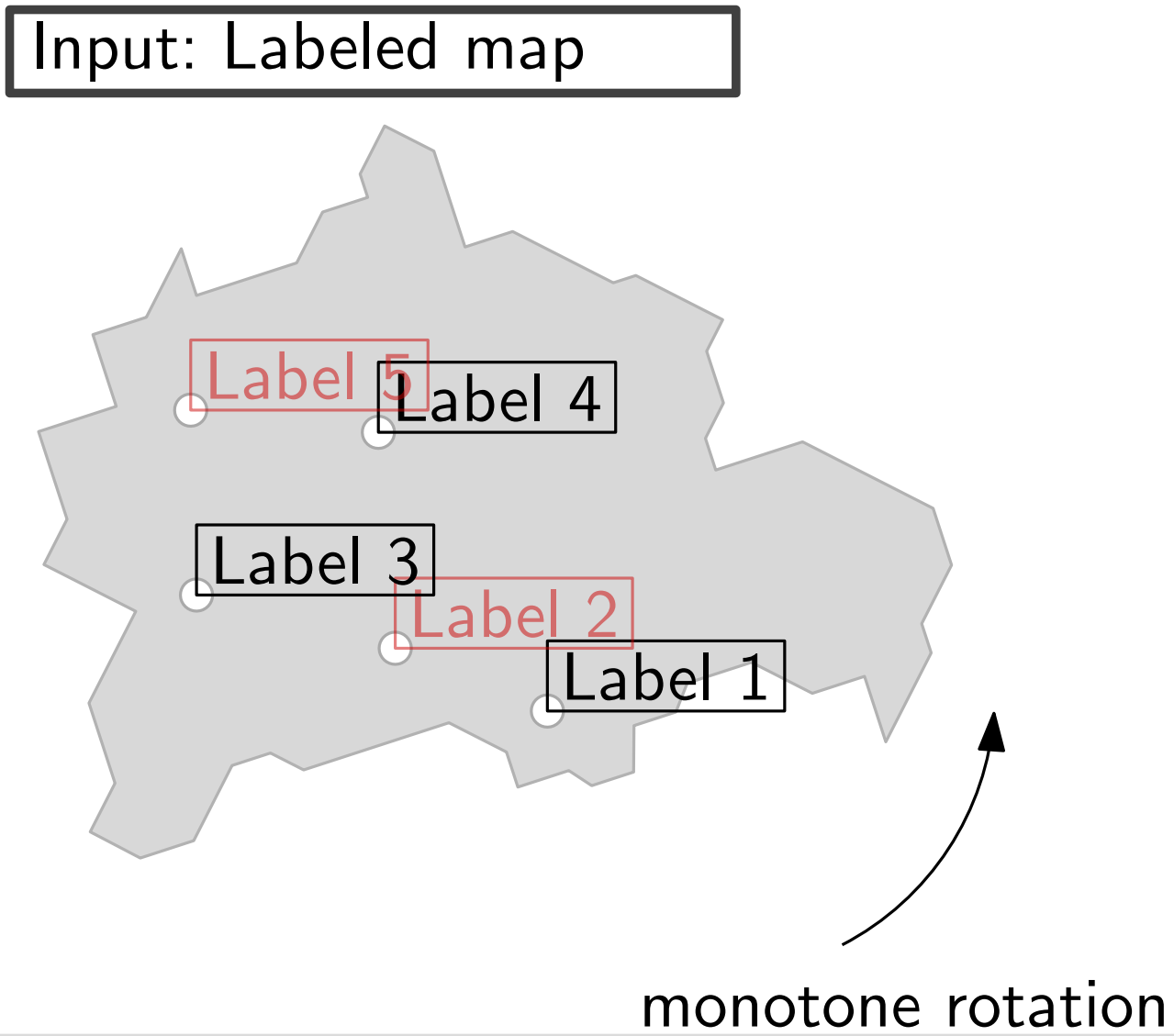
Our Problem


Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

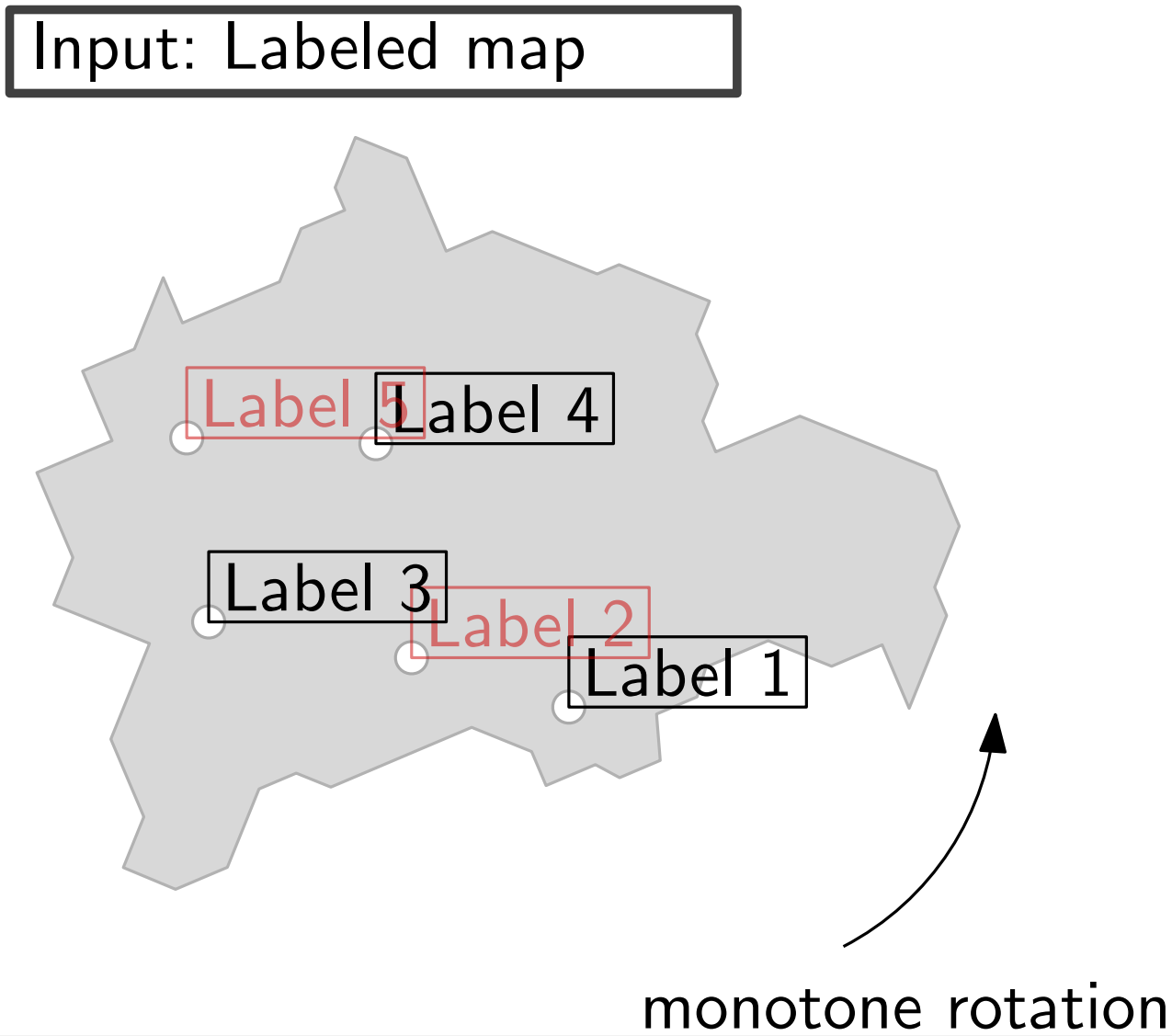
Our Problem


Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

Our Problem

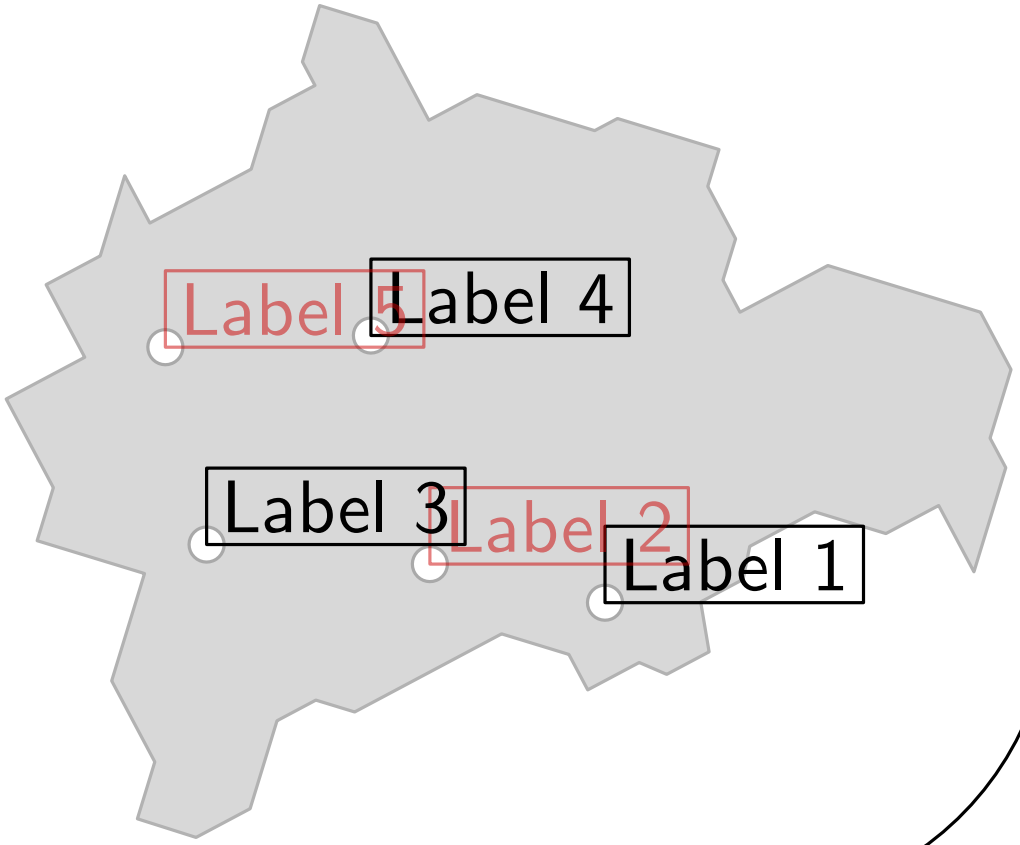

Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

Our Problem


Input: Labeled map
Label 5
Label 4
Label 3
Label 2
Label 1
monotone rotation

Our Problem

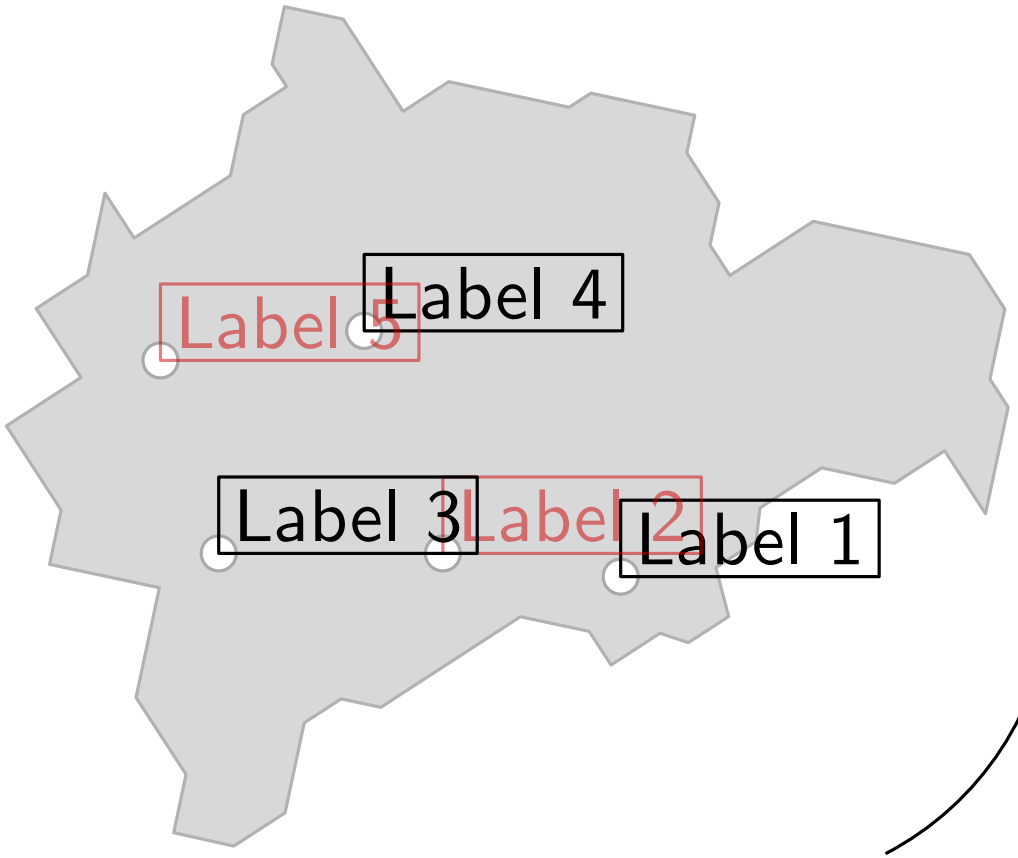
Input: Labeled map



monotone rotation

Our Problem

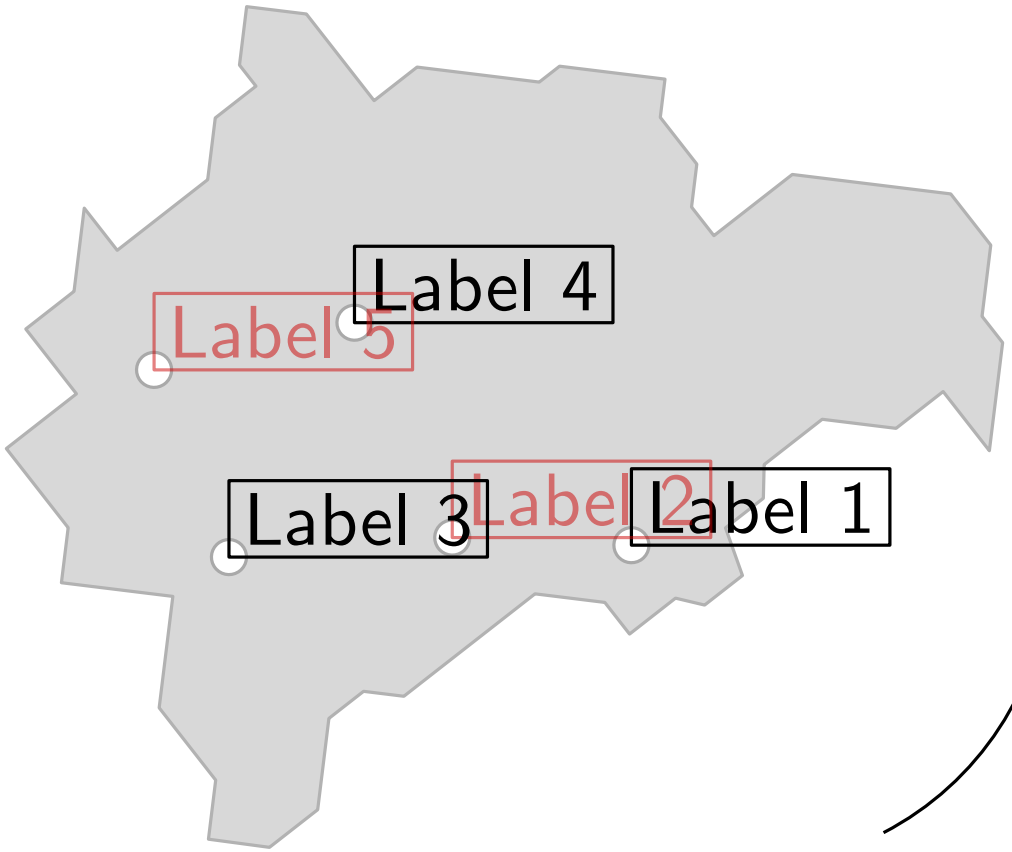
Input: Labeled map



monotone rotation

Our Problem

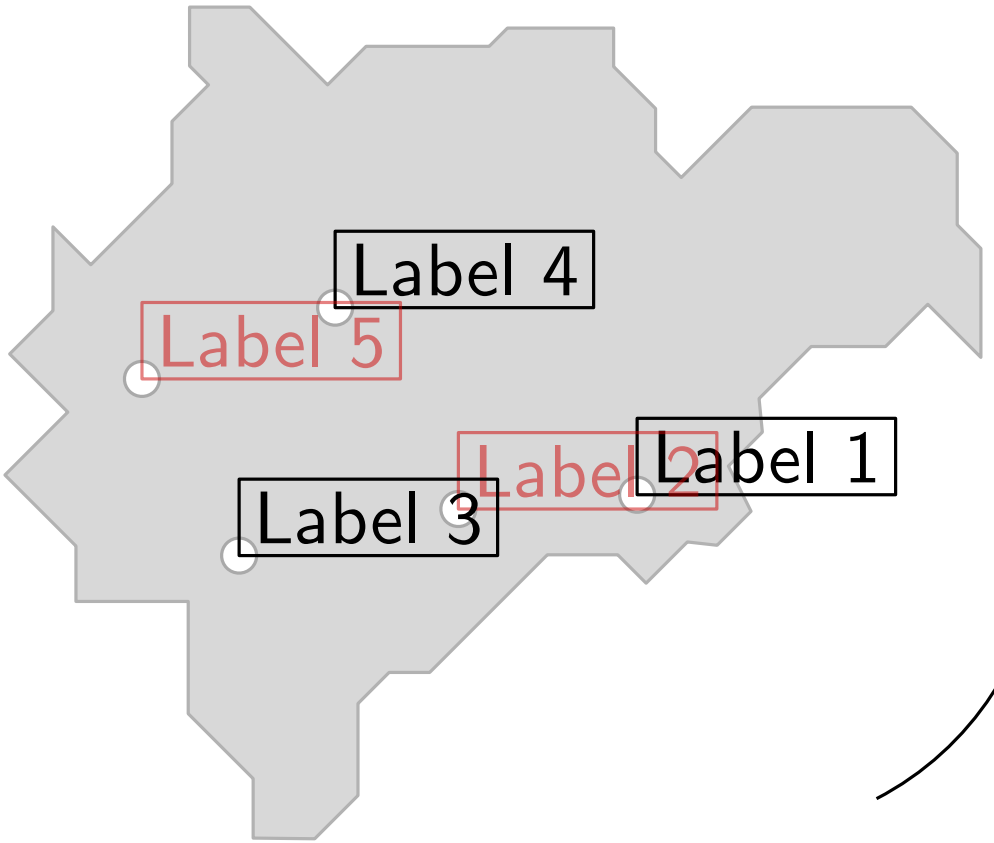
Input: Labeled map



monotone rotation

Our Problem

Input: Labeled map



monotone rotation

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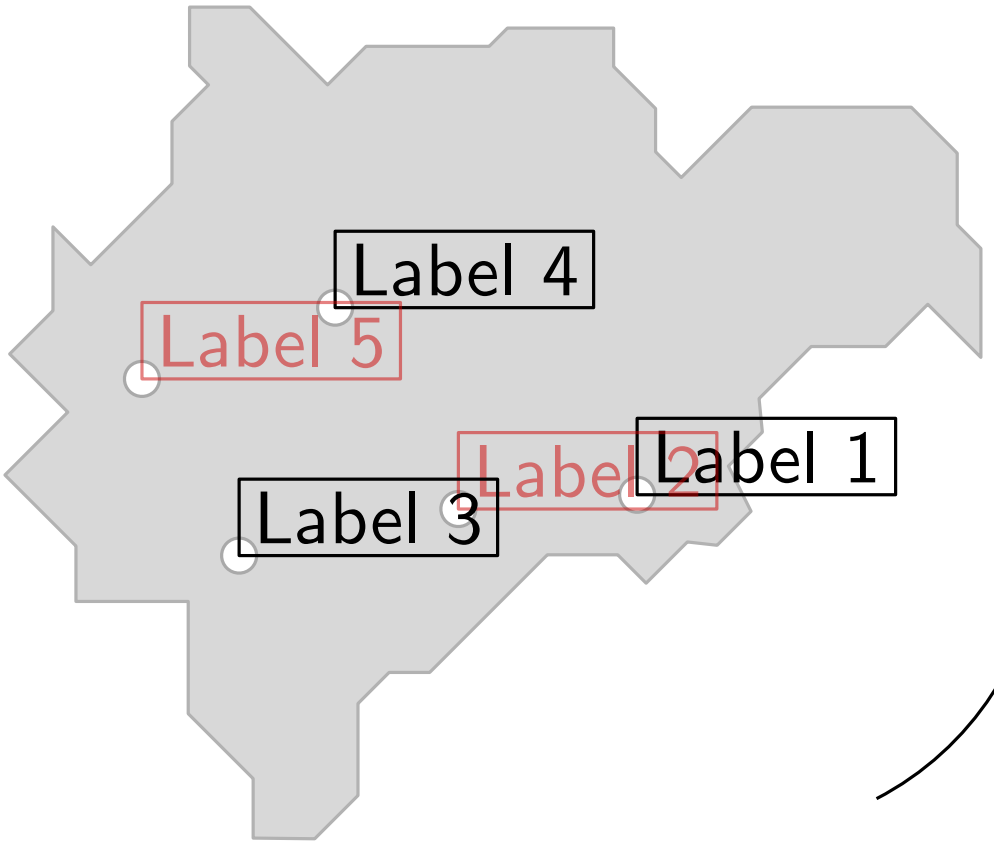

monotone rotation

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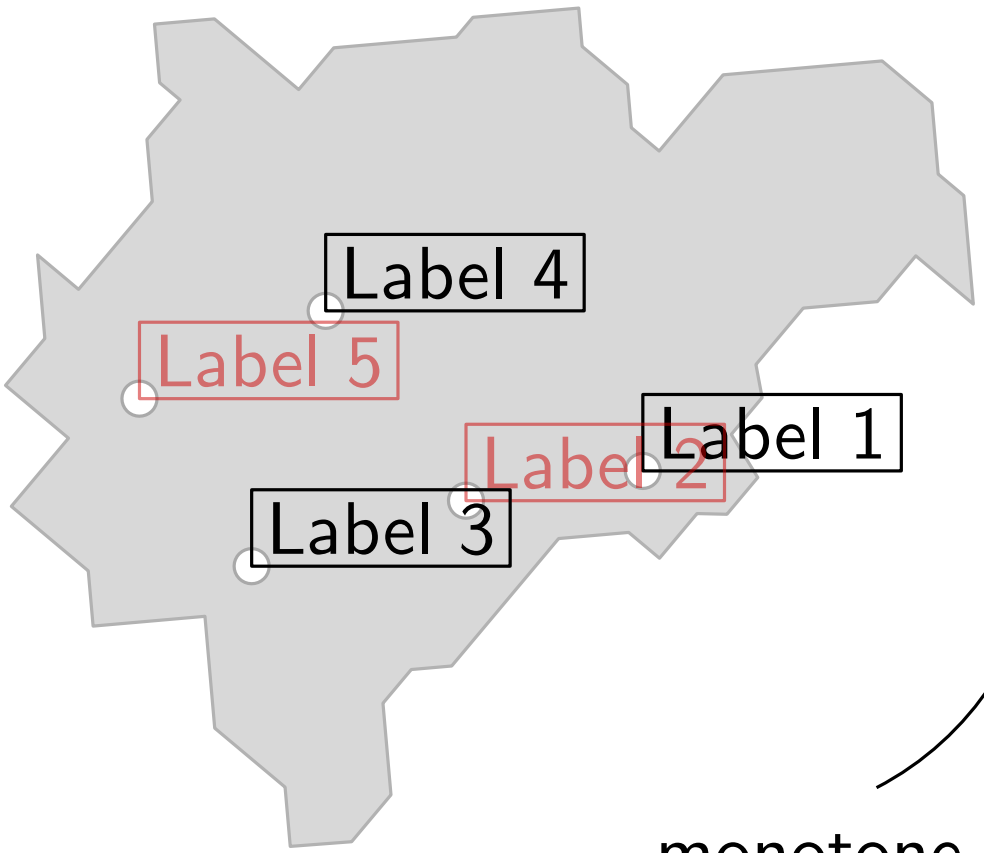
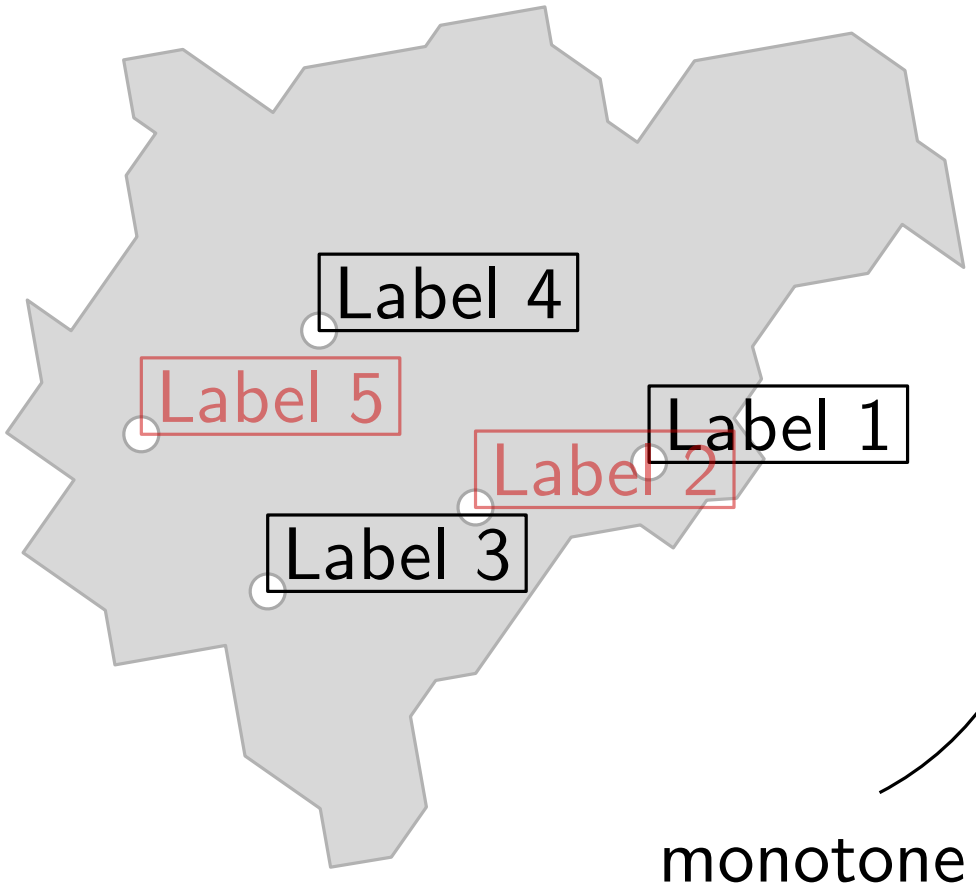
Input: Labeled map



monotone rotation

Our Problem

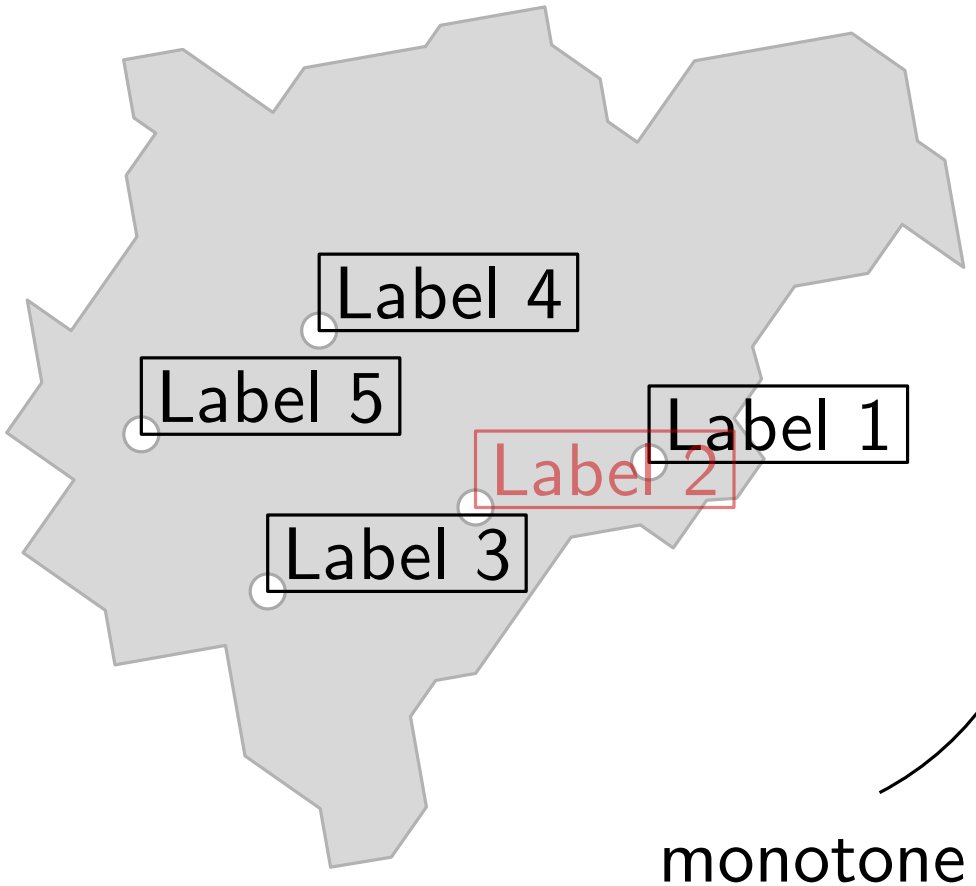
Input: Labeled map



monotone rotation

Our Problem

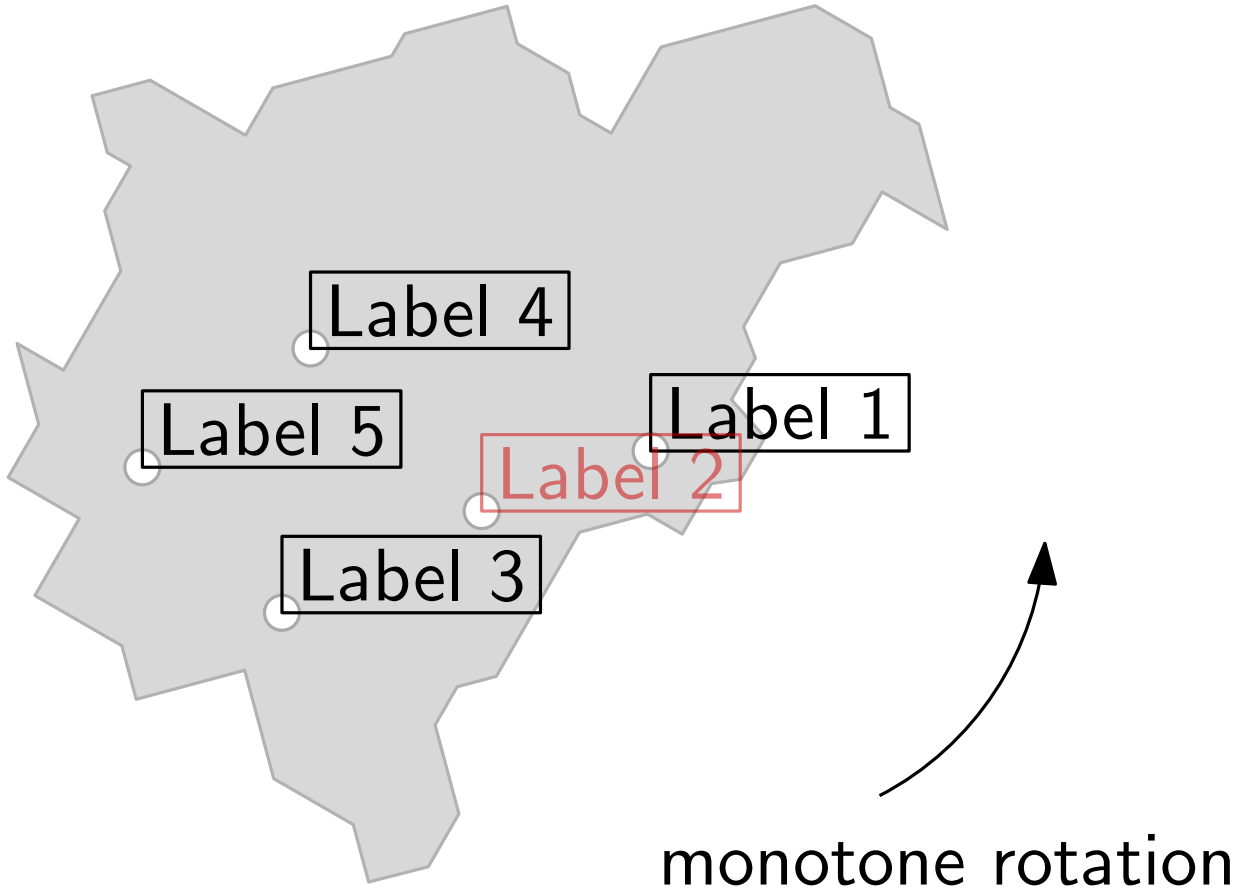
Input: Labeled map



monotone rotation

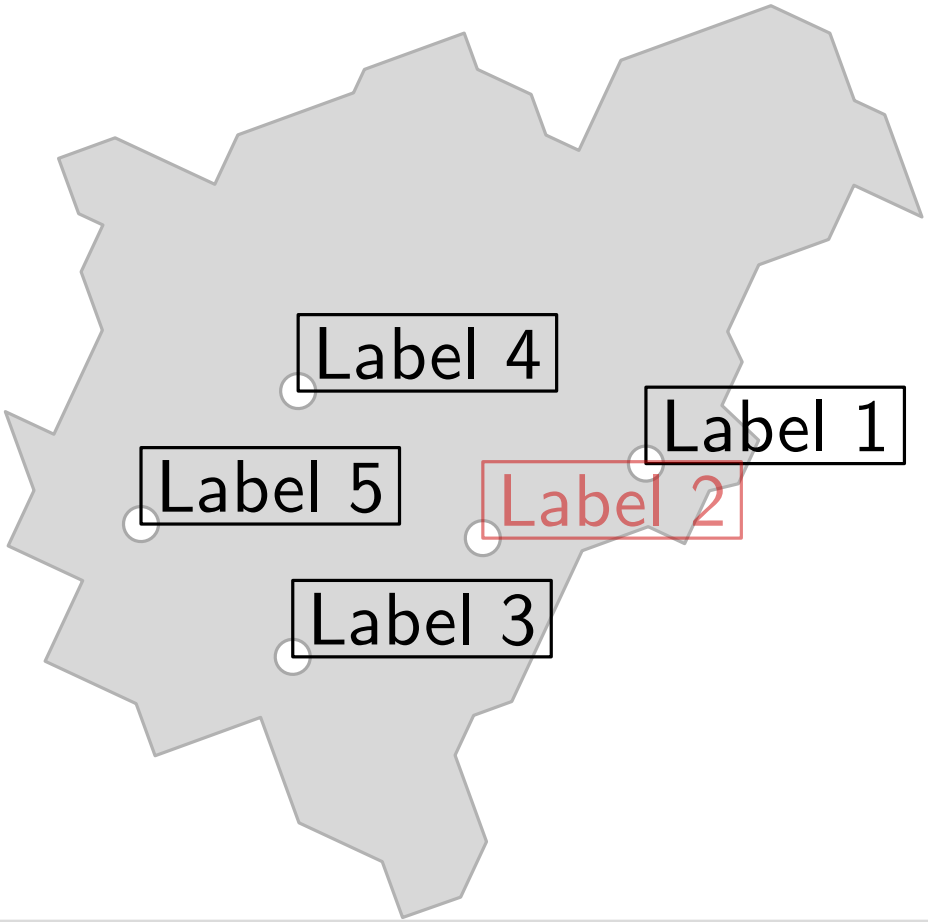
Our Problem

Input: Labeled map



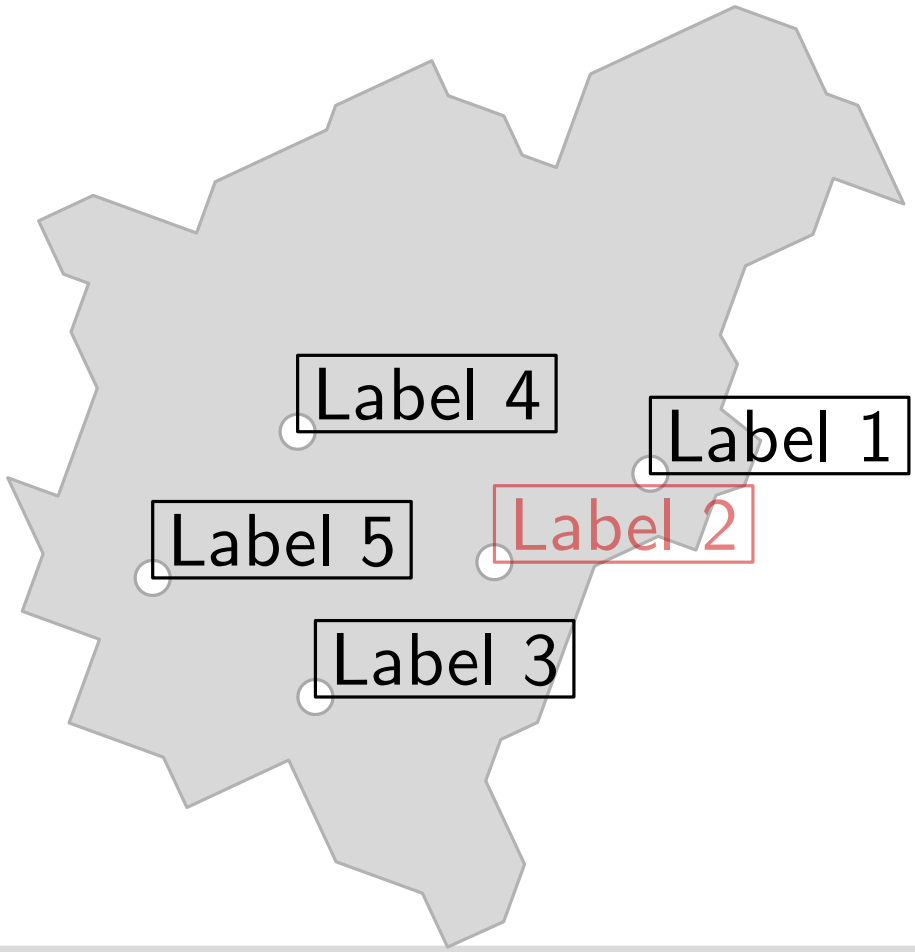
Our Problem

Input: Labeled map



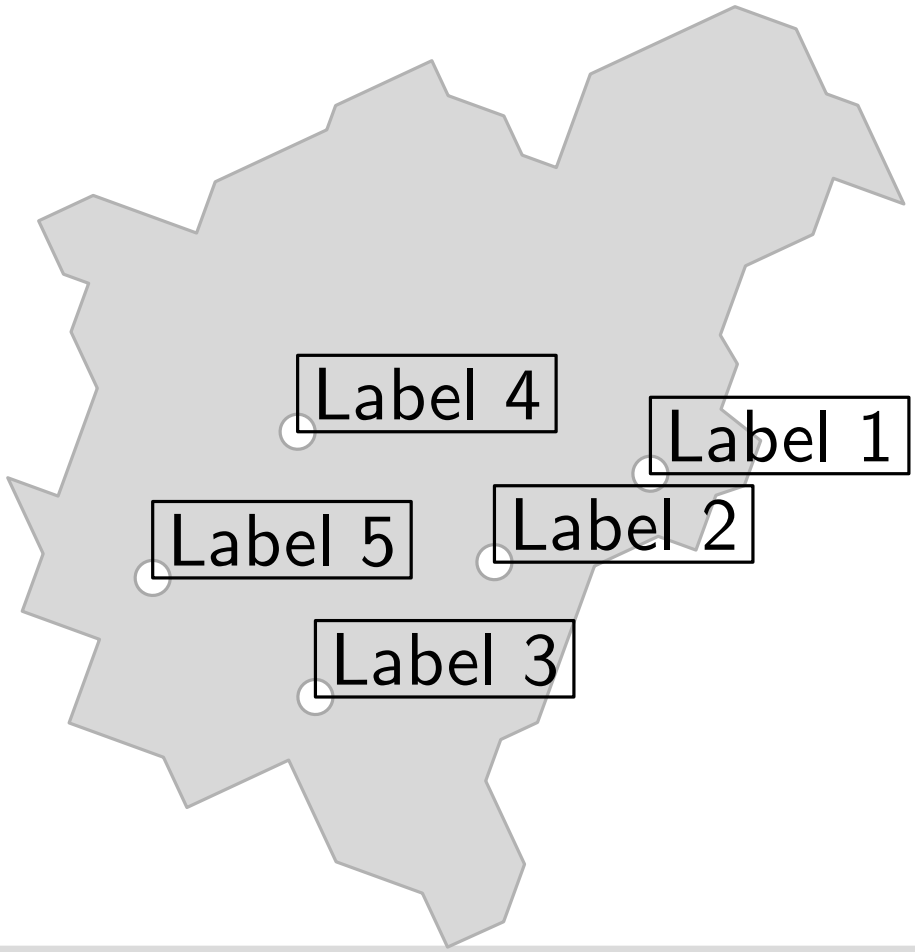
Our Problem

Input: Labeled map



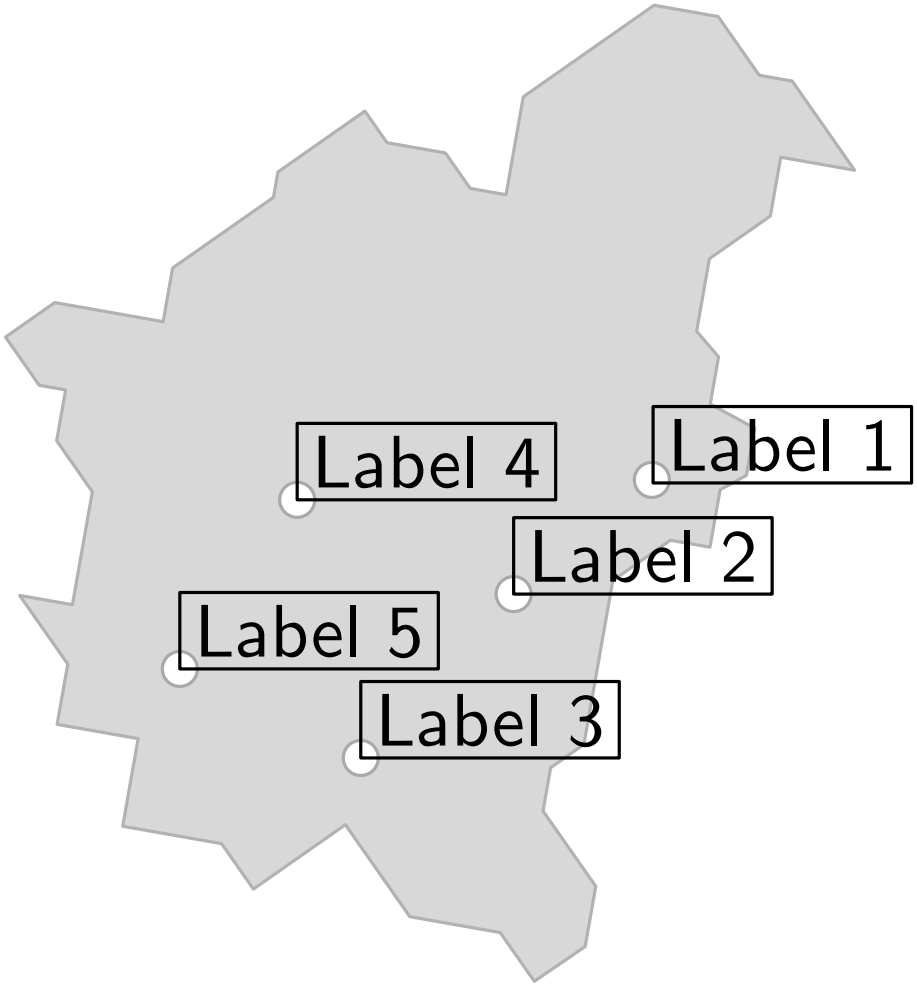
Our Problem

Input: Labeled map



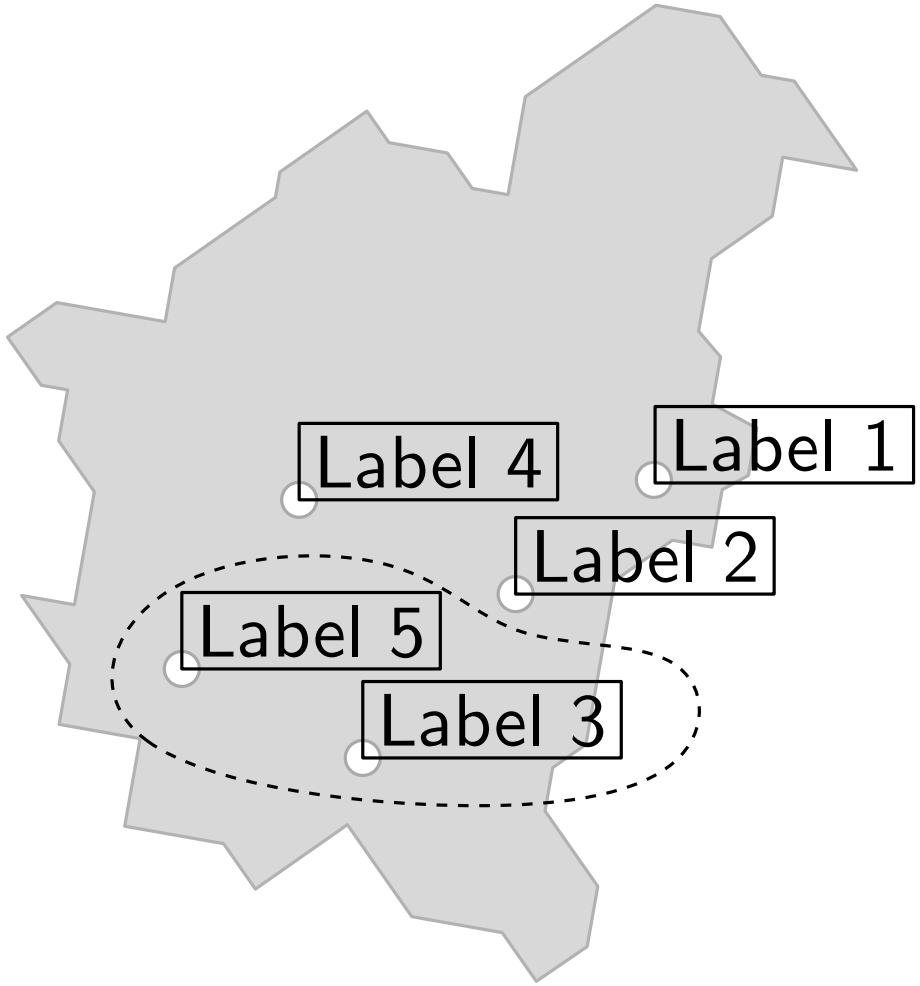
Our Problem

Input: Labeled map



Our Problem

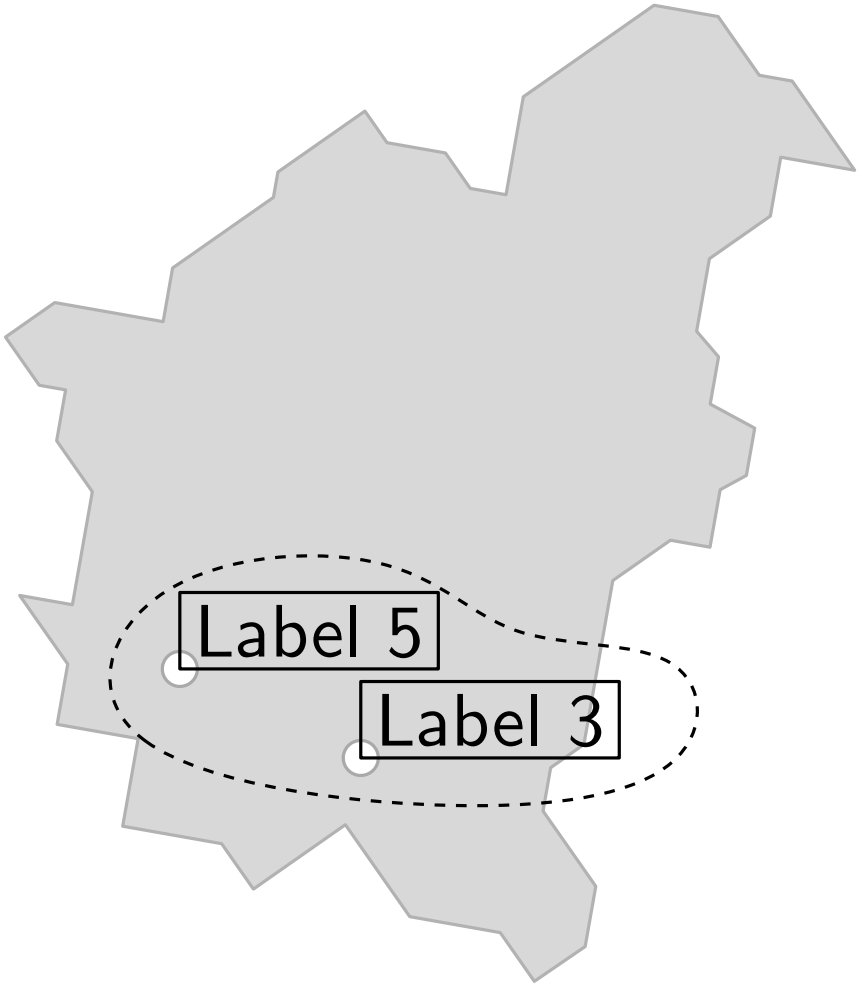
Input: Labeled map

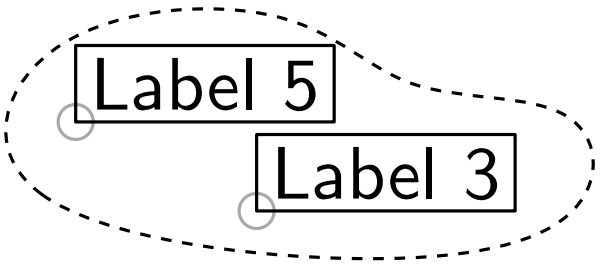


Our Problem

Input: Labeled map

Transformation of the problem

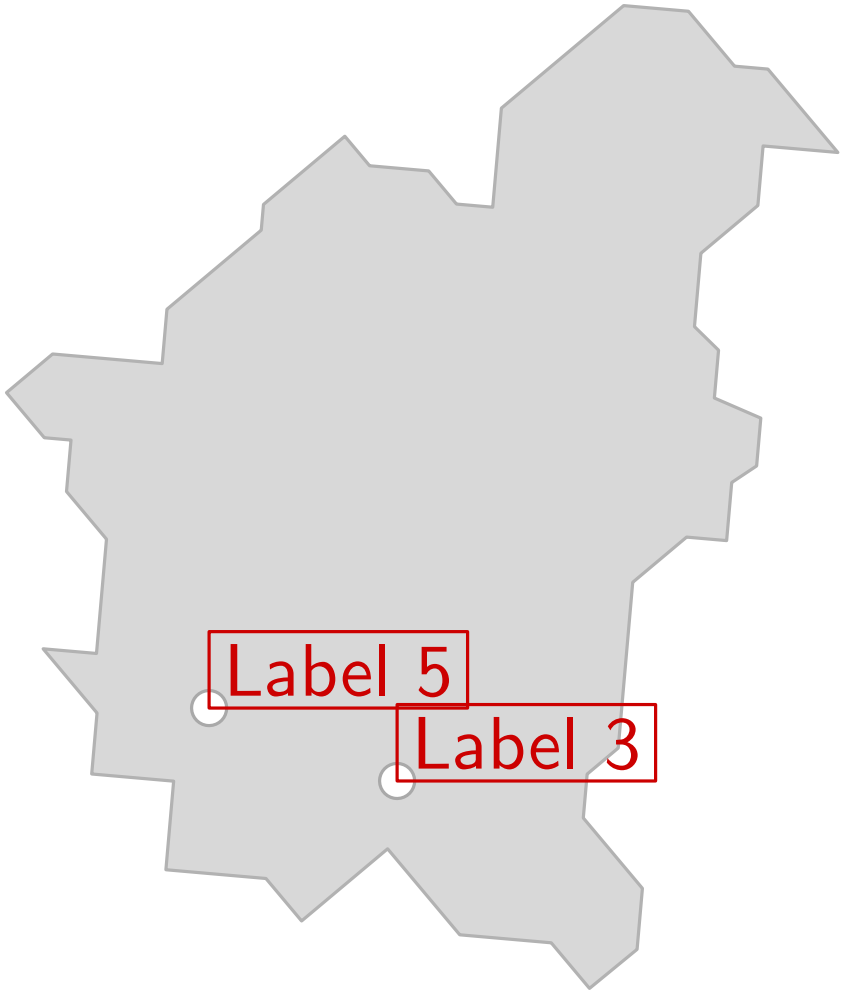


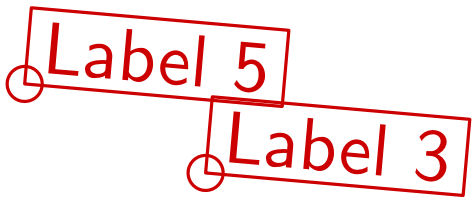


Our Problem

Input: Labeled map

Transformation of the problem

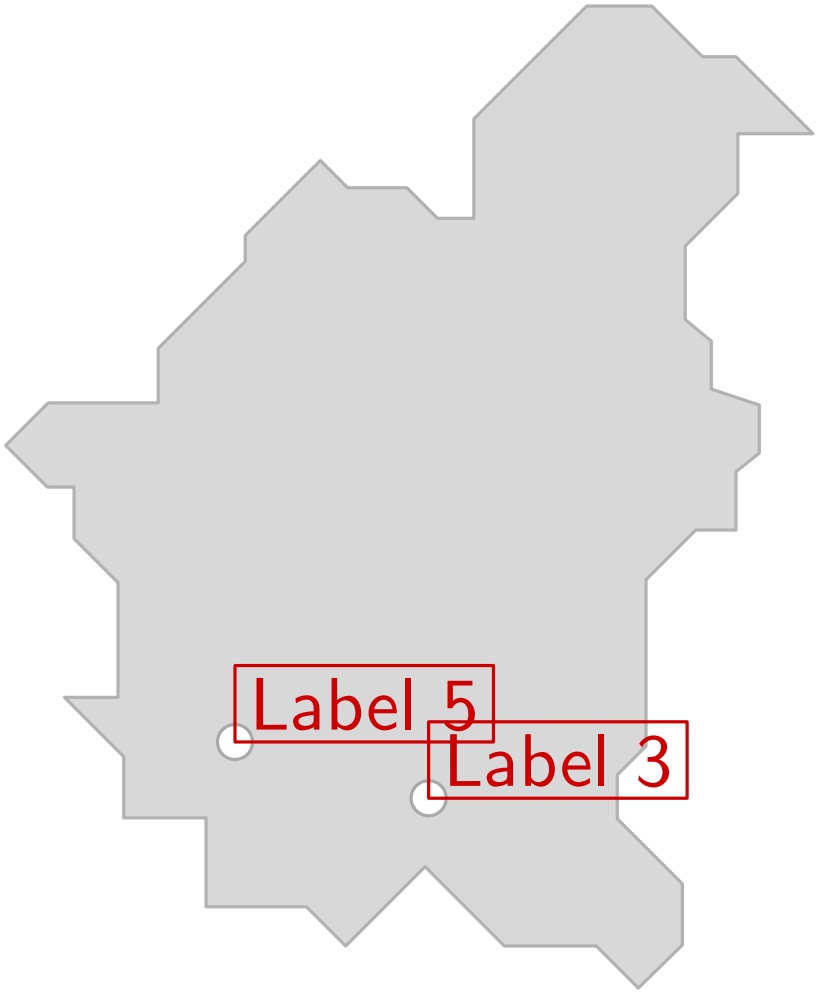


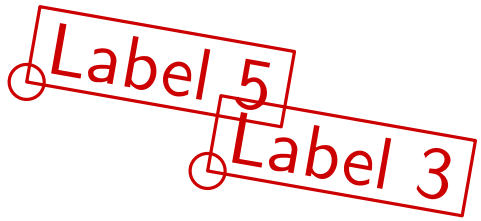


Our Problem

Input: Labeled map

Transformation of the problem

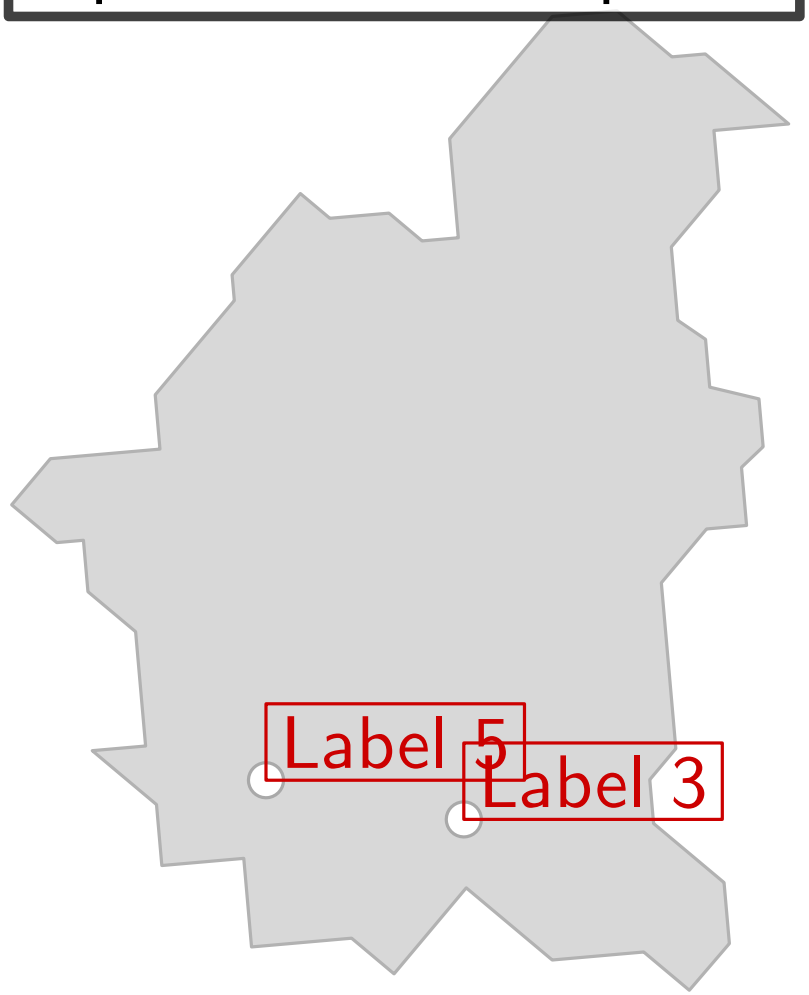


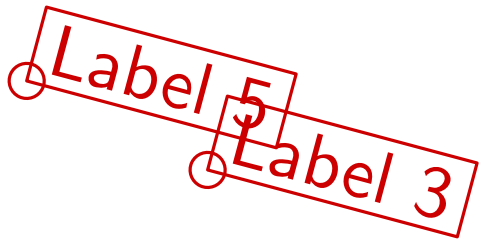


Our Problem

Input: Labeled map

Transformation of the problem

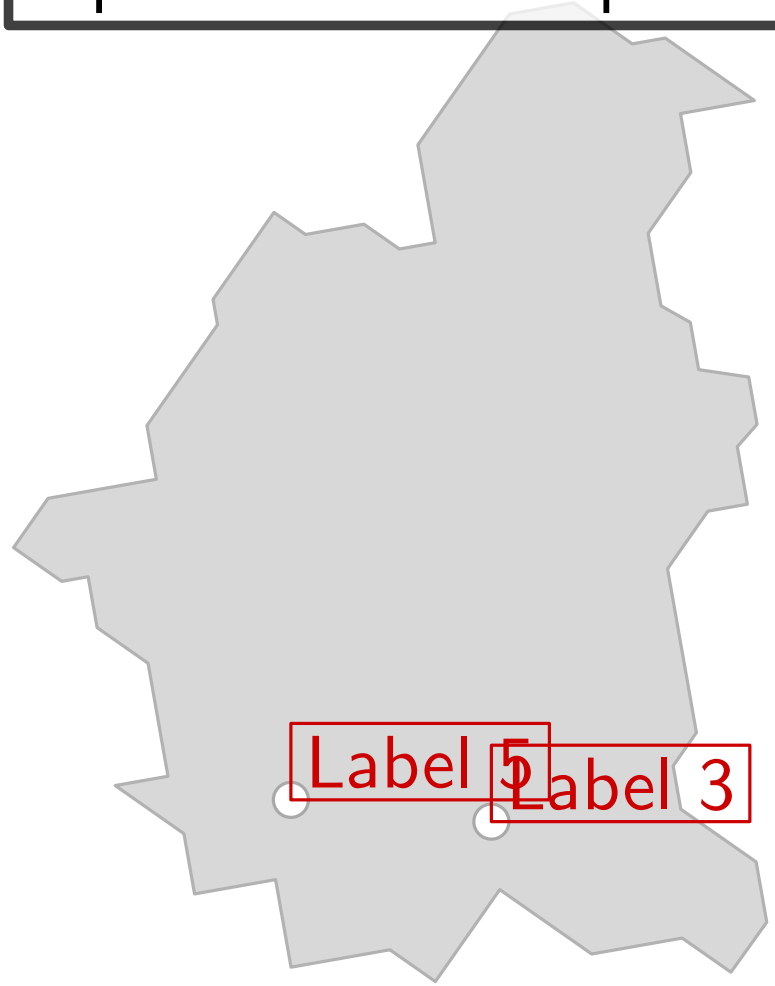


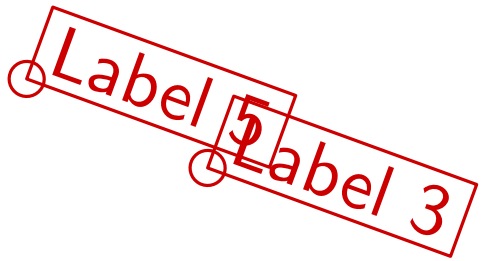


Our Problem

Input: Labeled map

Transformation of the problem

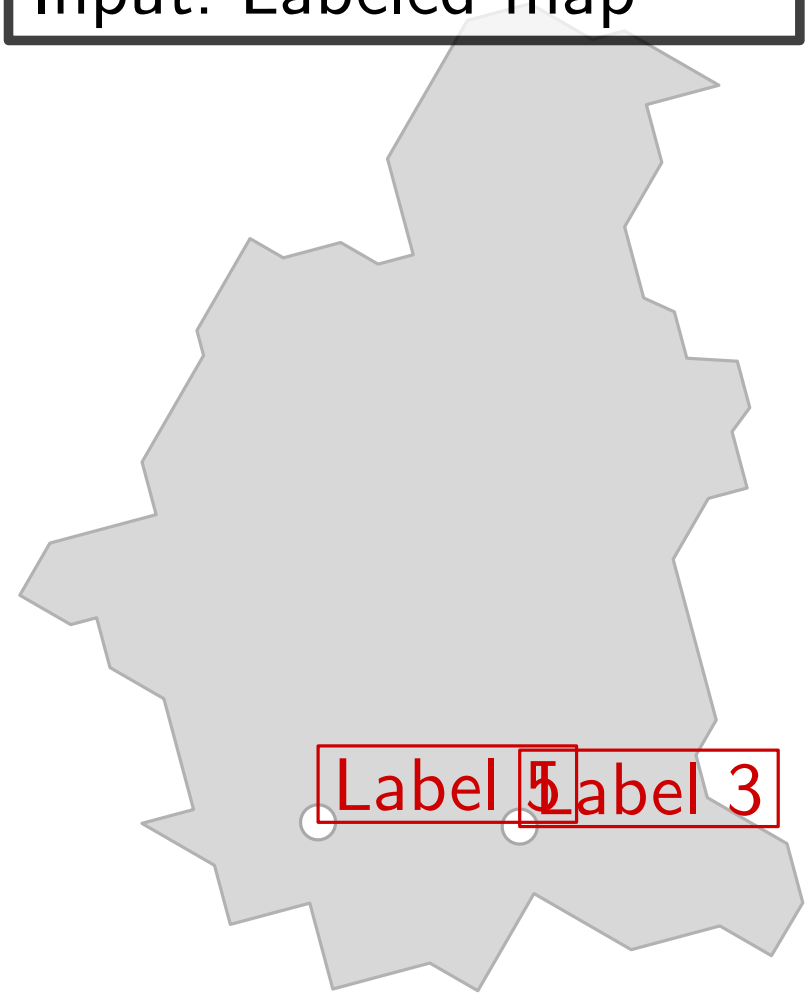




Our Problem

Input: Labeled map

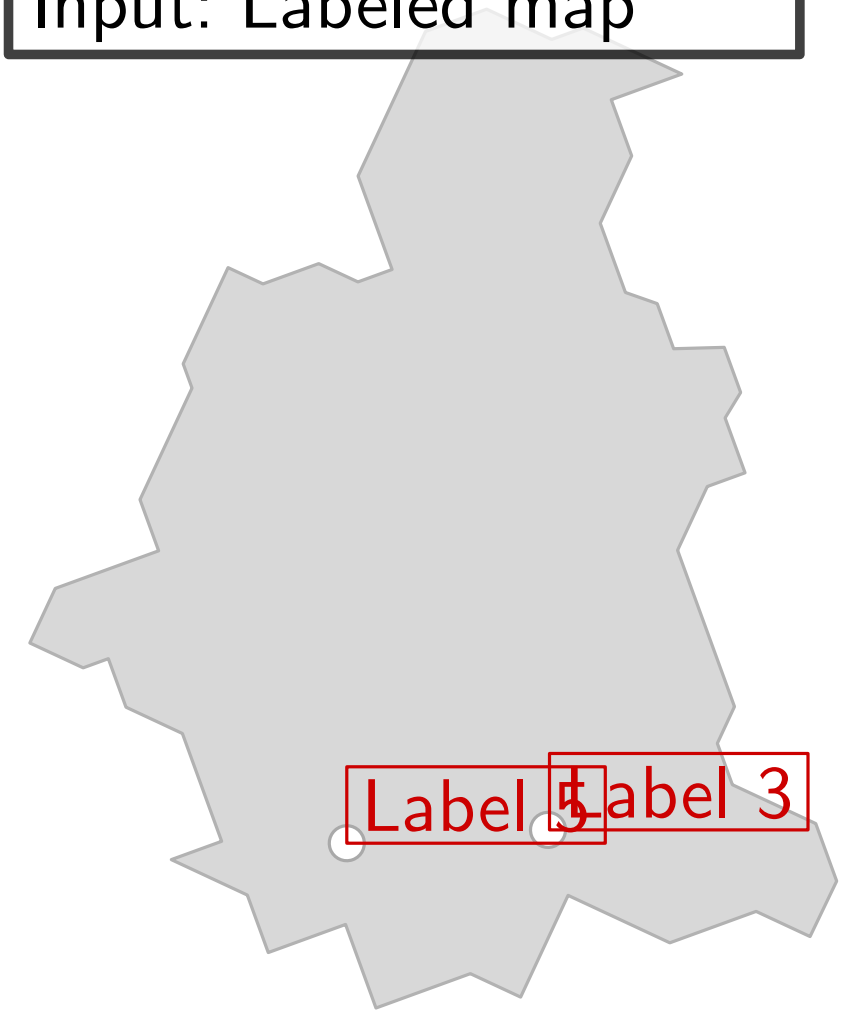
Transformation of the problem



Our Problem

Input: Labeled map

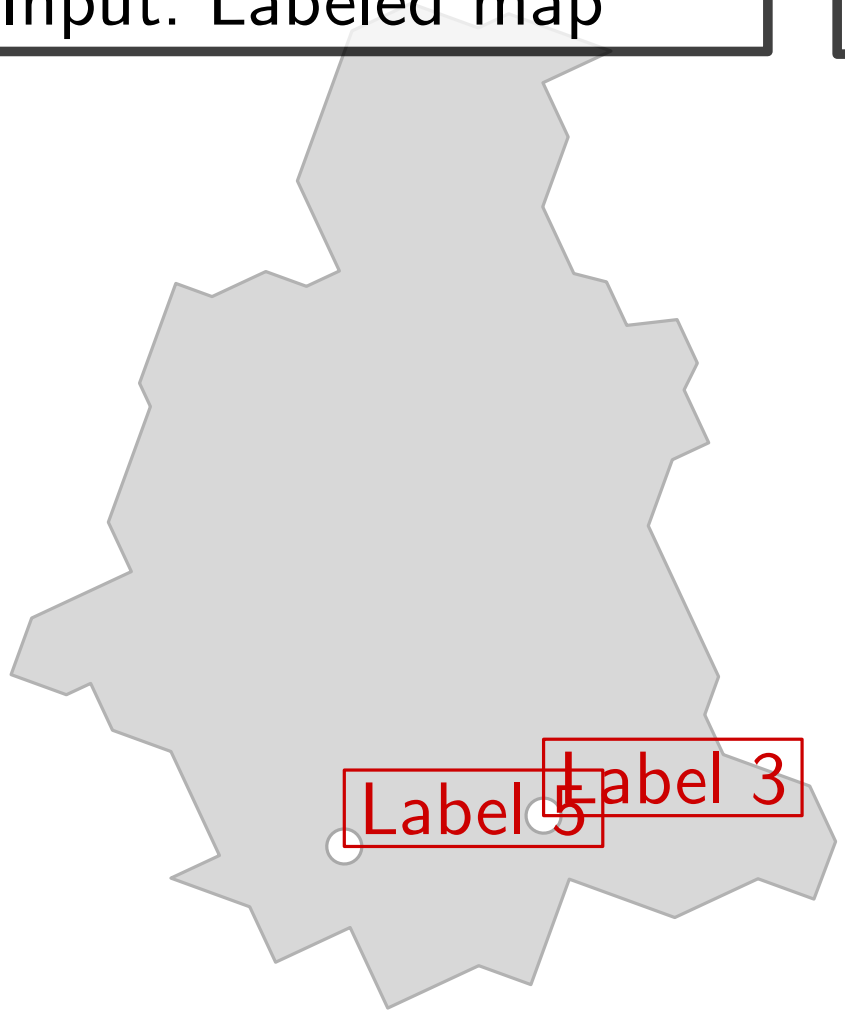
Transformation of the problem



Our Problem

Input: Labeled map

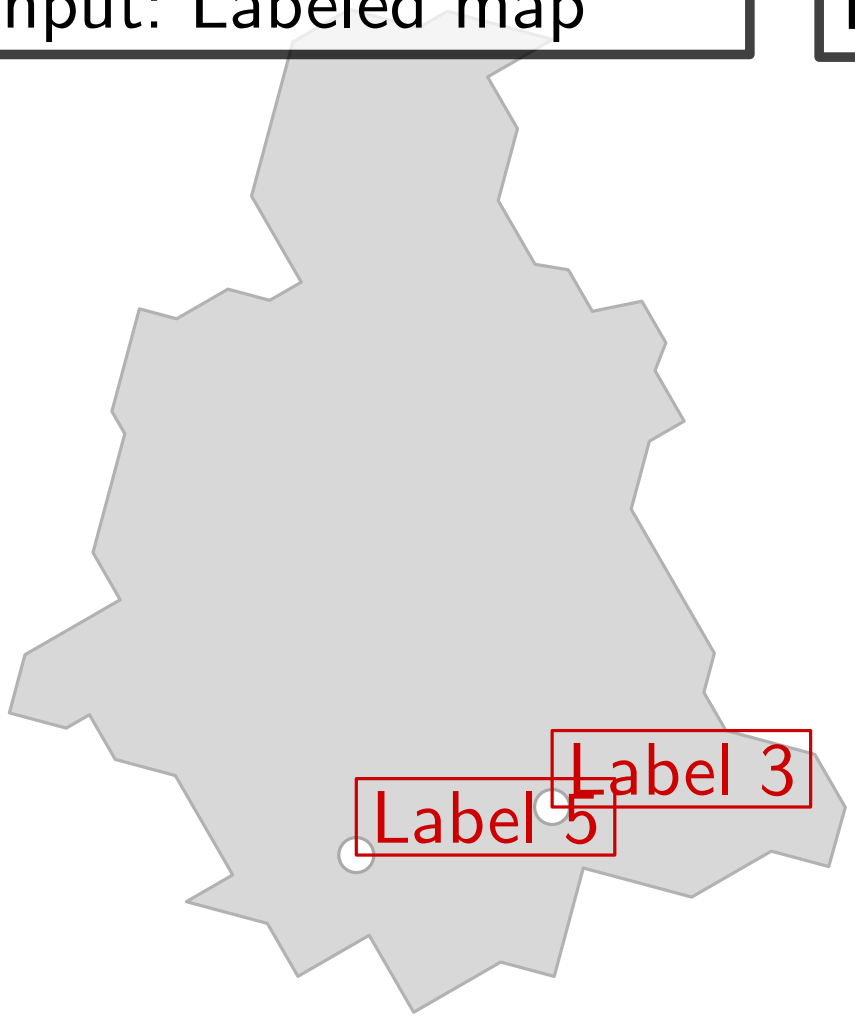
Transformation of the problem



Our Problem

Input: Labeled map

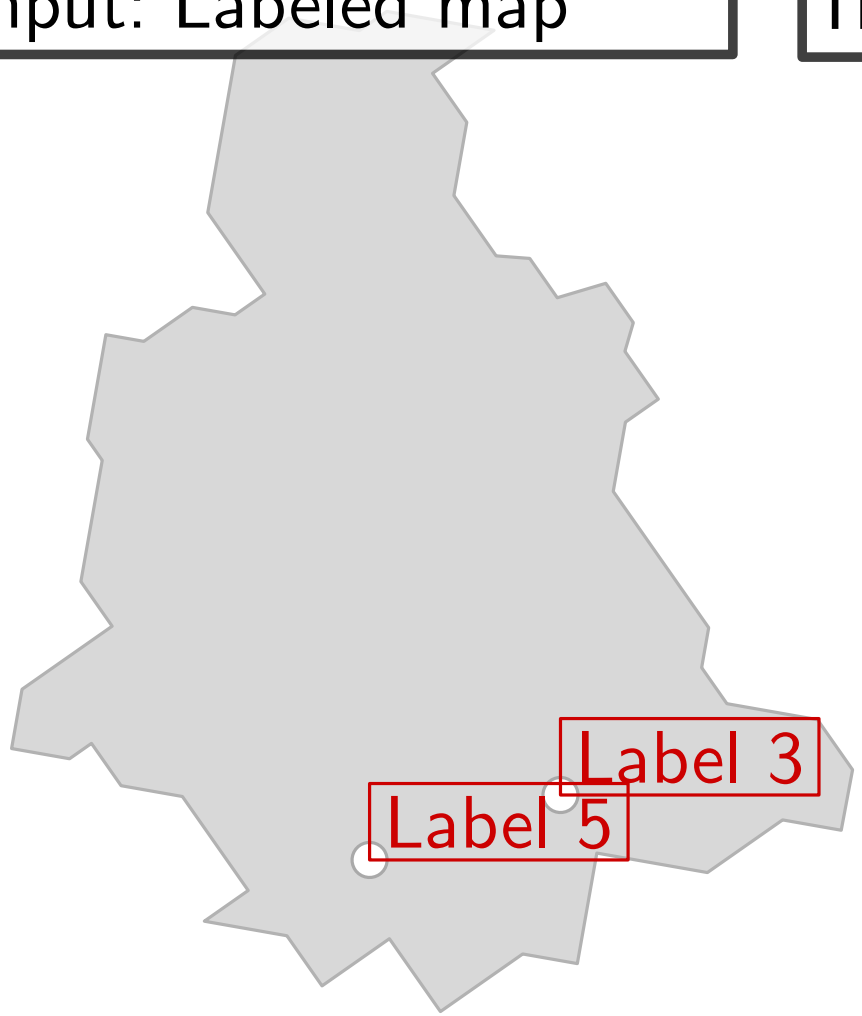
Transformation of the problem

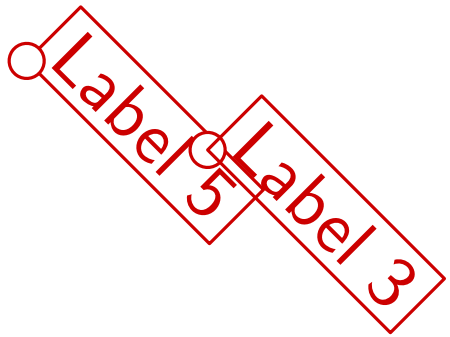


Our Problem

Input: Labeled map

Transformation of the problem

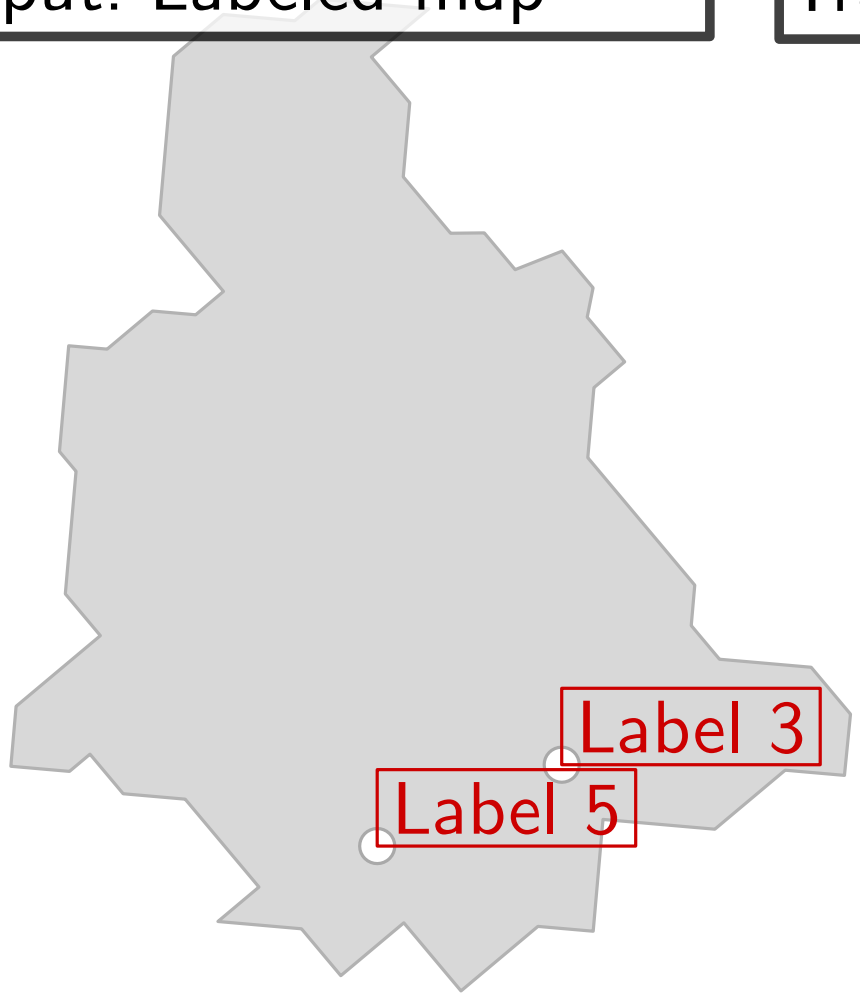


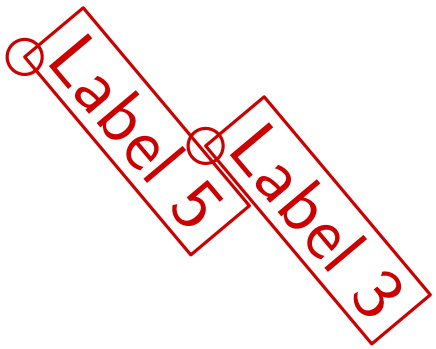


Our Problem

Input: Labeled map

Transformation of the problem

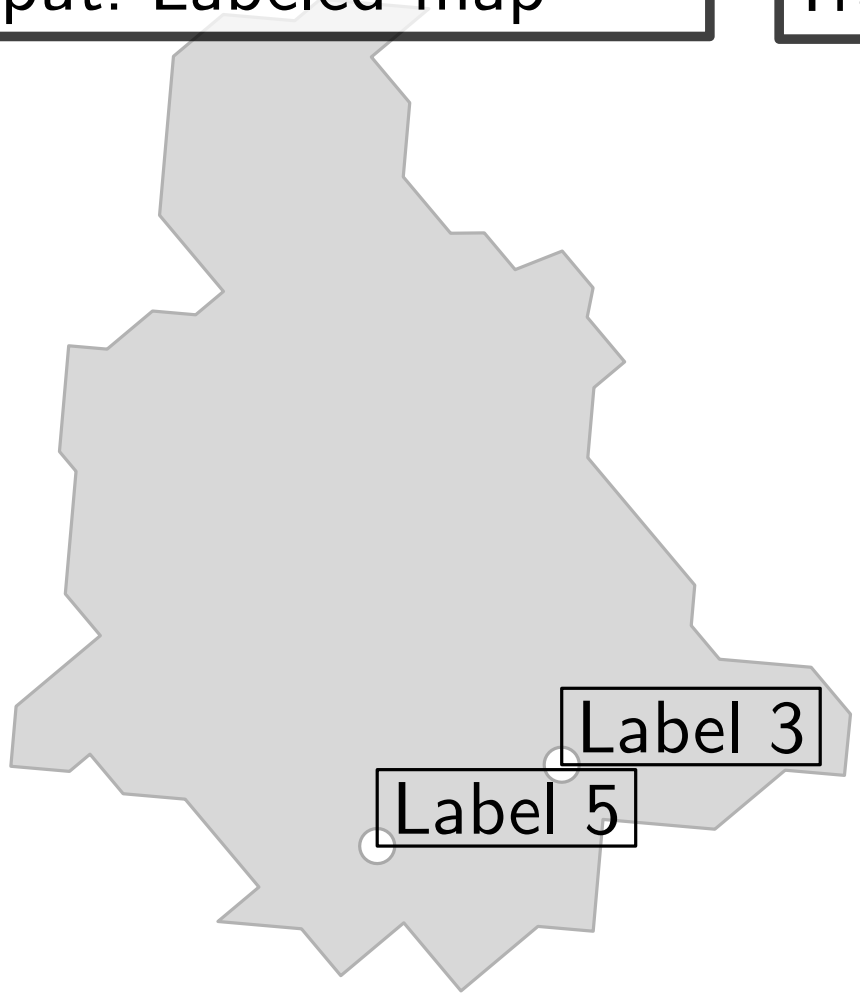


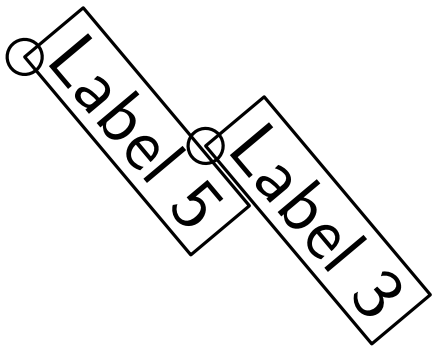


Our Problem

Input: Labeled map

Transformation of the problem

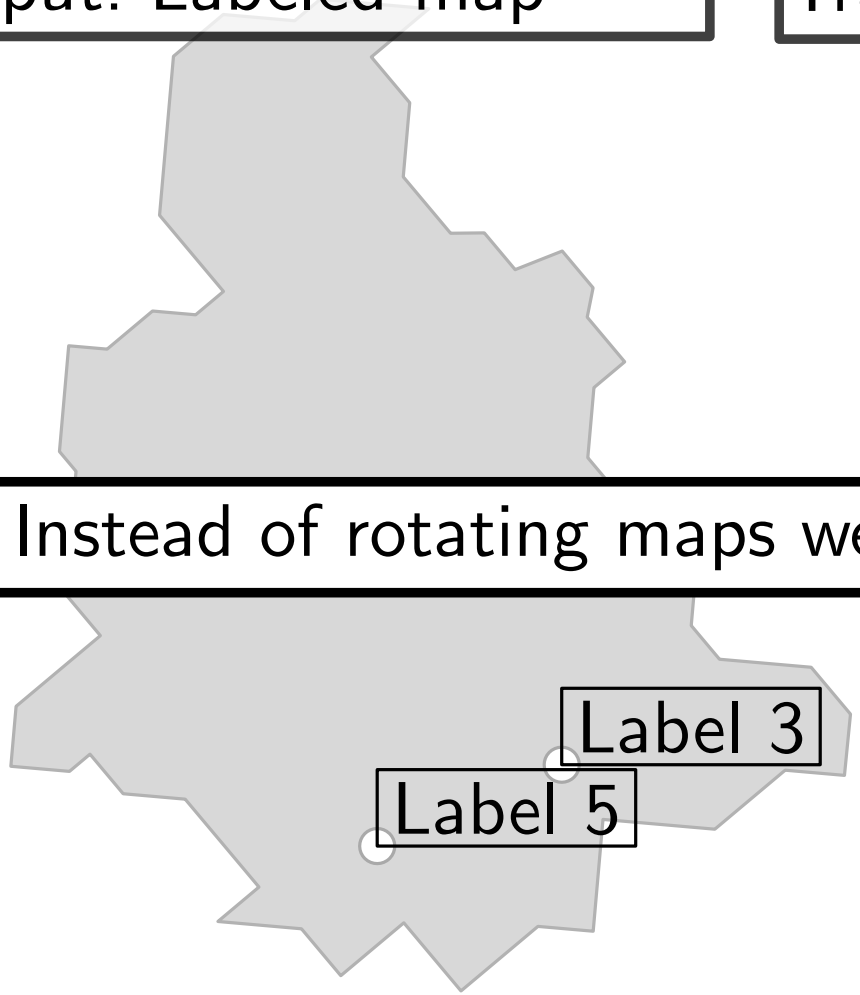




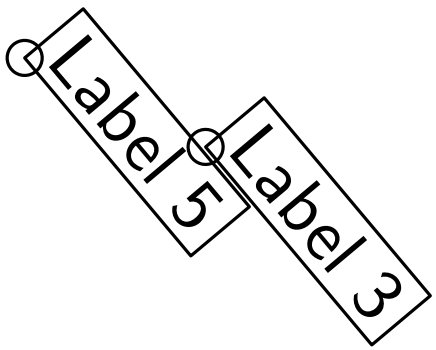
Our Problem

Input: Labeled map

Transformation of the problem



Instead of rotating maps we consider **rotating labels**



Desiderata

- no label occludes a point
- no two labels overlap

consistency:

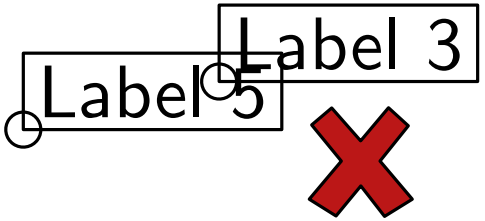
- no “**jumping**”
- no “**flickering**”

Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap

consistency:

- no “**jumping**”
- no “**flickering**”

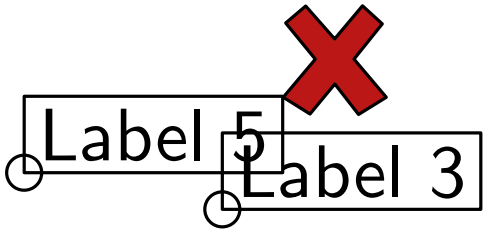


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

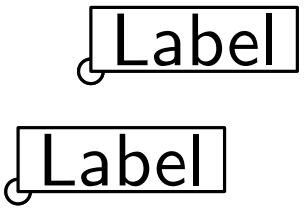


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

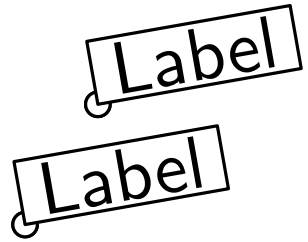


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

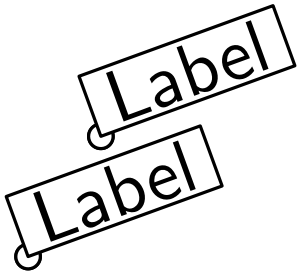


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

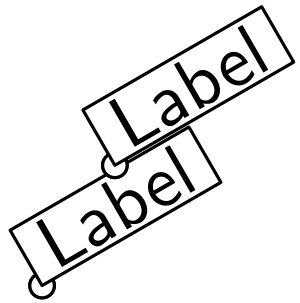


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

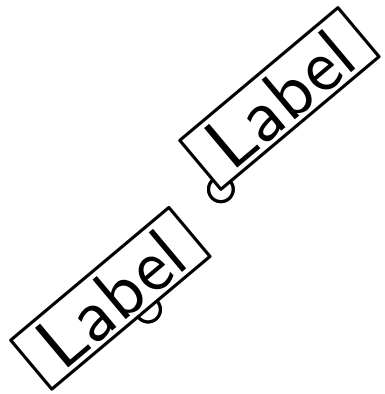


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

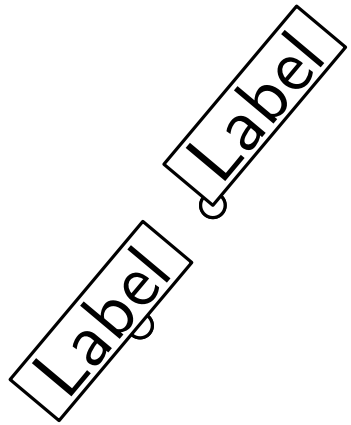


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

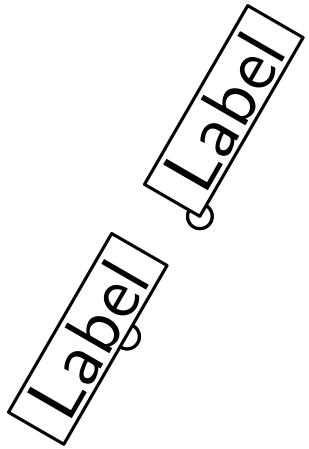


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no “**jumping**”
- no “**flickering**”



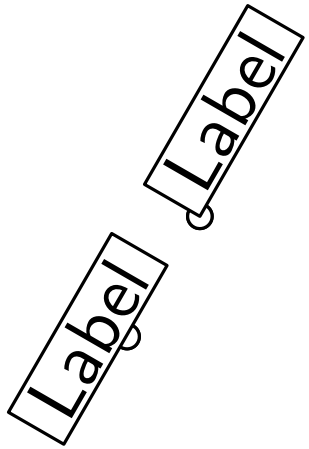
Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"

no jumping:
fix relative position of the anchor



Desiderata

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consistency:

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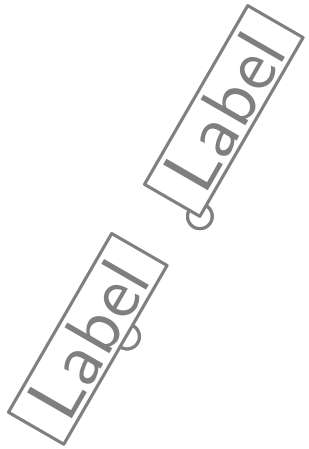

Desiderata

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consistency:

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- no "**flickering**"

no jumping:
fix relative position of the anchor

Desiderata

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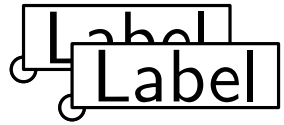

Desiderata

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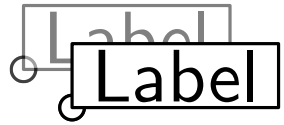
no jumping:
fix relative position of the anchor



Desiderata

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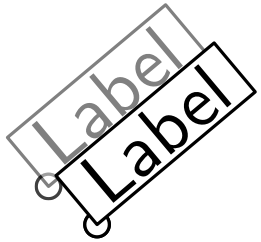
no jumping:
fix relative position of the anchor



Desiderata

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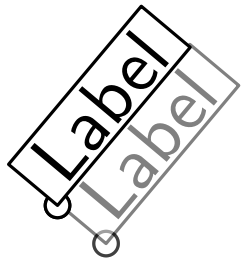
consistency:

- no "**jumping**"
- no "**flickering**"

no jumping:
fix relative position of the anchor

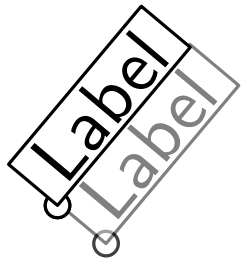


Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"



no jumping:
fix relative position of the anchor

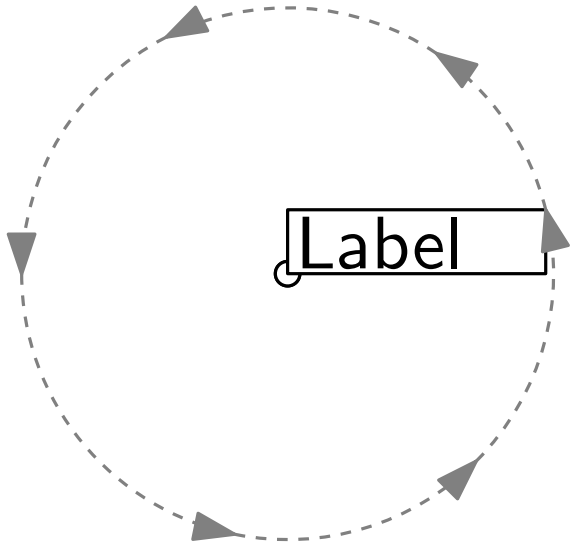
no flickering:
active in single contiguous range

Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"



no jumping:
fix relative position of the anchor

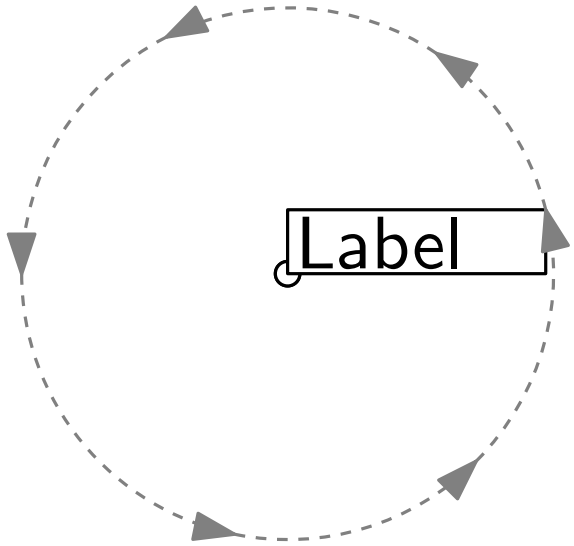
no flickering:
active in single contiguous range

Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"



no jumping:
fix relative position of the anchor

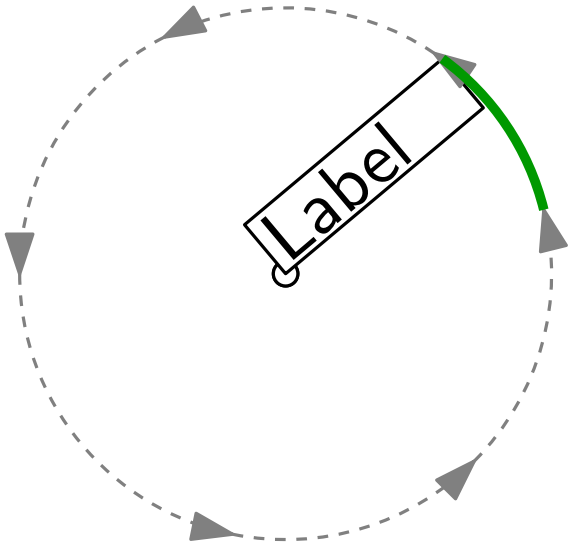
no flickering:
active in single contiguous range

Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
- no "**flickering**"



no jumping:
fix relative position of the anchor

no flickering:
active in single contiguous range

Desiderata

- no label occludes a point: **hard conflict**
- no two labels overlap: **soft conflict**

consistency:

- no "**jumping**"
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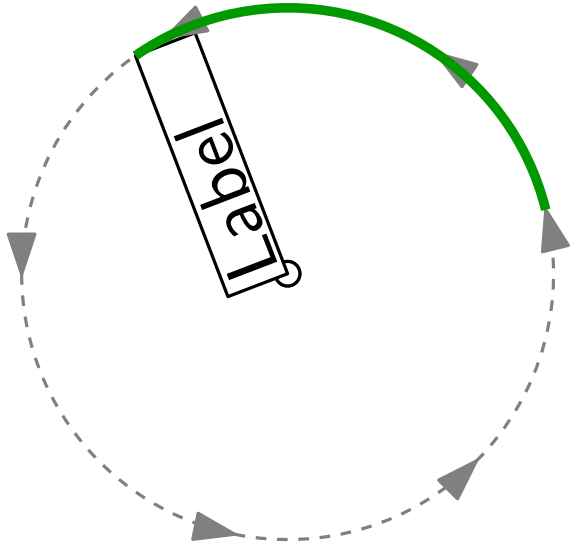

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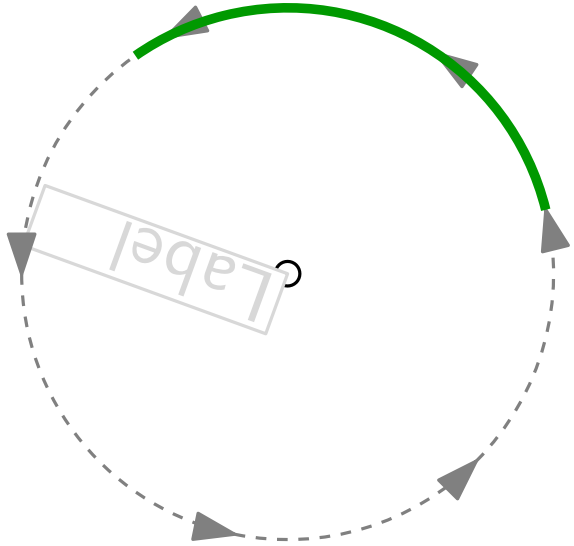

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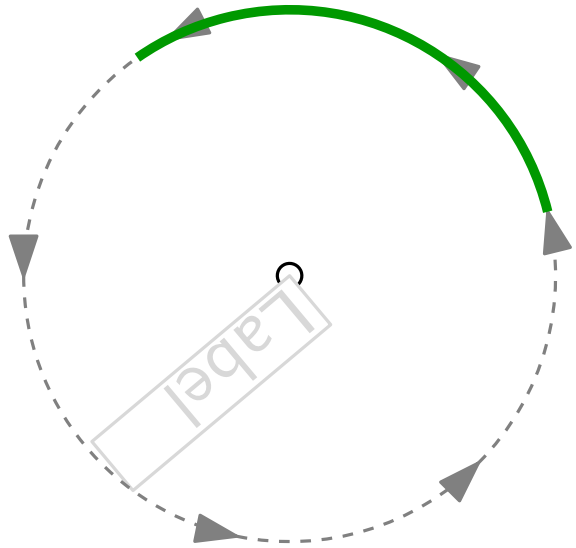

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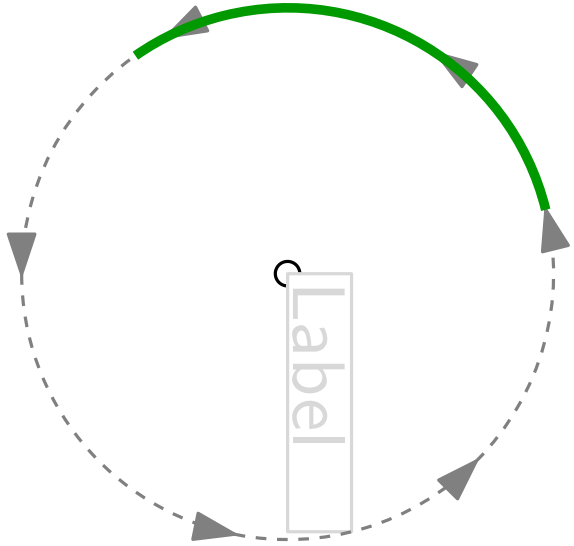

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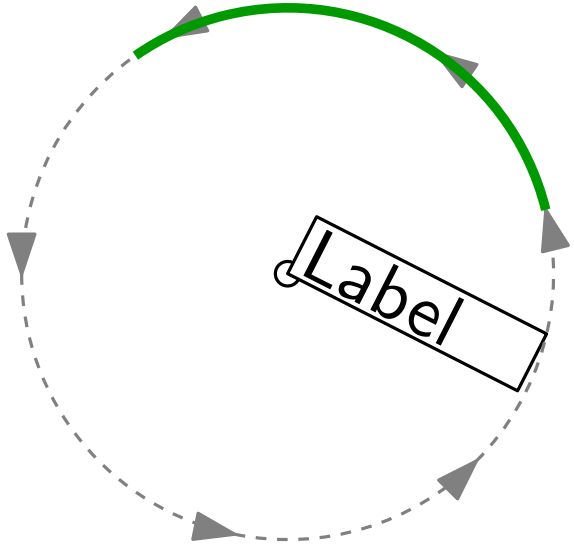

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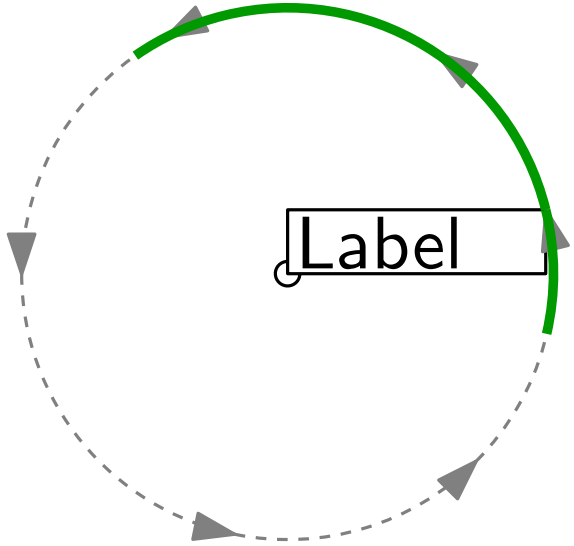

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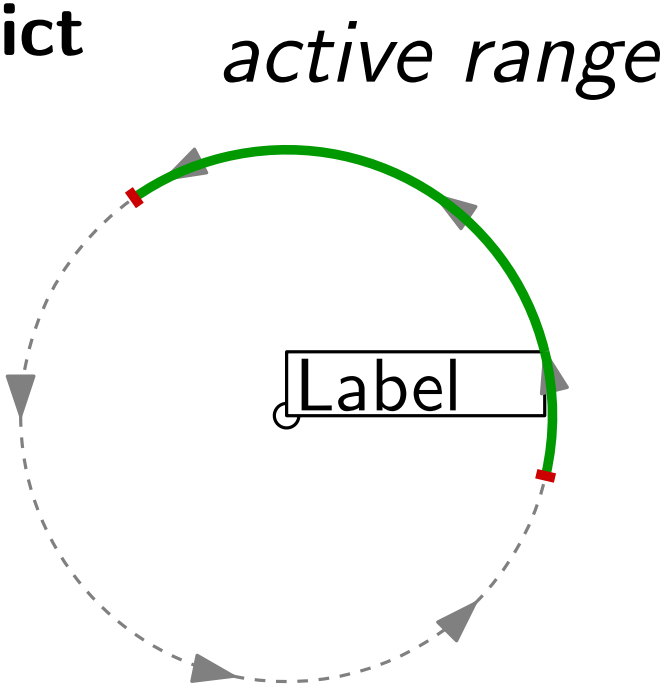

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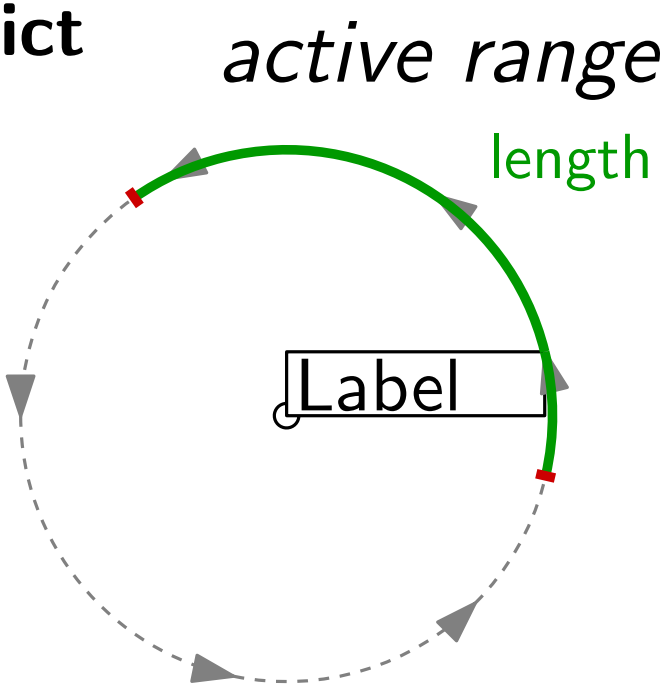

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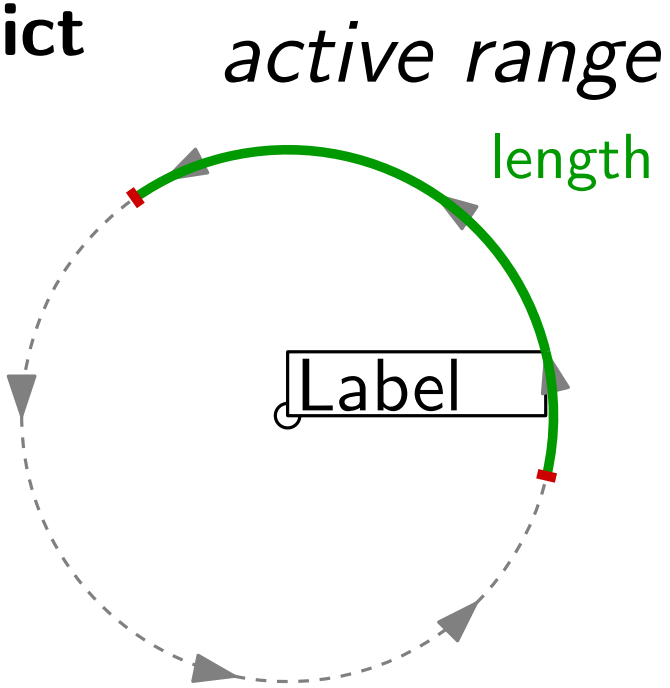

no jumping:
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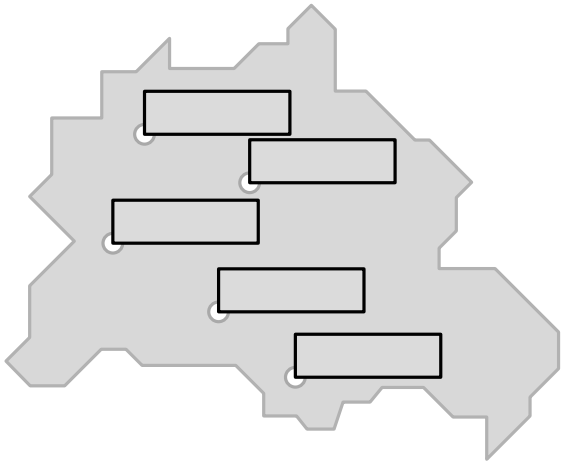
no flickering:
active in single contiguous range

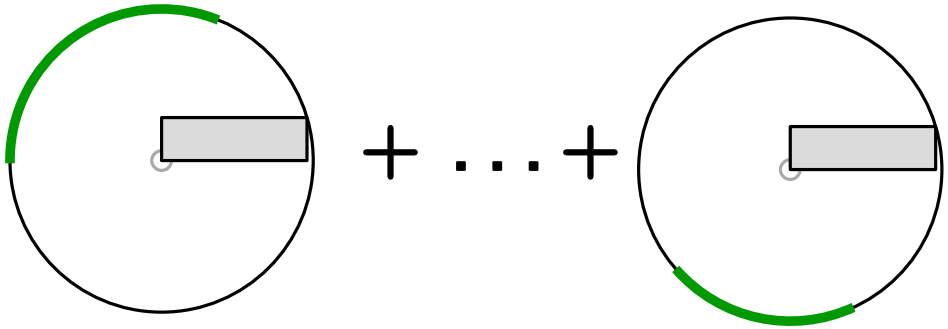
consistent rotation labeling

Problem Statement

Input: A map M, points P, **valid** labeling $L(P)$



MaxTotal



MaxTotal

Output: consistent rotation labeling that maximizes **the sum of all active ranges**

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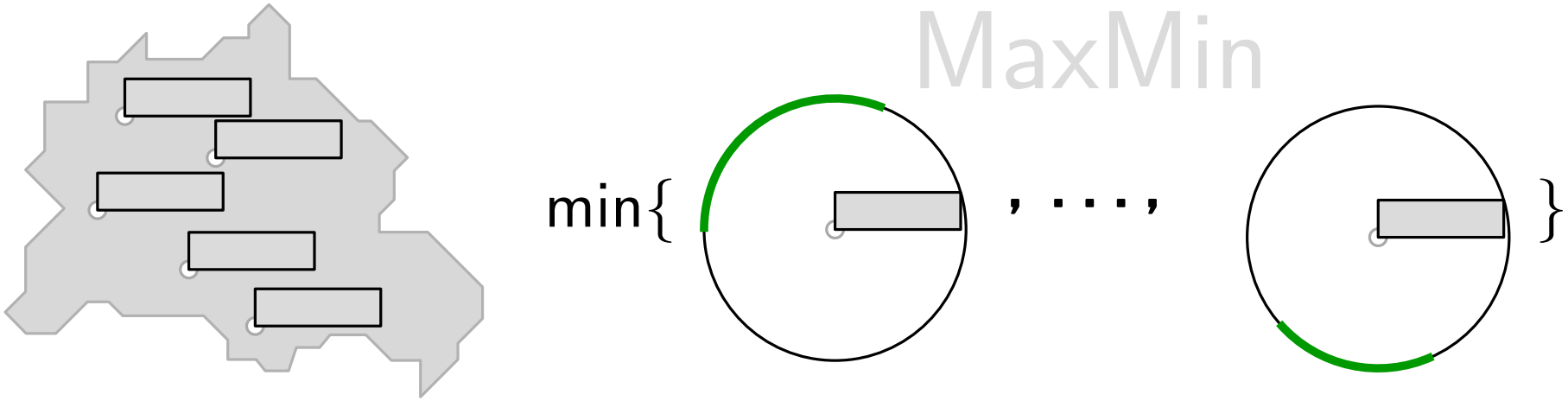


MaxTotal

Output: consistent rotation labeling that maximizes **the sum of all active ranges**

MaxMin

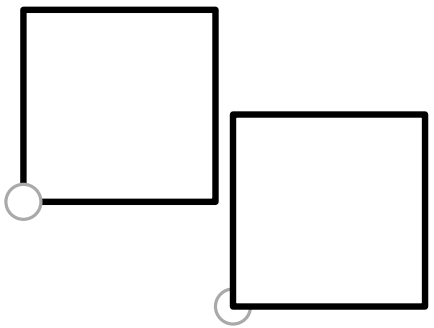
Output: consistent rotation labeling that maximizes **the smallest active range length**

Some Observations

Determining Conflicts

Conflict Lemma:

For two labels the set of conflicts consists of at most four contiguous conflict regions.



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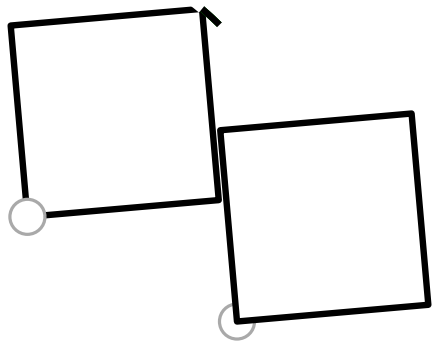

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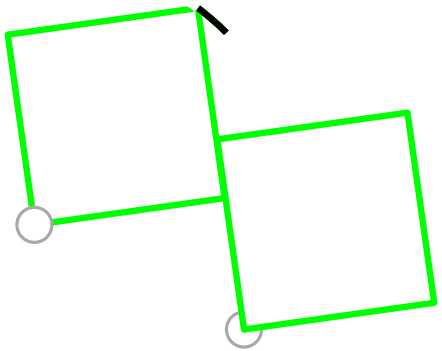

soft conflict: labels overlap

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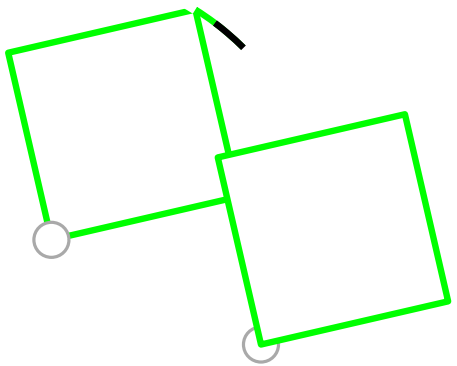

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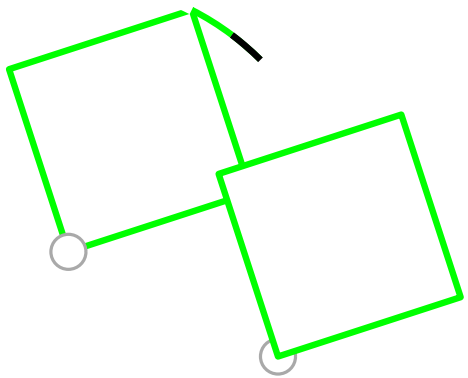

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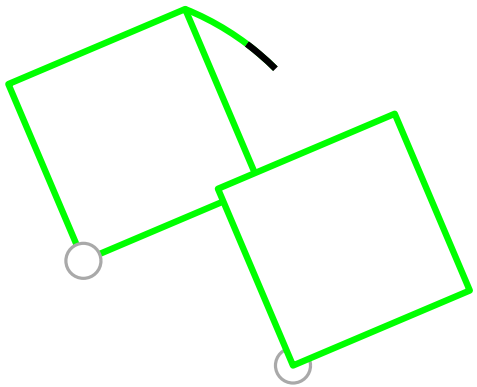

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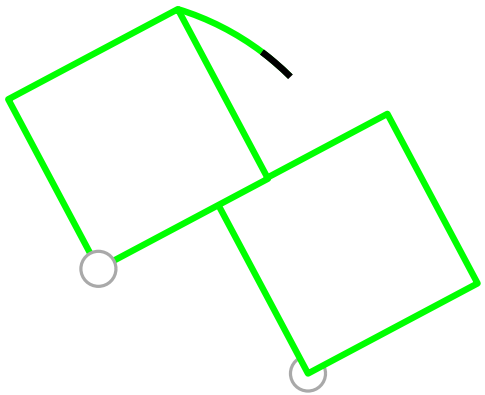

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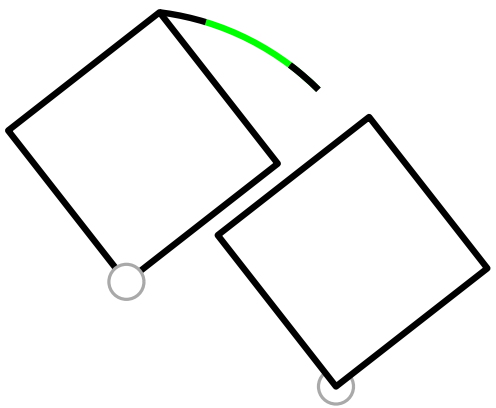

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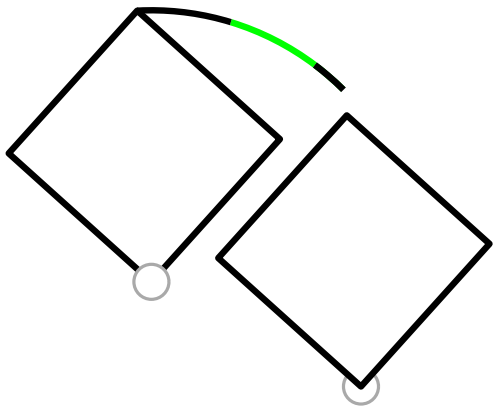

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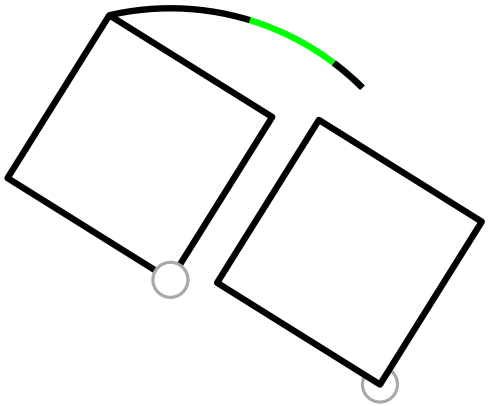

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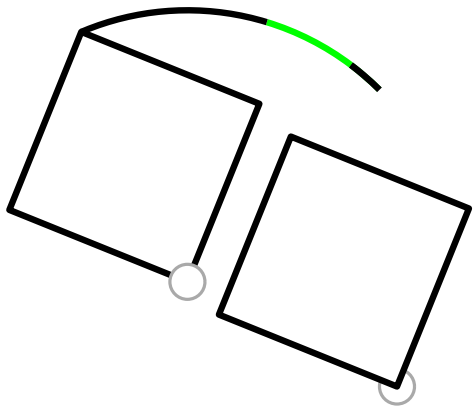

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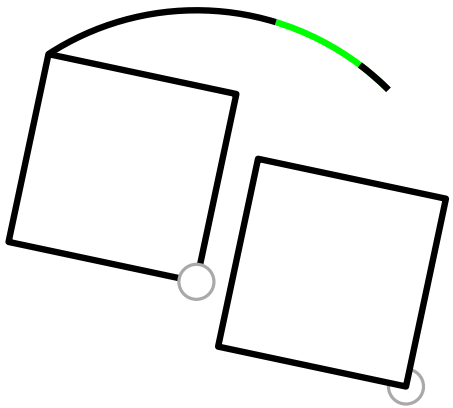

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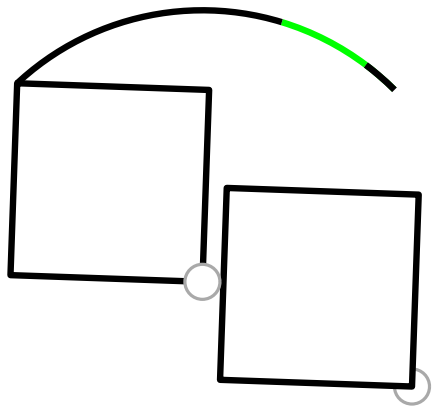

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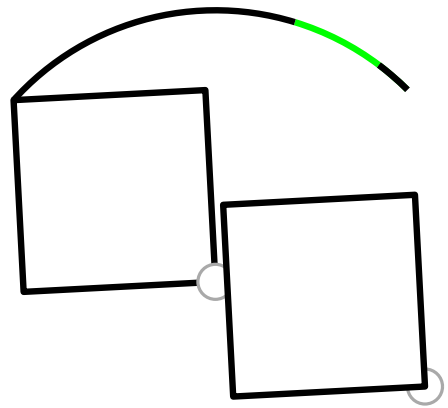

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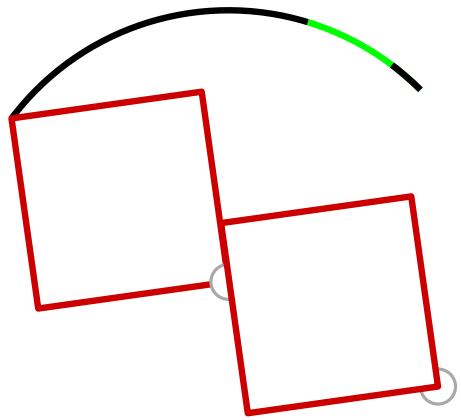

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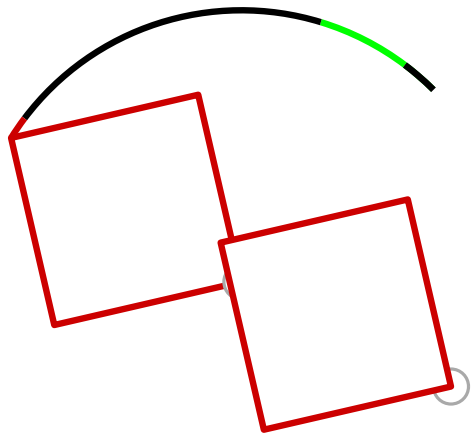

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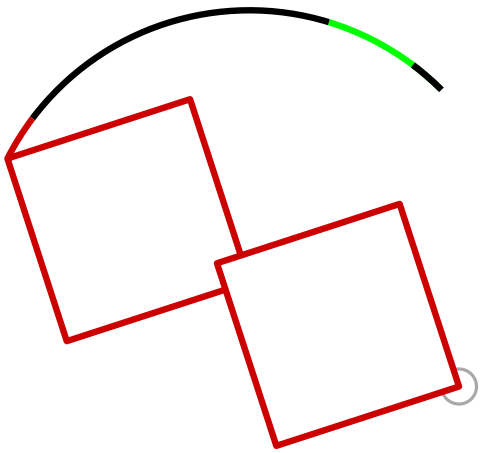

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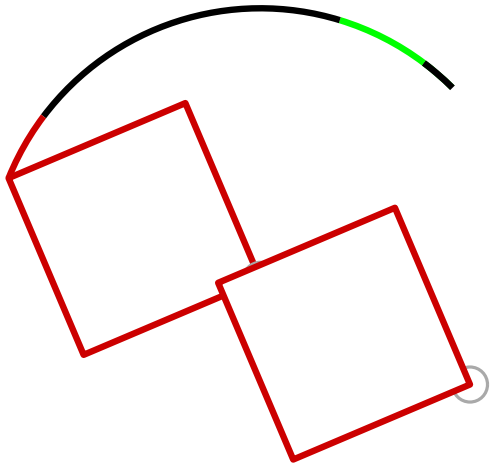

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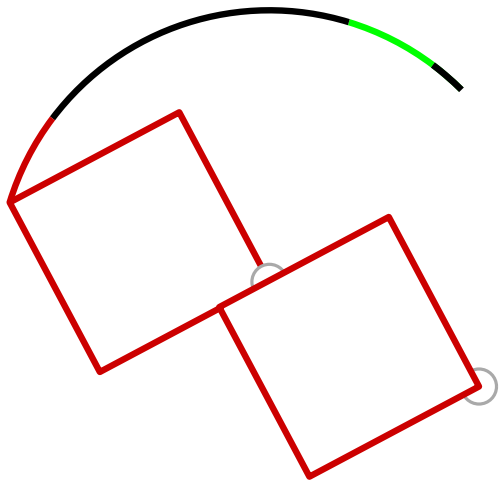

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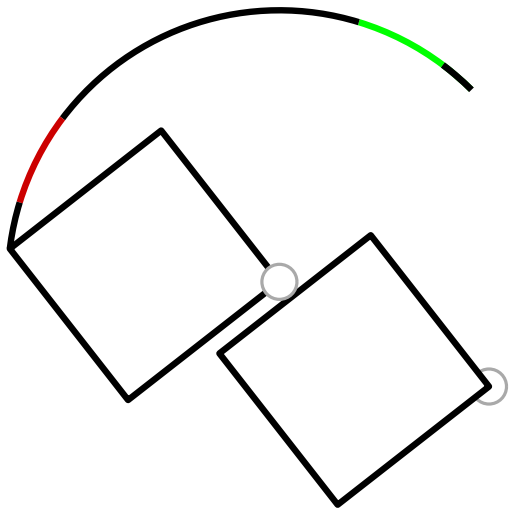

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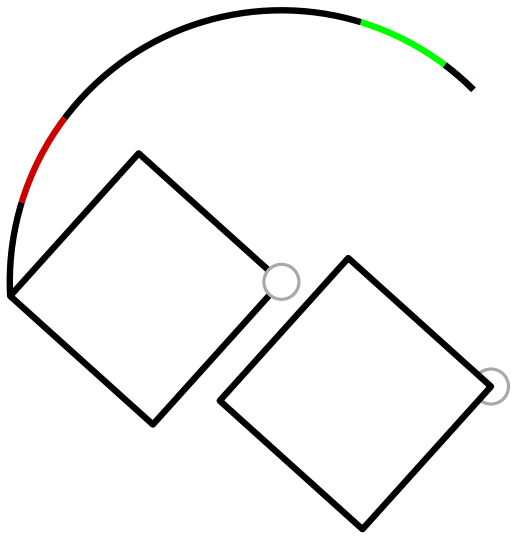

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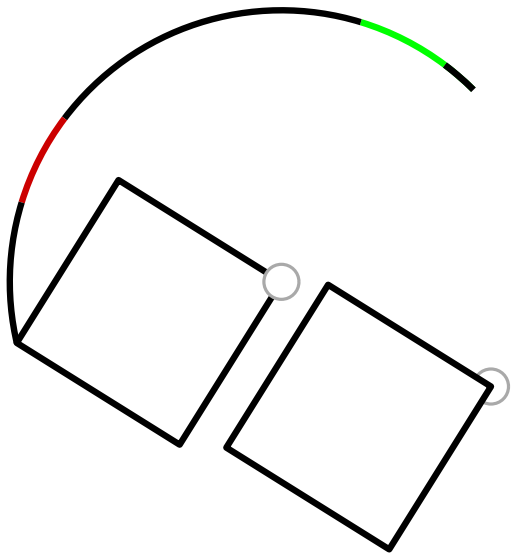

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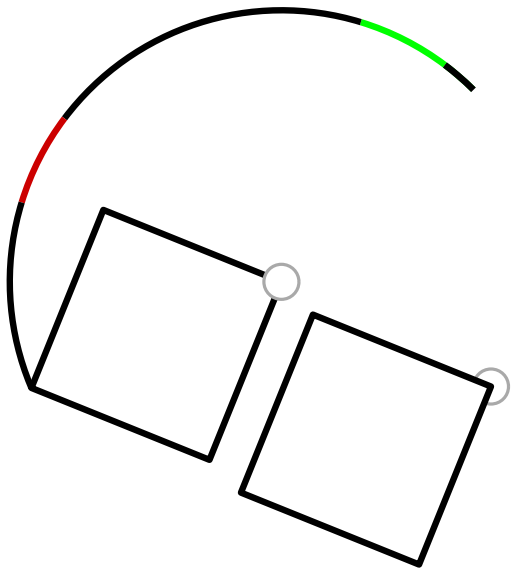

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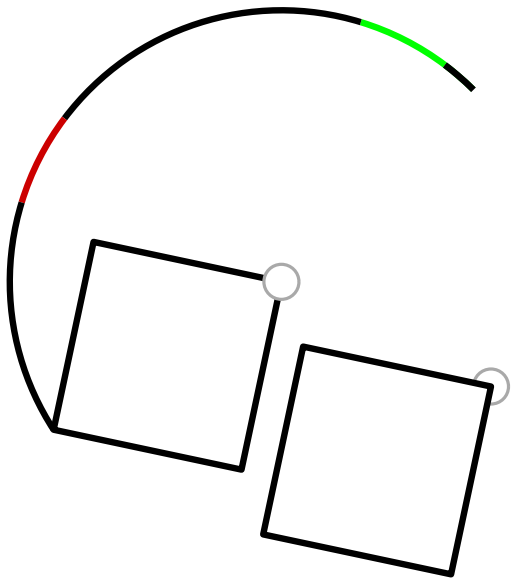

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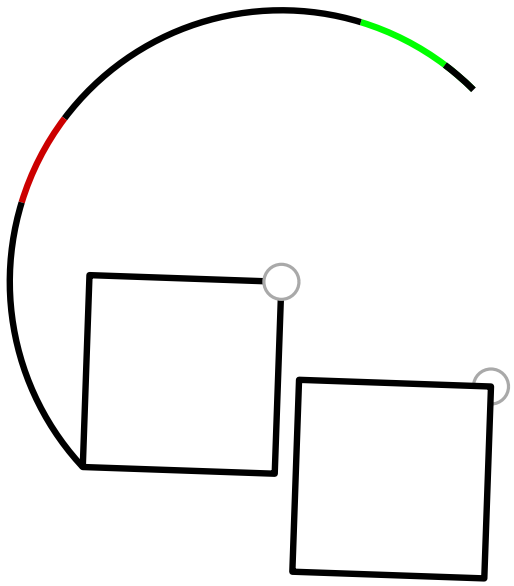

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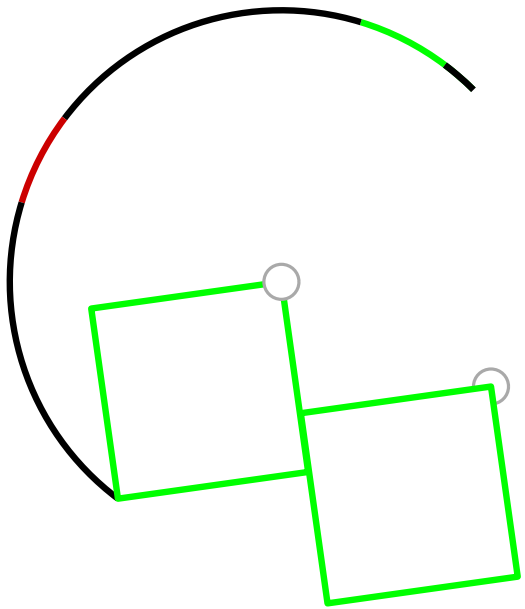

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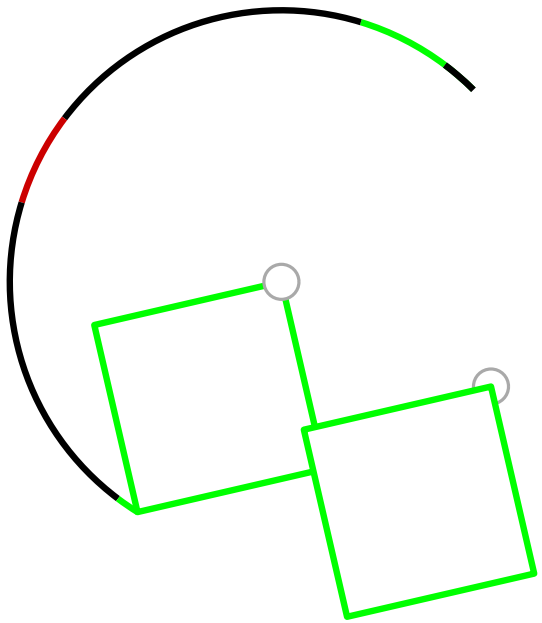

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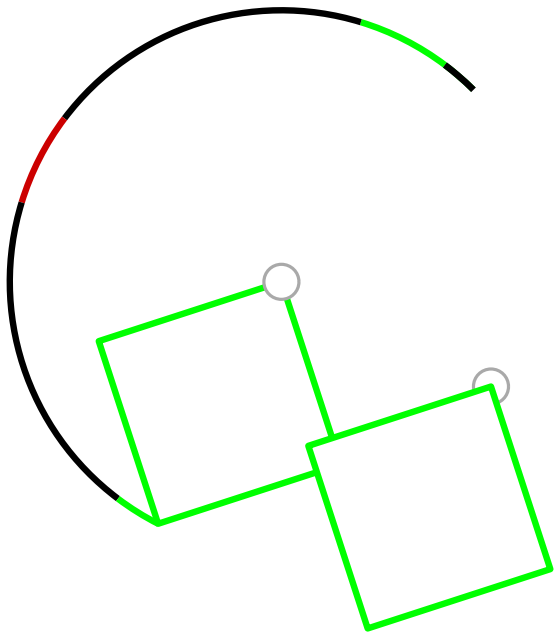

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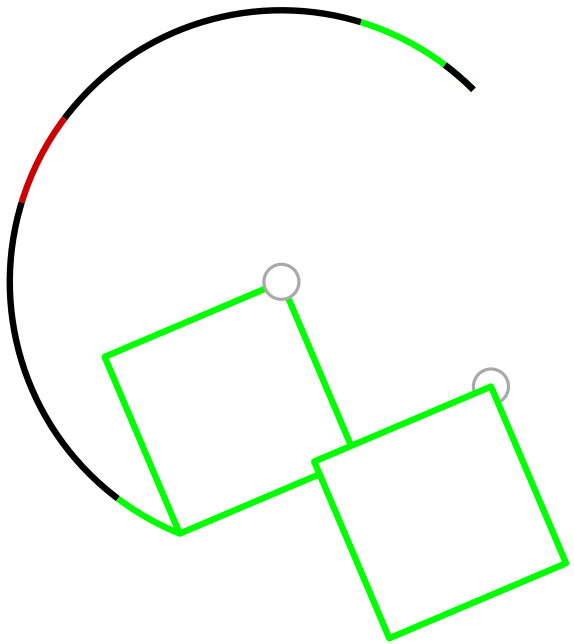

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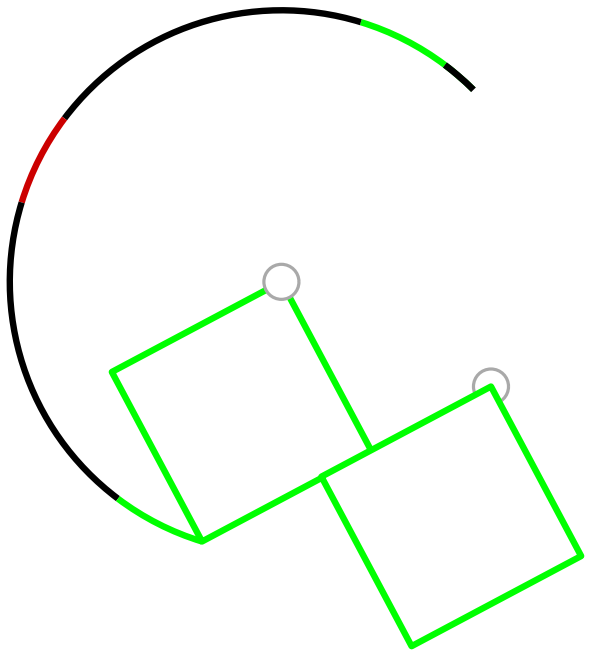

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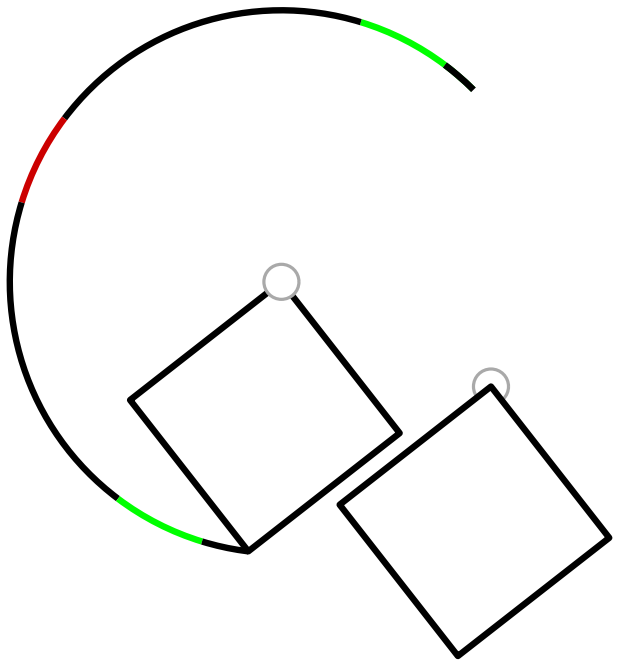

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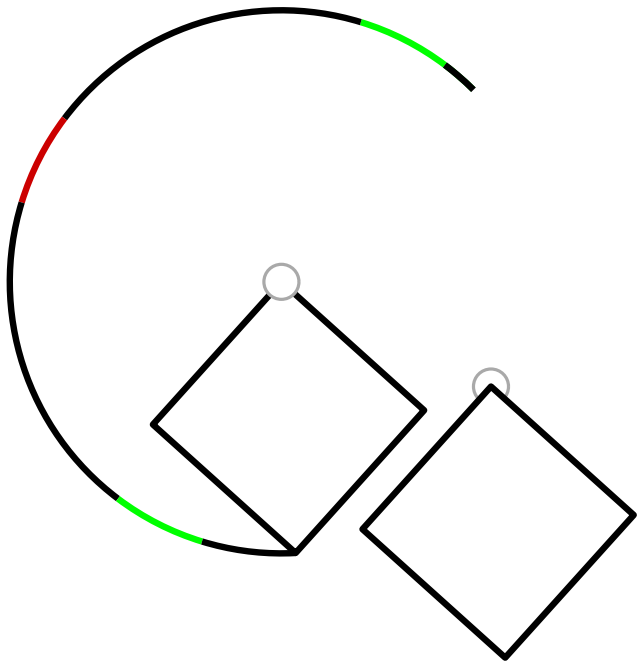

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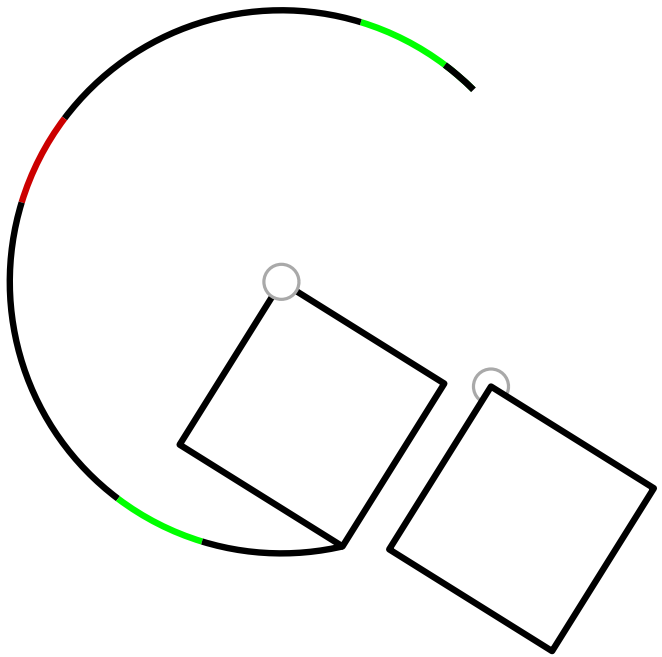

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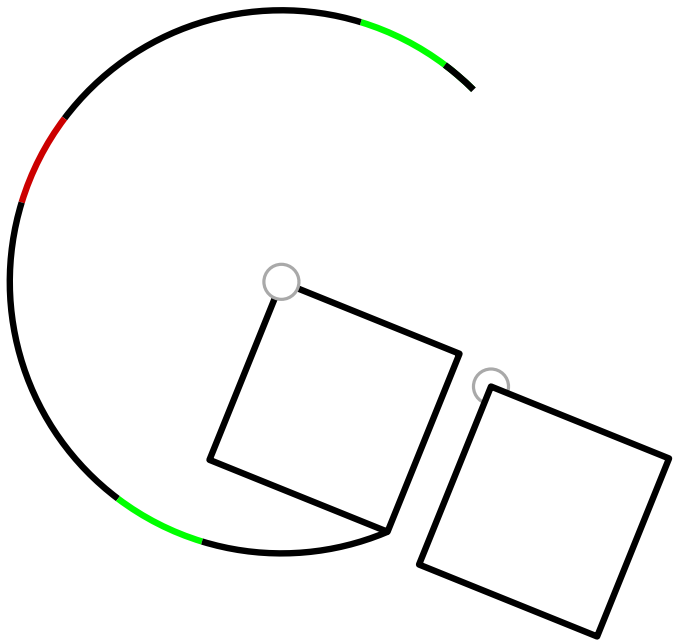

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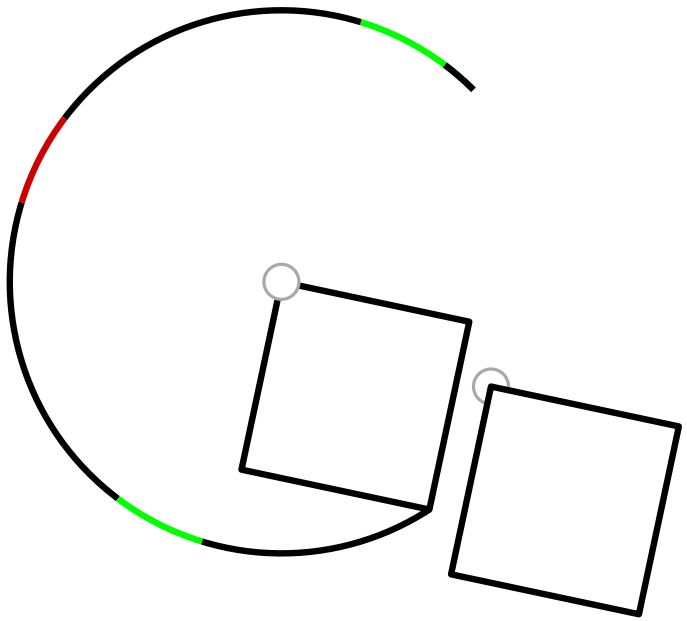

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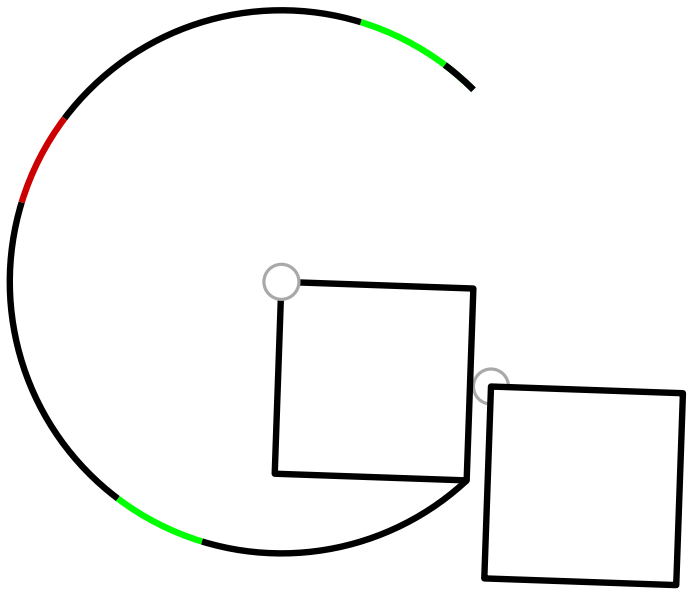

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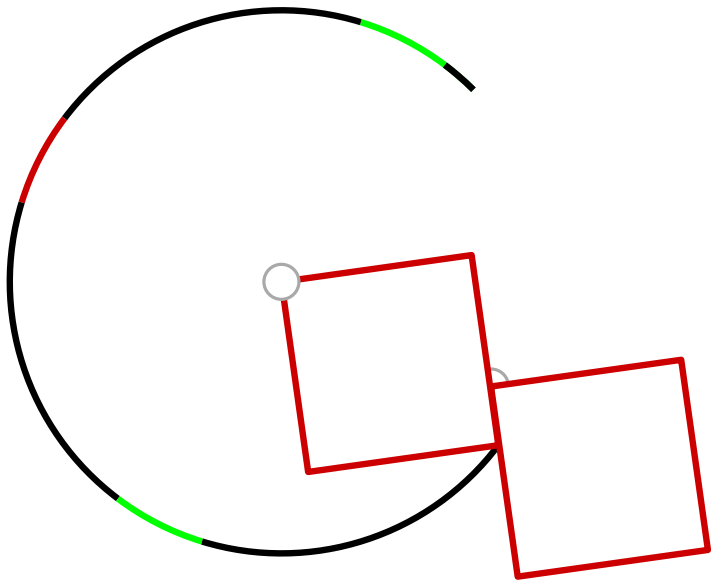

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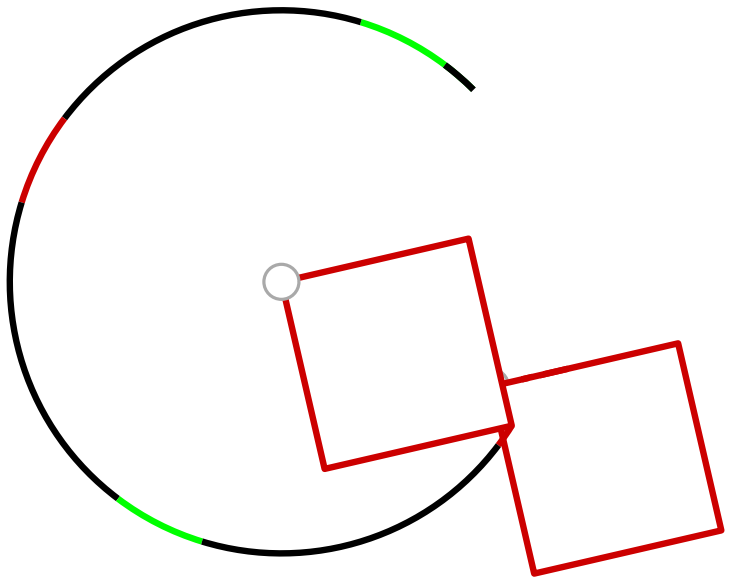

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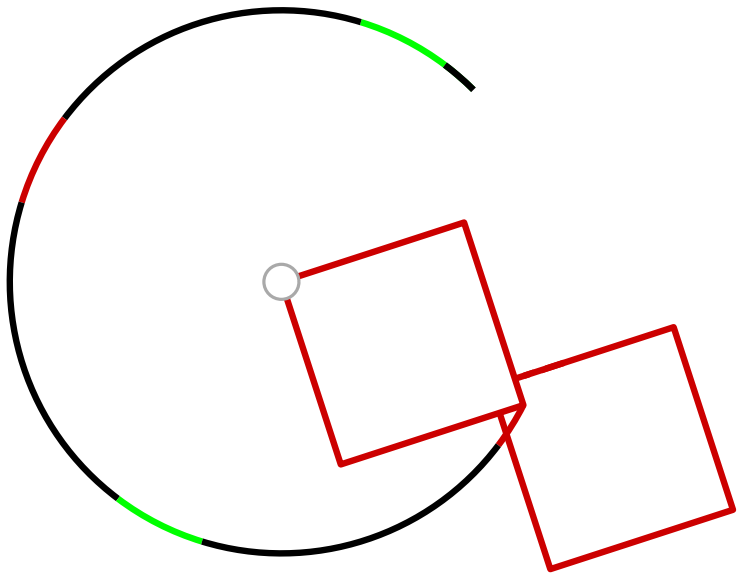

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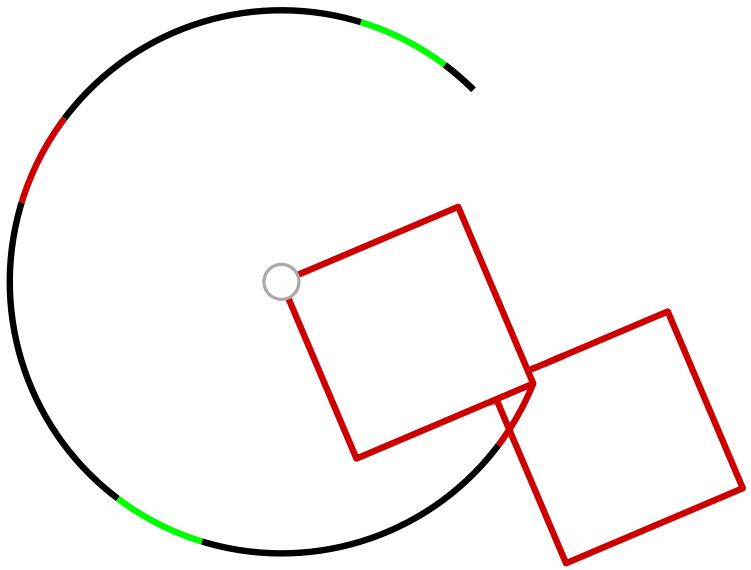

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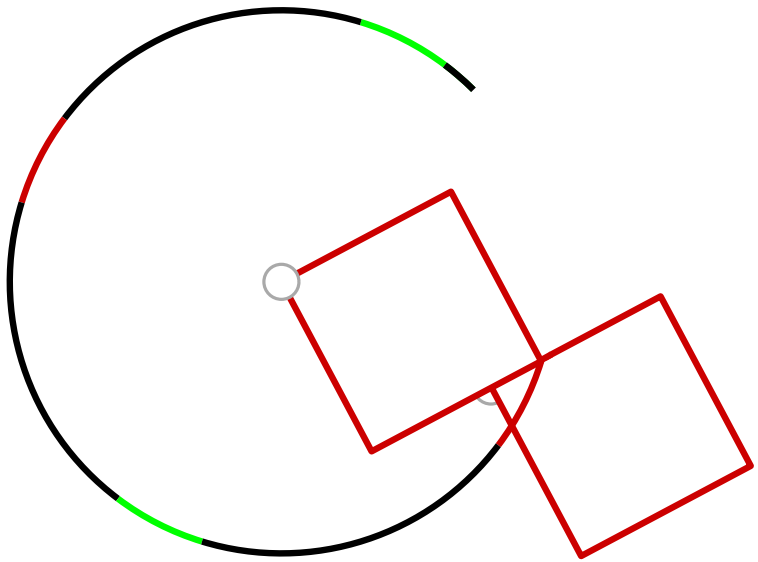

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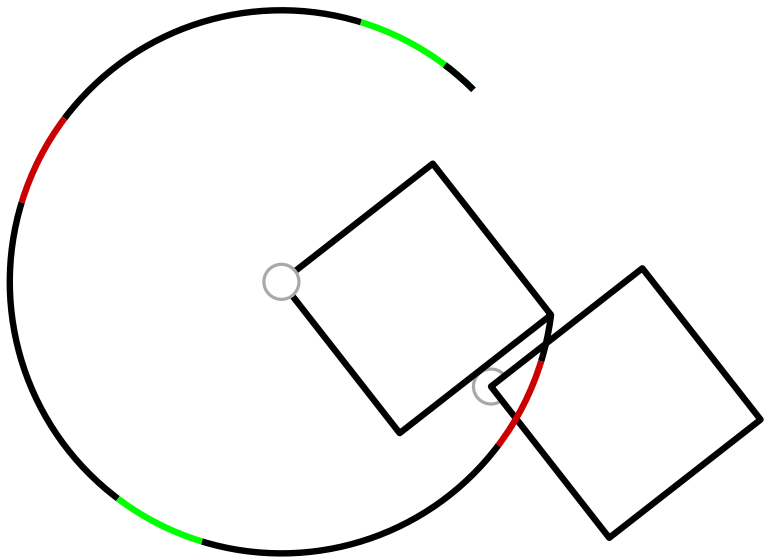

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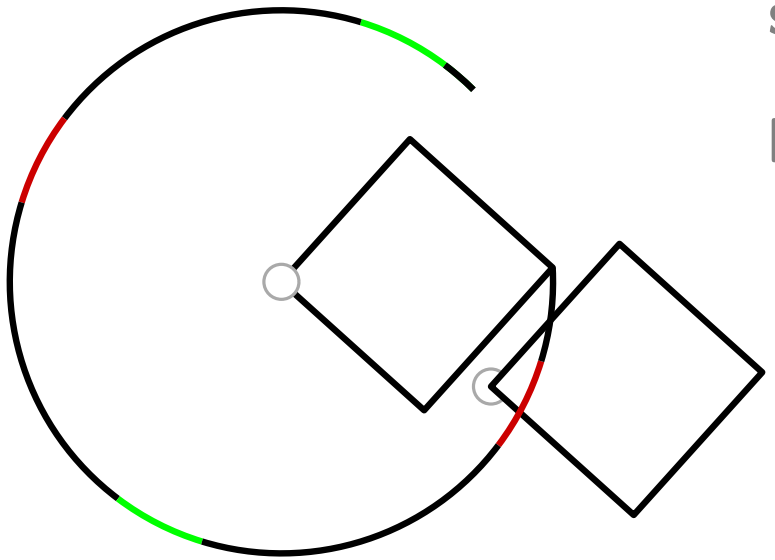

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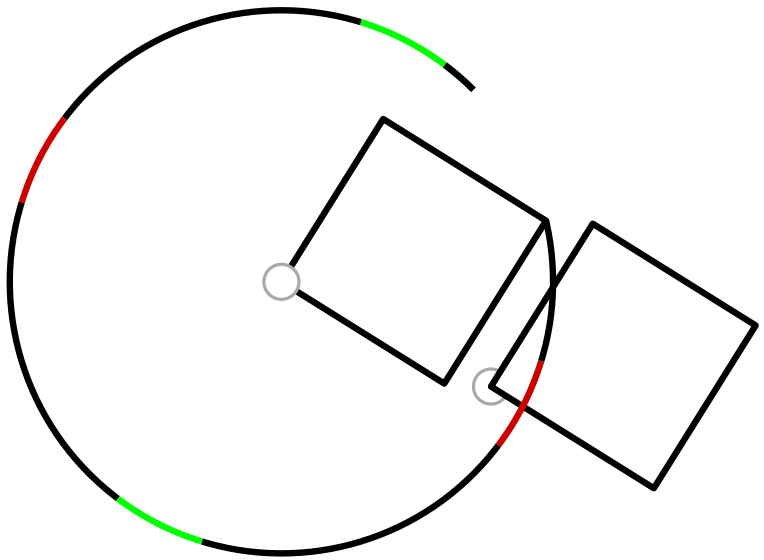

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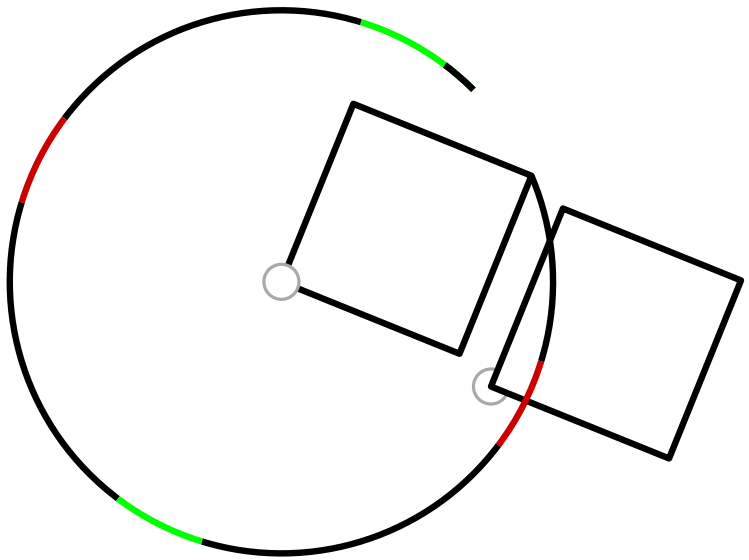

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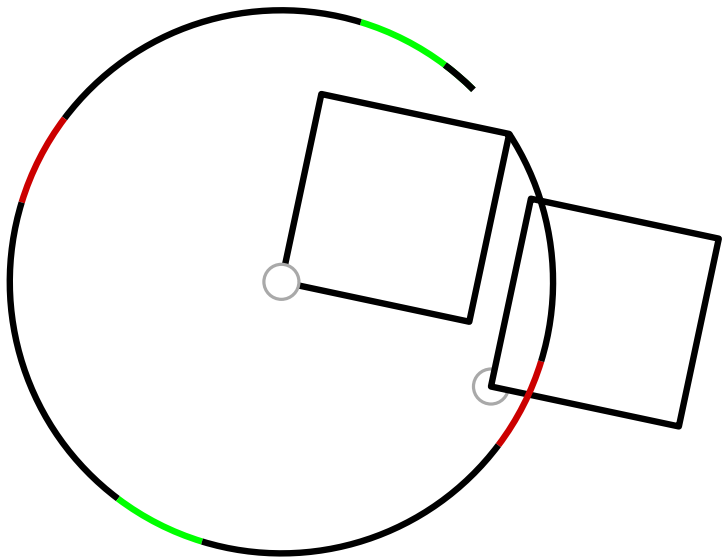

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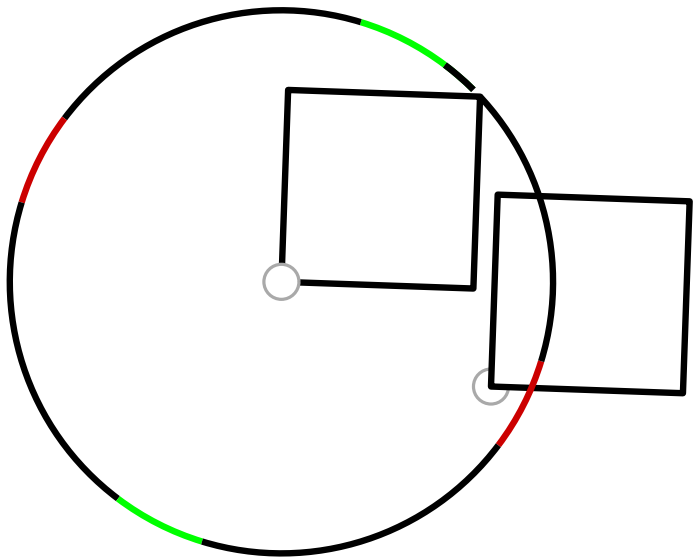

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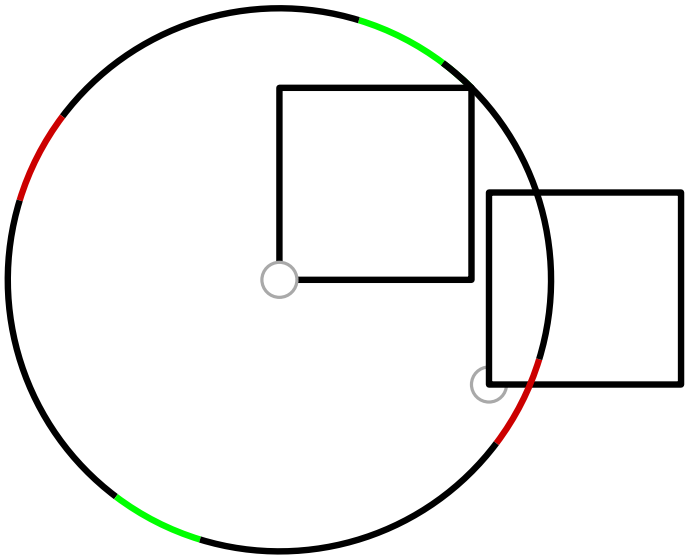

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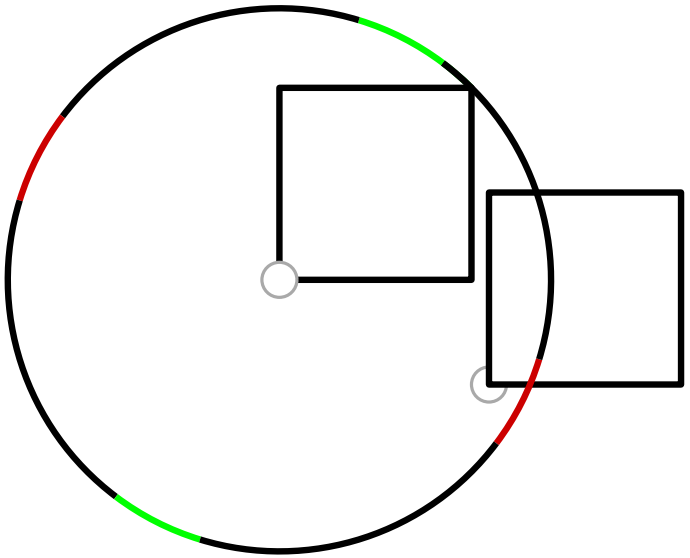

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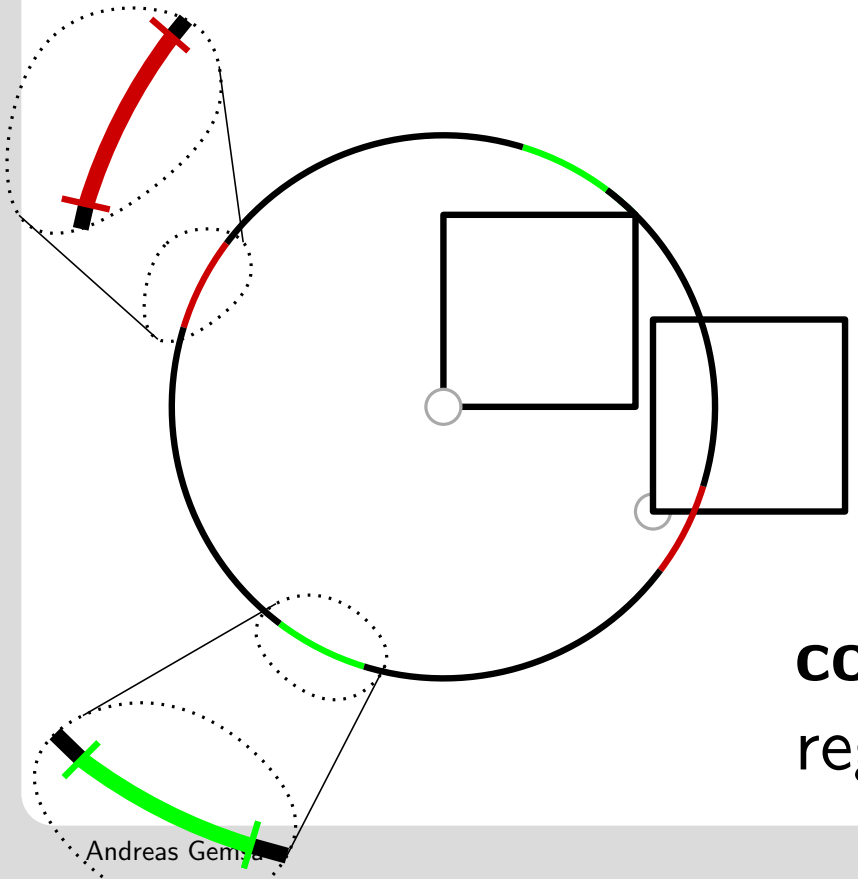

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conflict events: begin/end of a conflict region (borders of labels intersect)

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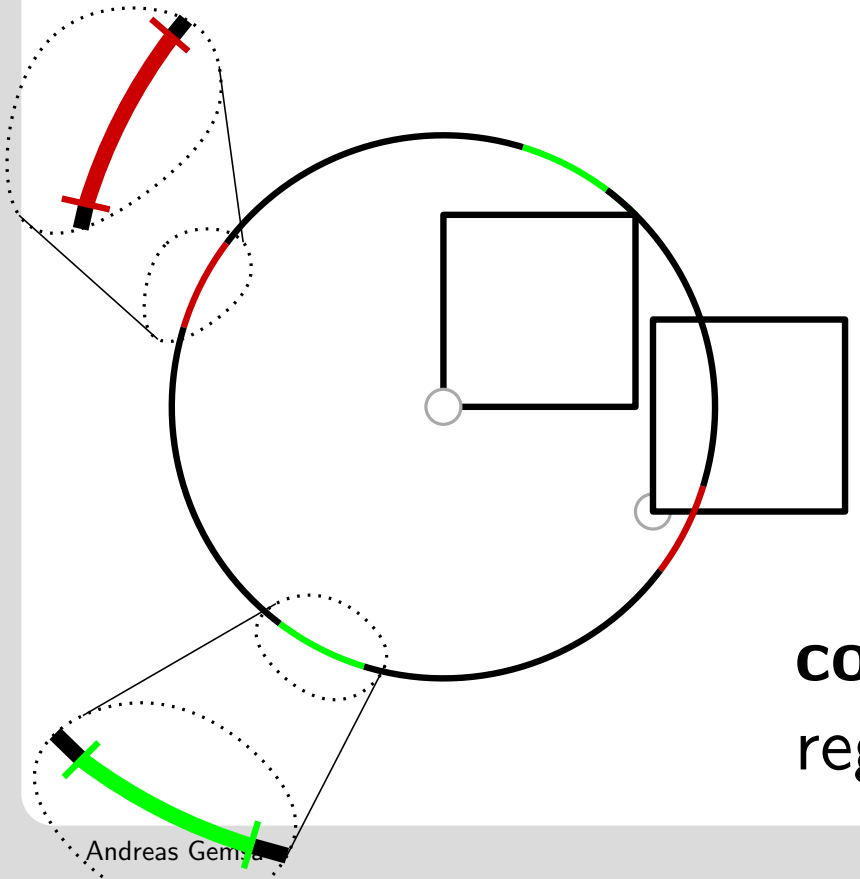

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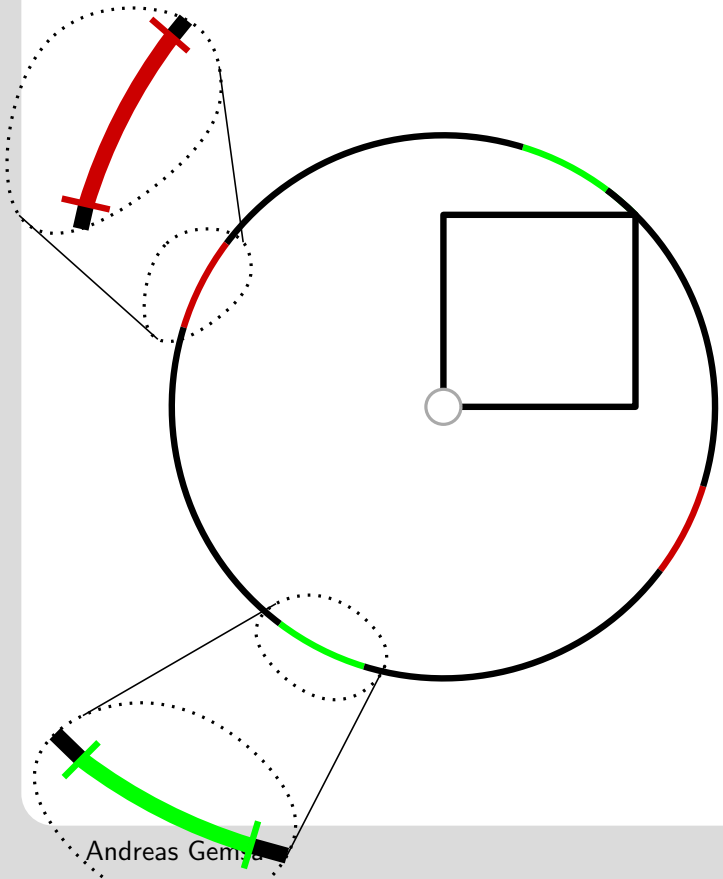
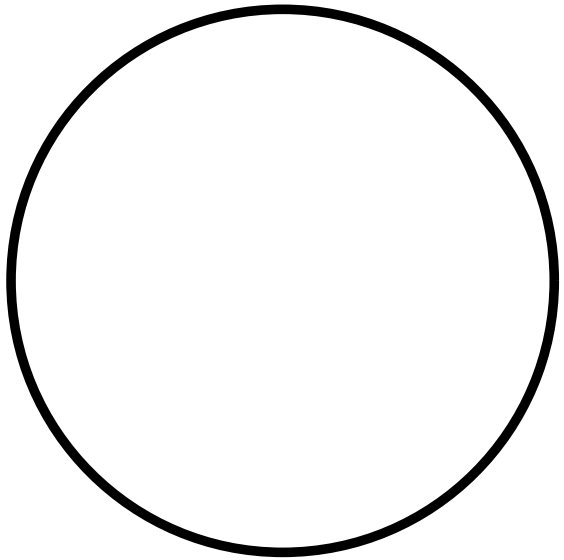
at most 8 such events per pair

conflict events: begin/end of a conflict region (borders of labels intersect)

Discretization Lemma



only for MaxTotal



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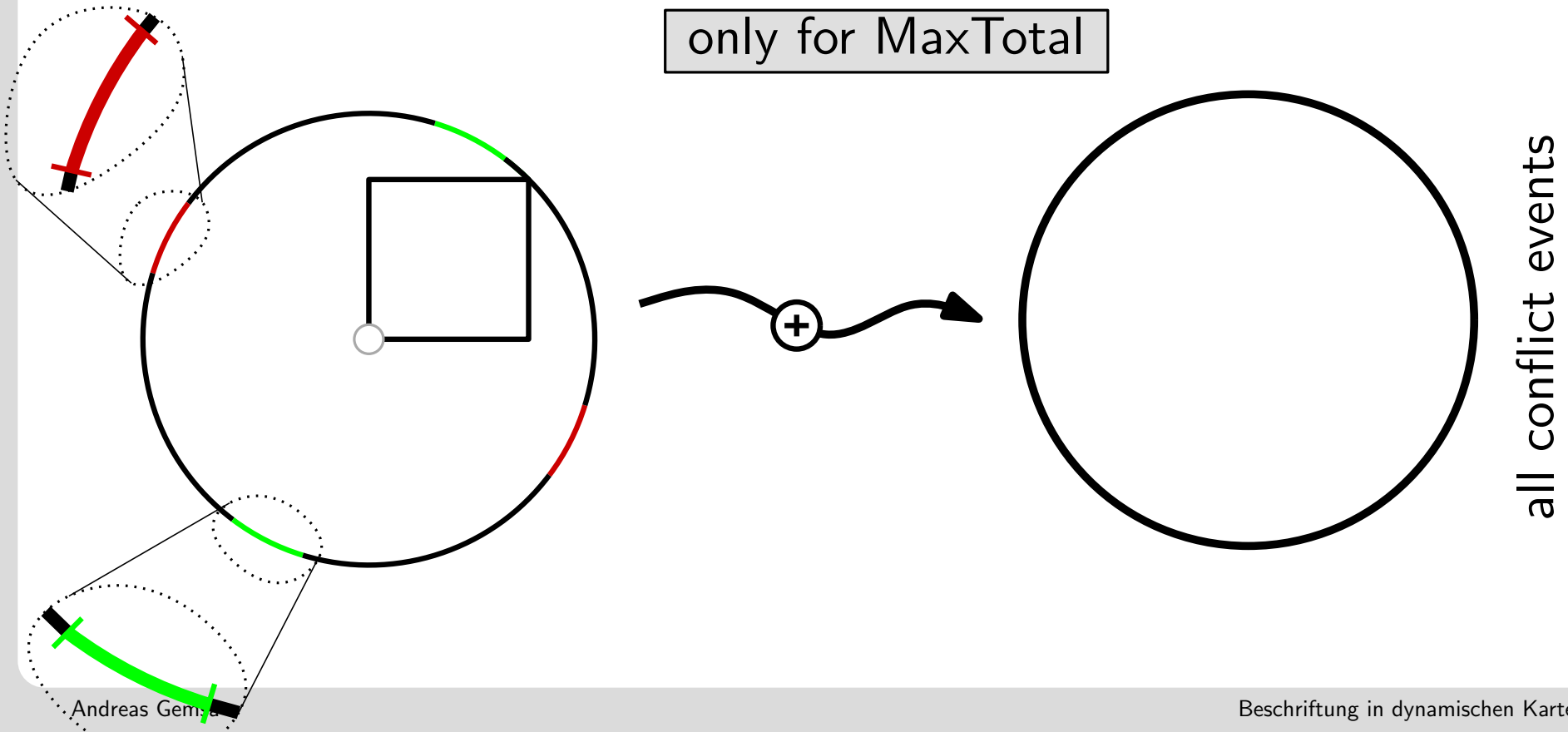
There is an optimal solution for MaxTotal where all active ranges start and end at conflict events.



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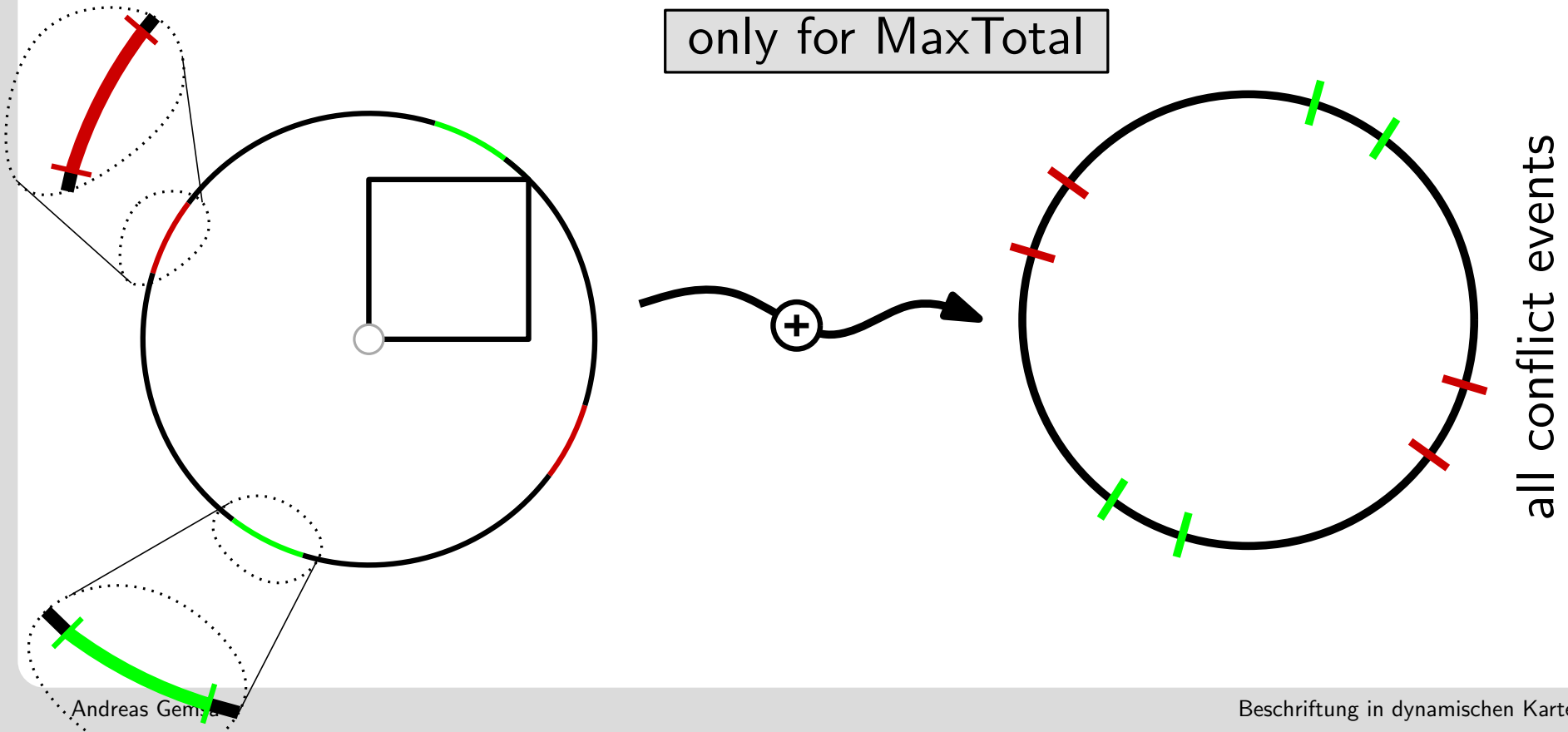

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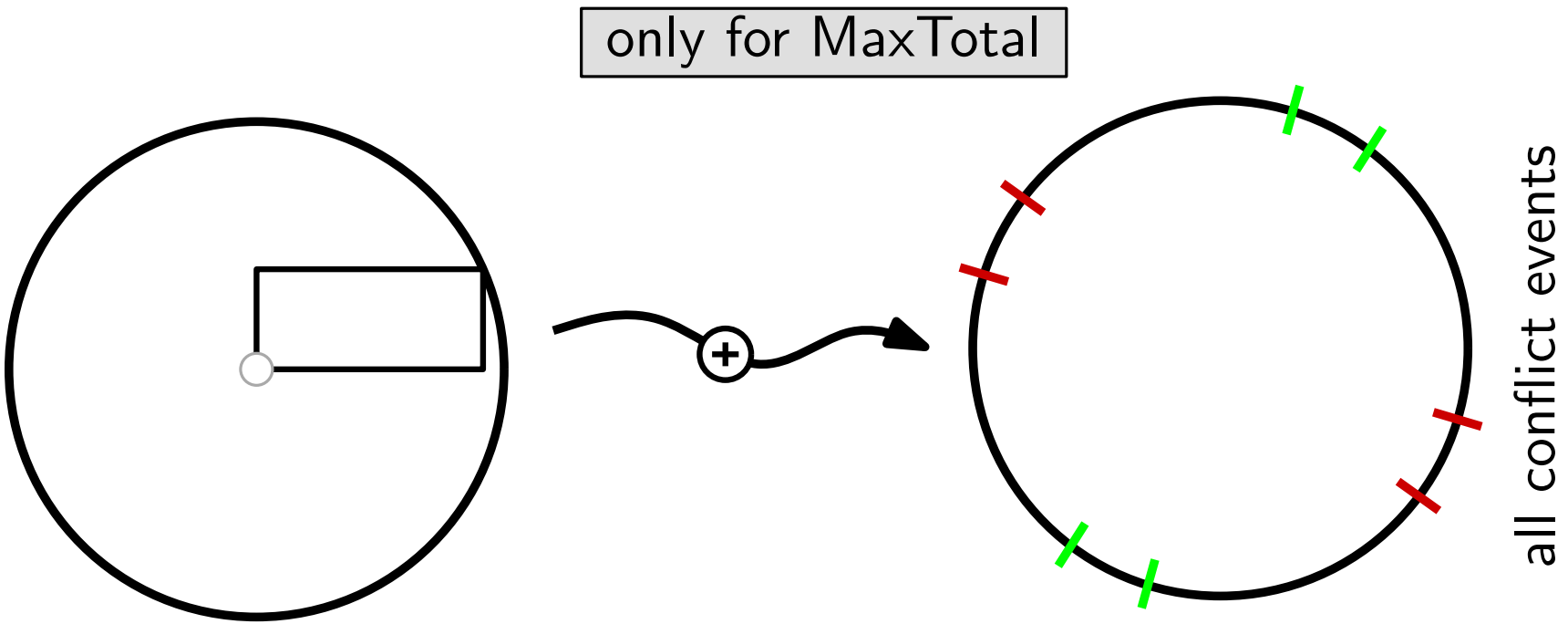

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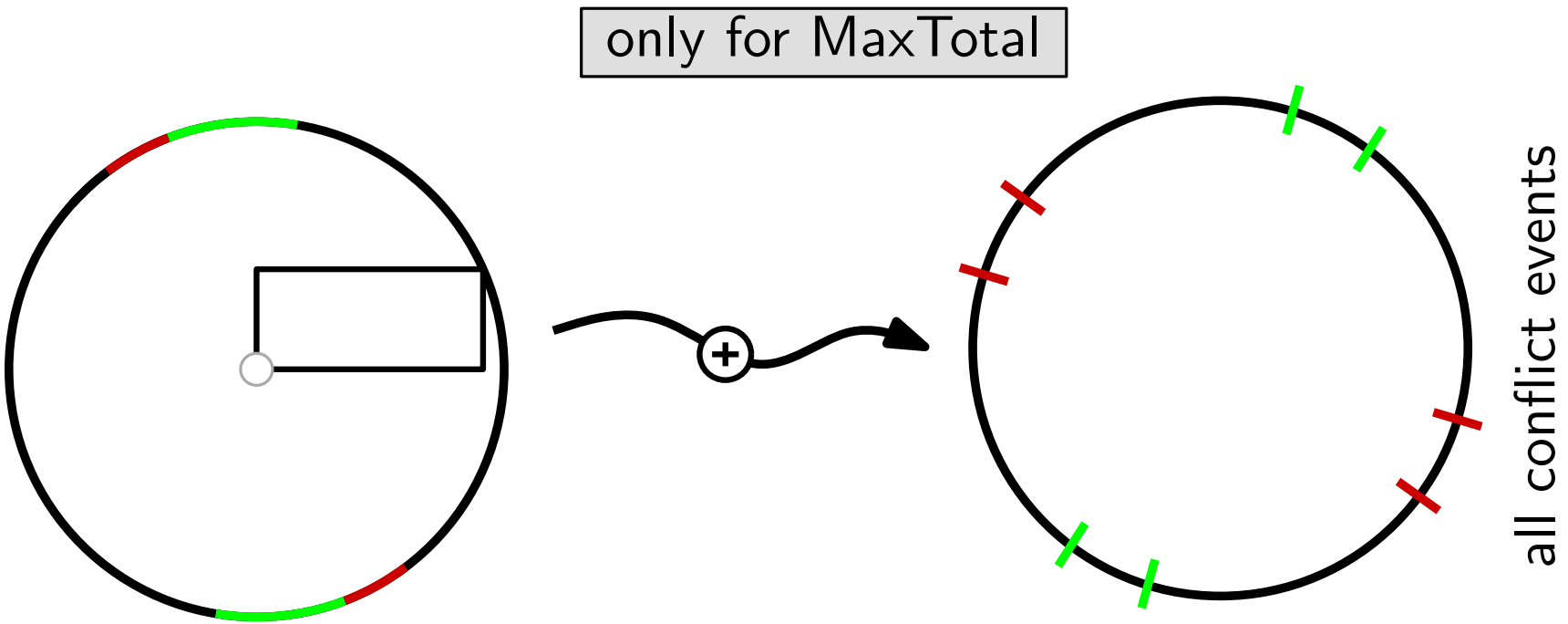

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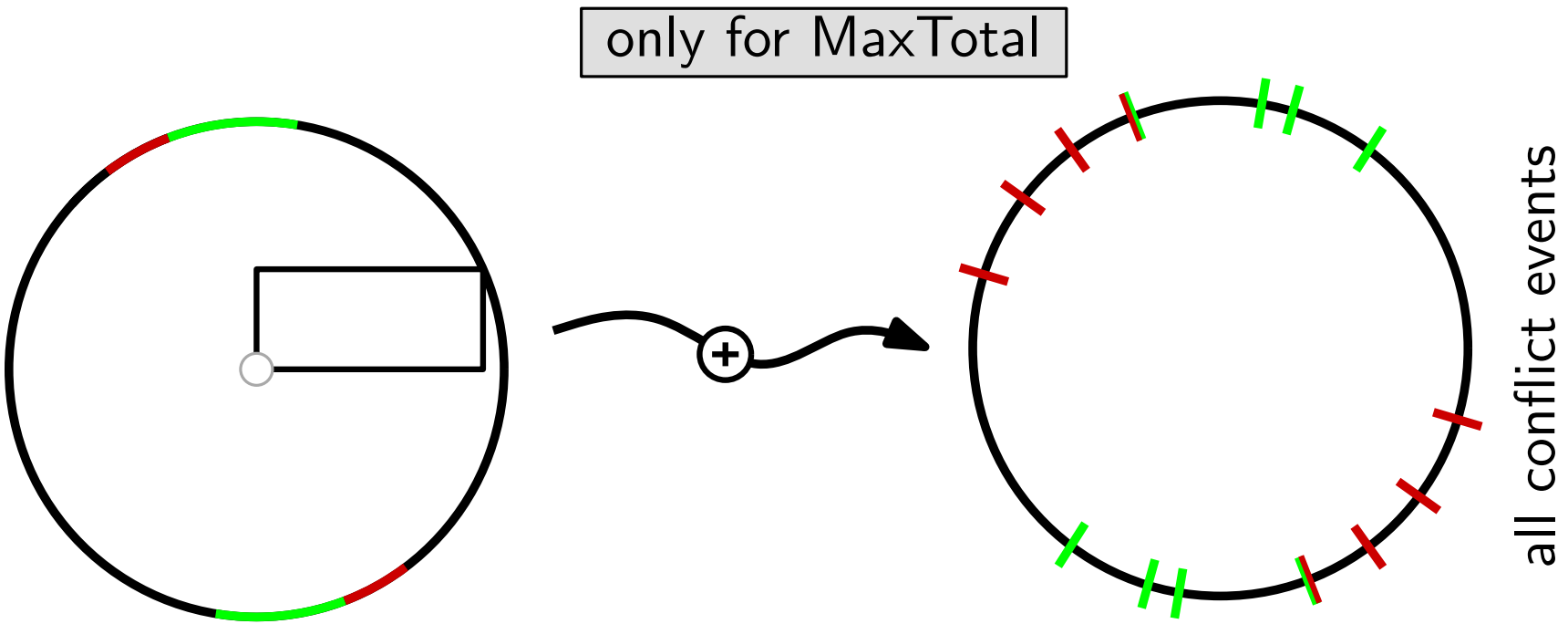

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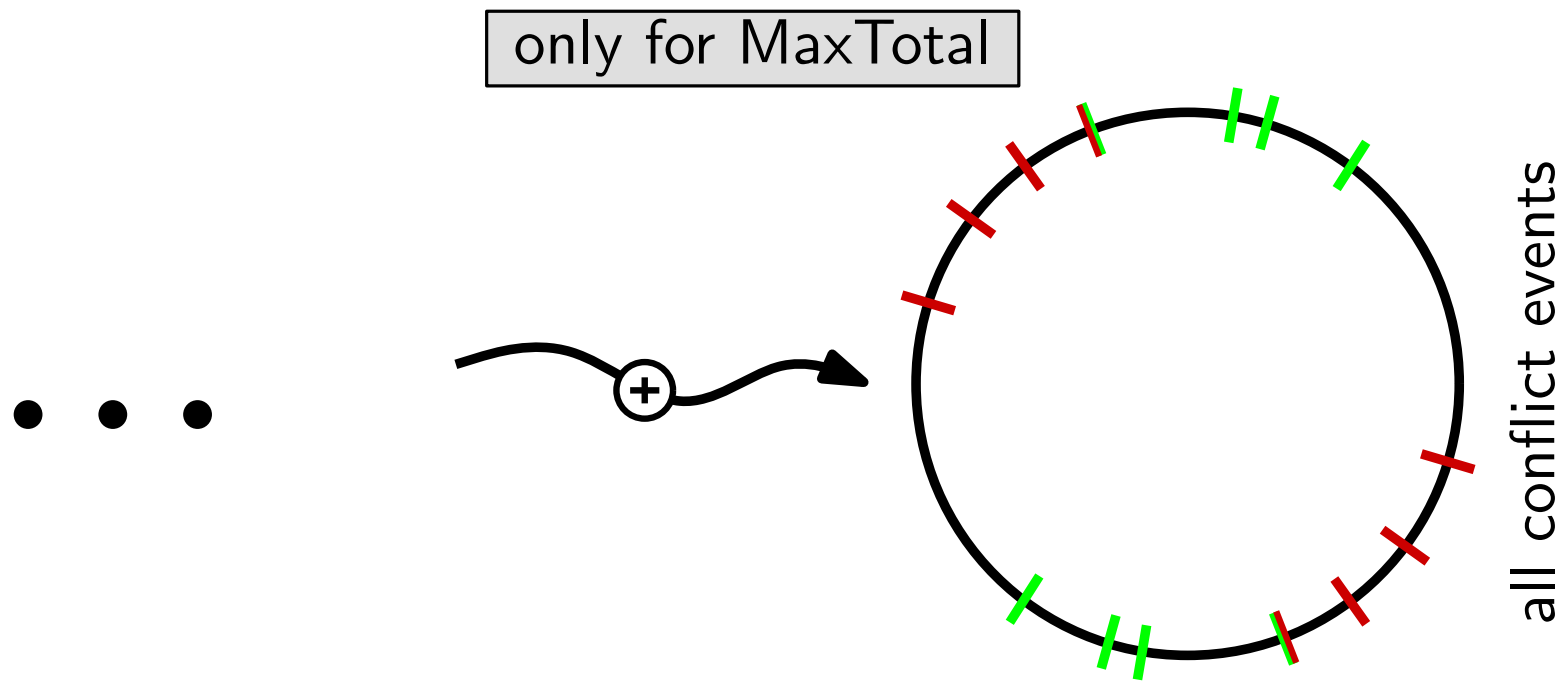

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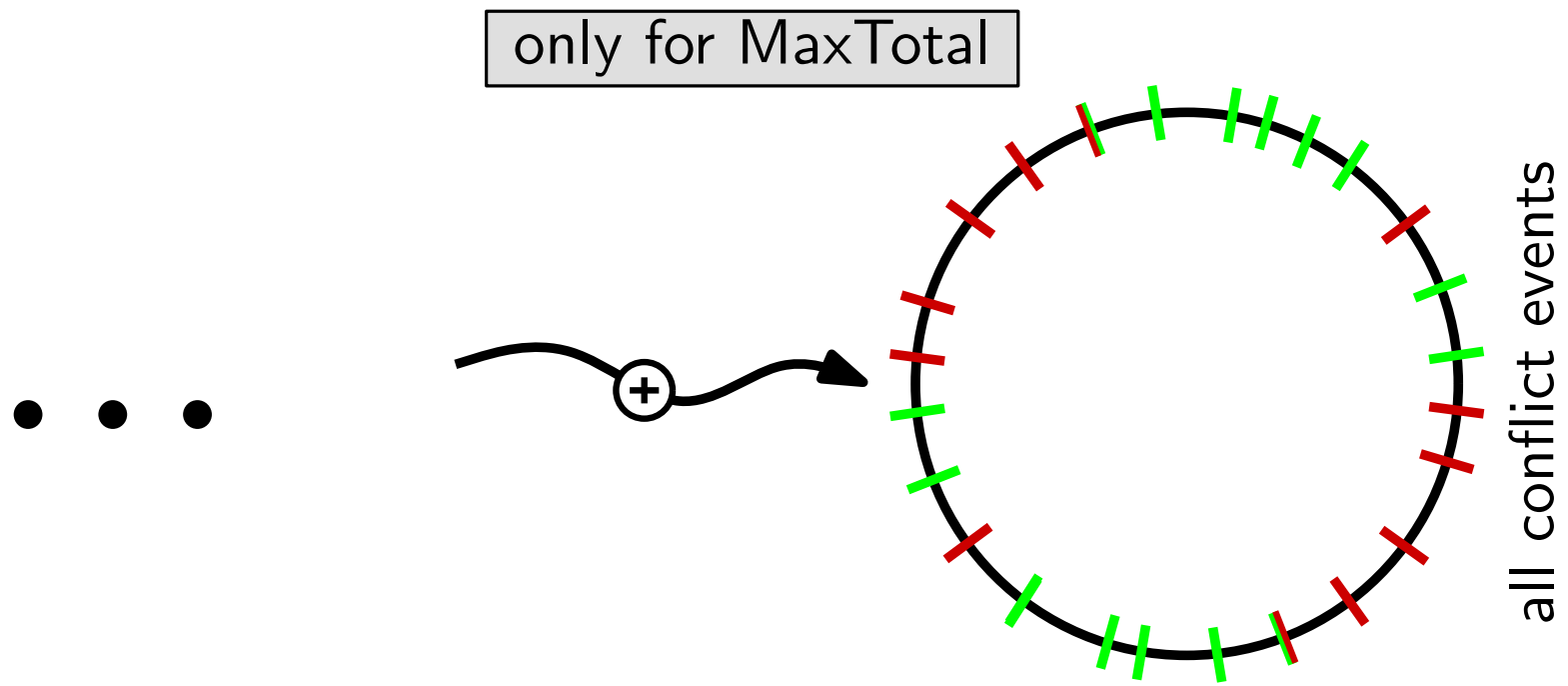

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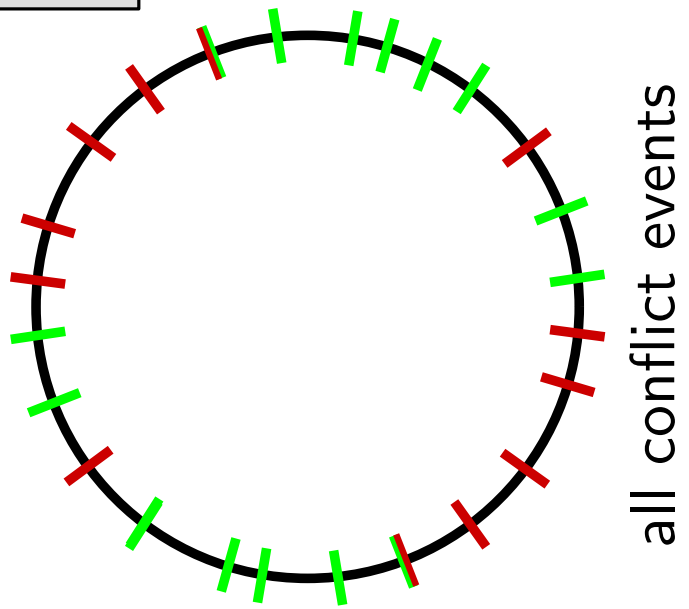

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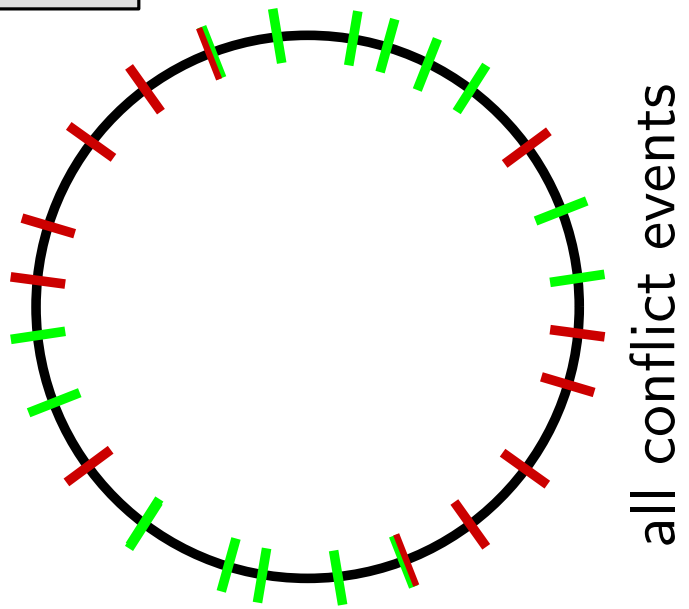
Q: (naïve) algorithm for finding optimal solution?



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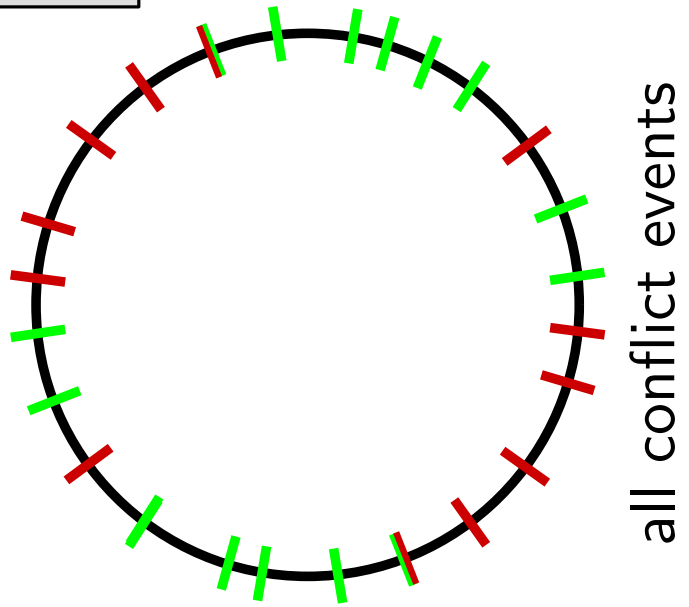

naïve approach

find optimal solution:

- compute all conflict events
- per label $\mathcal{O}(n^4)$ active range candidates
- determine all possible combinations

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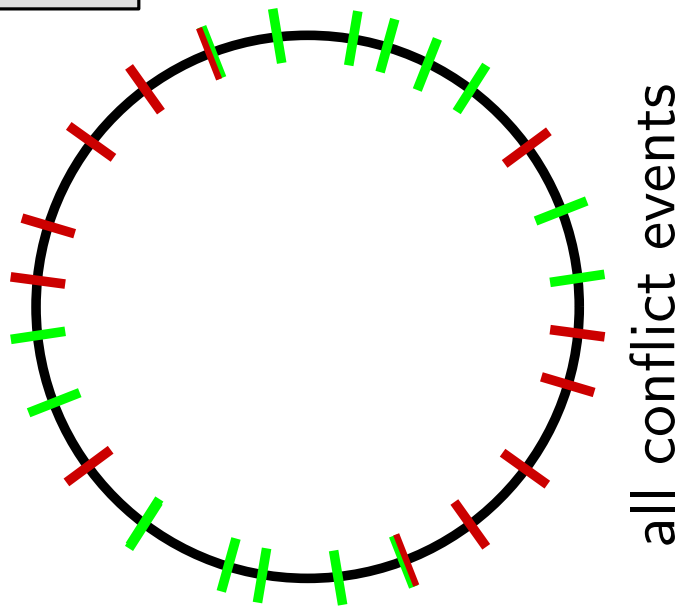

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Time Complexity?

Computational Complexity

Complexity

Theorem 1

MaxTotal is NP-complete

MaxMin is NP-hard

Complexity

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Reduction from PLANAR 3-SAT:
(NP-hard: [Lichtenstein '82])

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planar 3-Sat formula φ

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Menge von Punkten & Labeln, $K > 0$:
φ erfüllbar $\Leftrightarrow \max \sum_L |A_L| \geq K$

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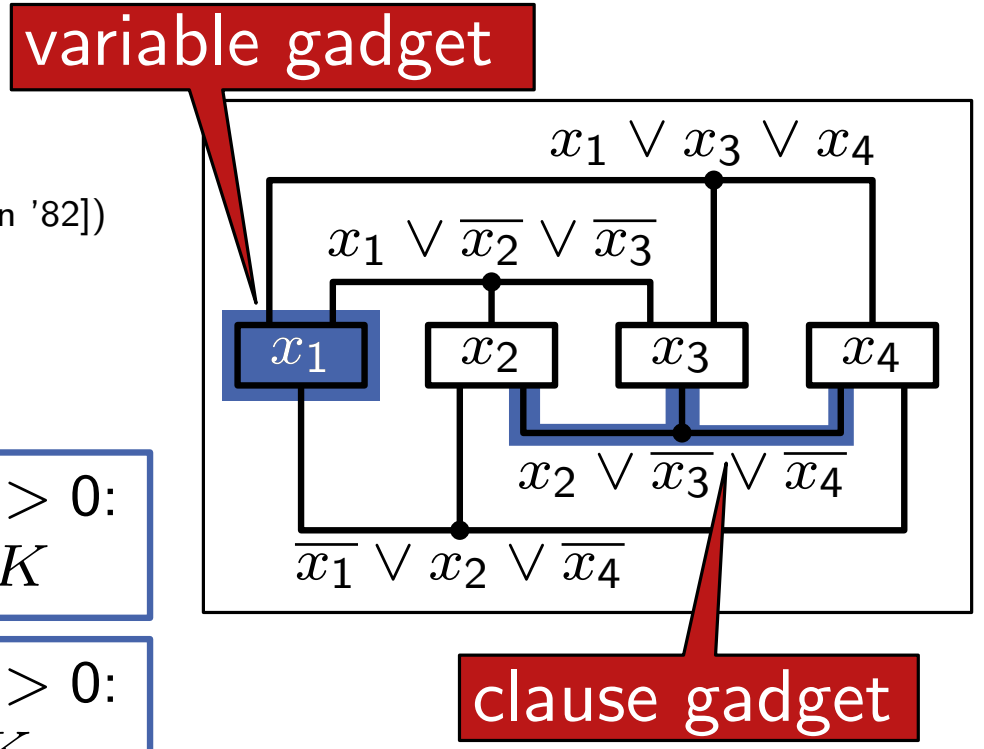

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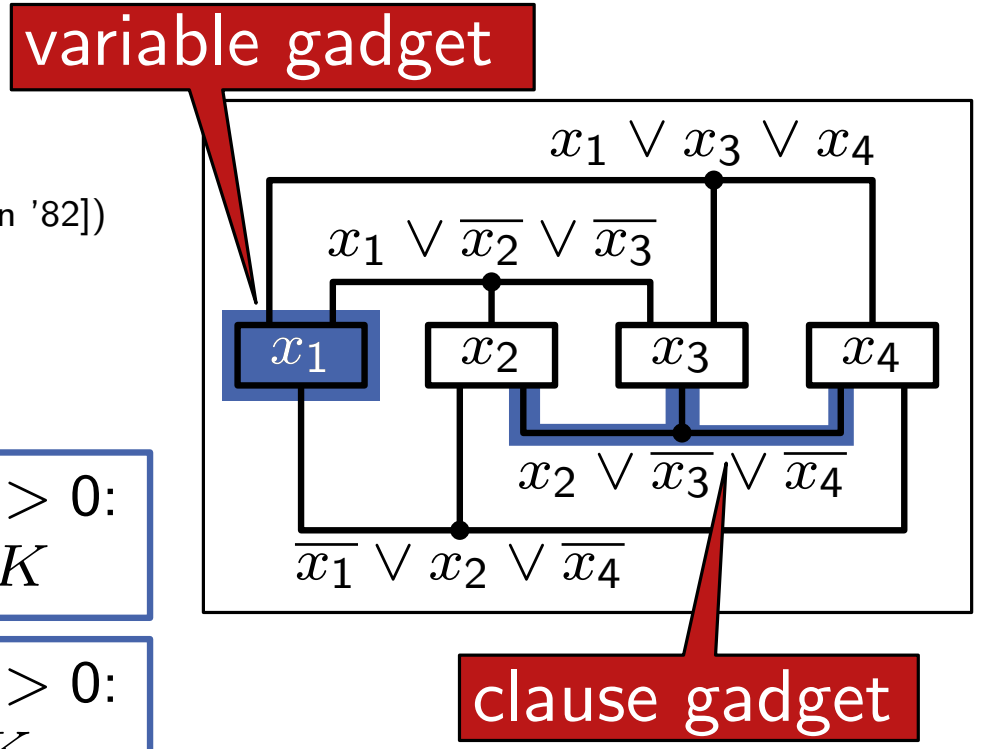

Unless $P = NP$ MaxMin cannot be efficiently approximated within a factor of 3/4.

1/4–Approximation for MaxTotal
for unit squares

1/4 Approximation of MaxTotal

use **shifting technique** or **line stabbing**

(NP-hard: [Hochbaum and Maass '85])

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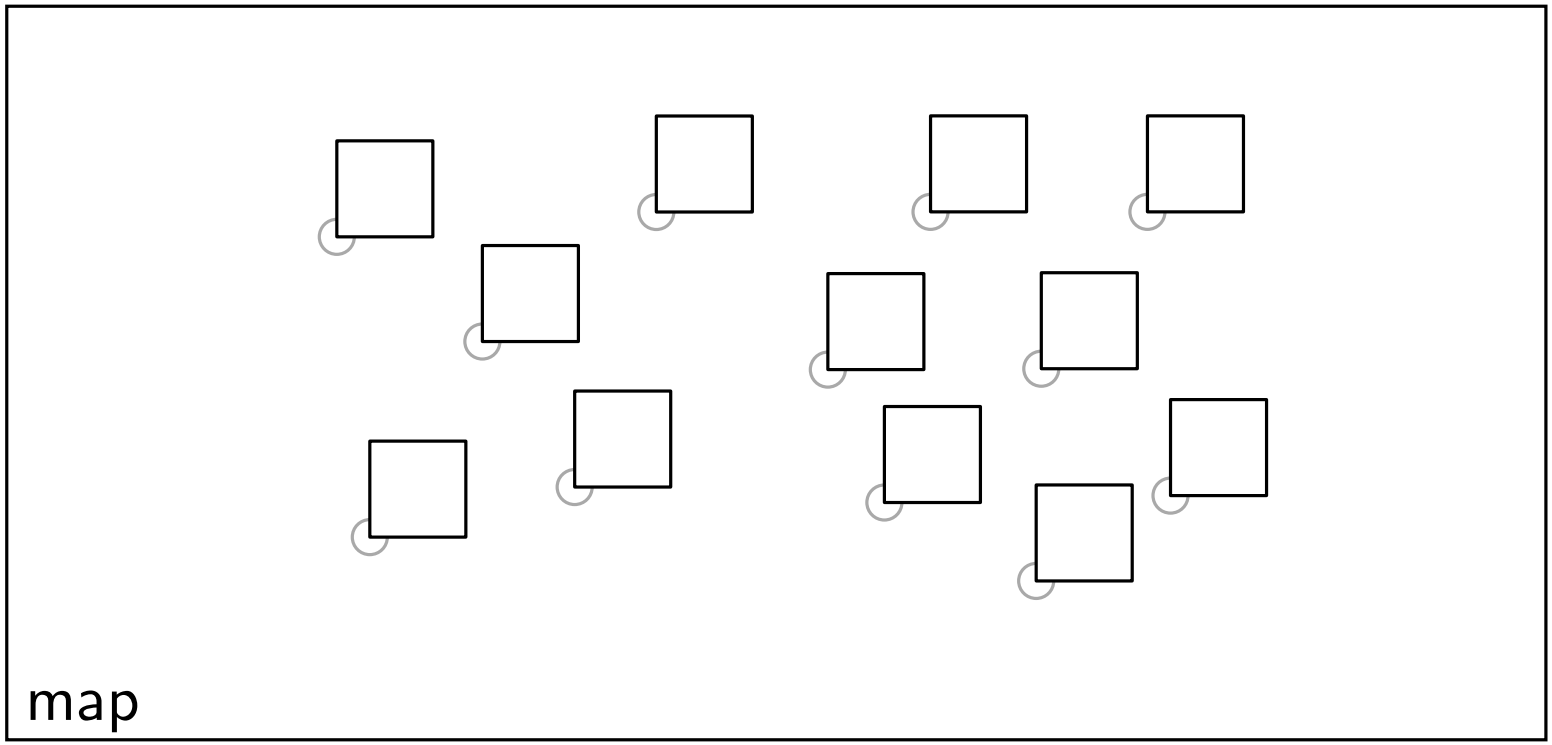

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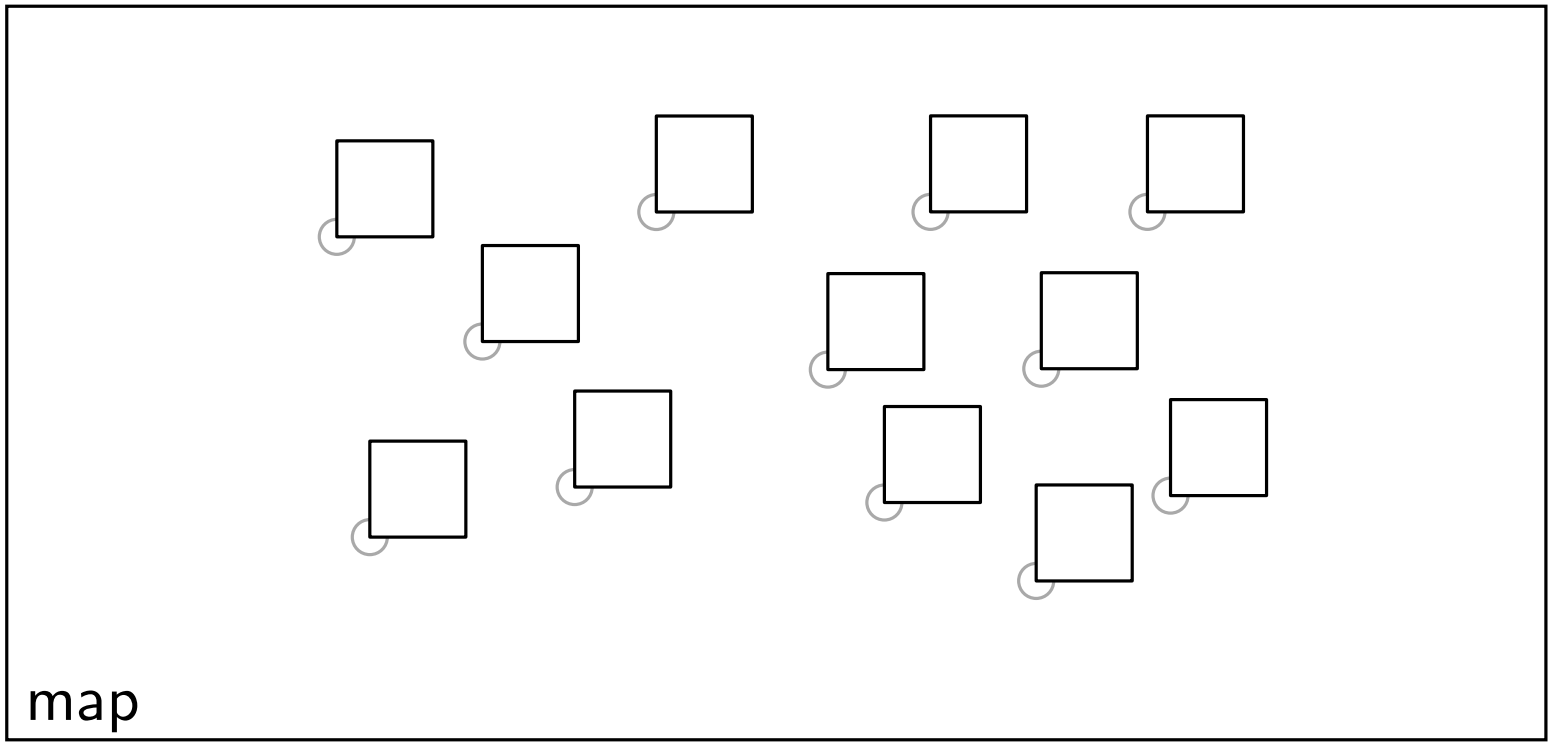

- split set of labels into two sets

1/4 Approximation of MaxTotal

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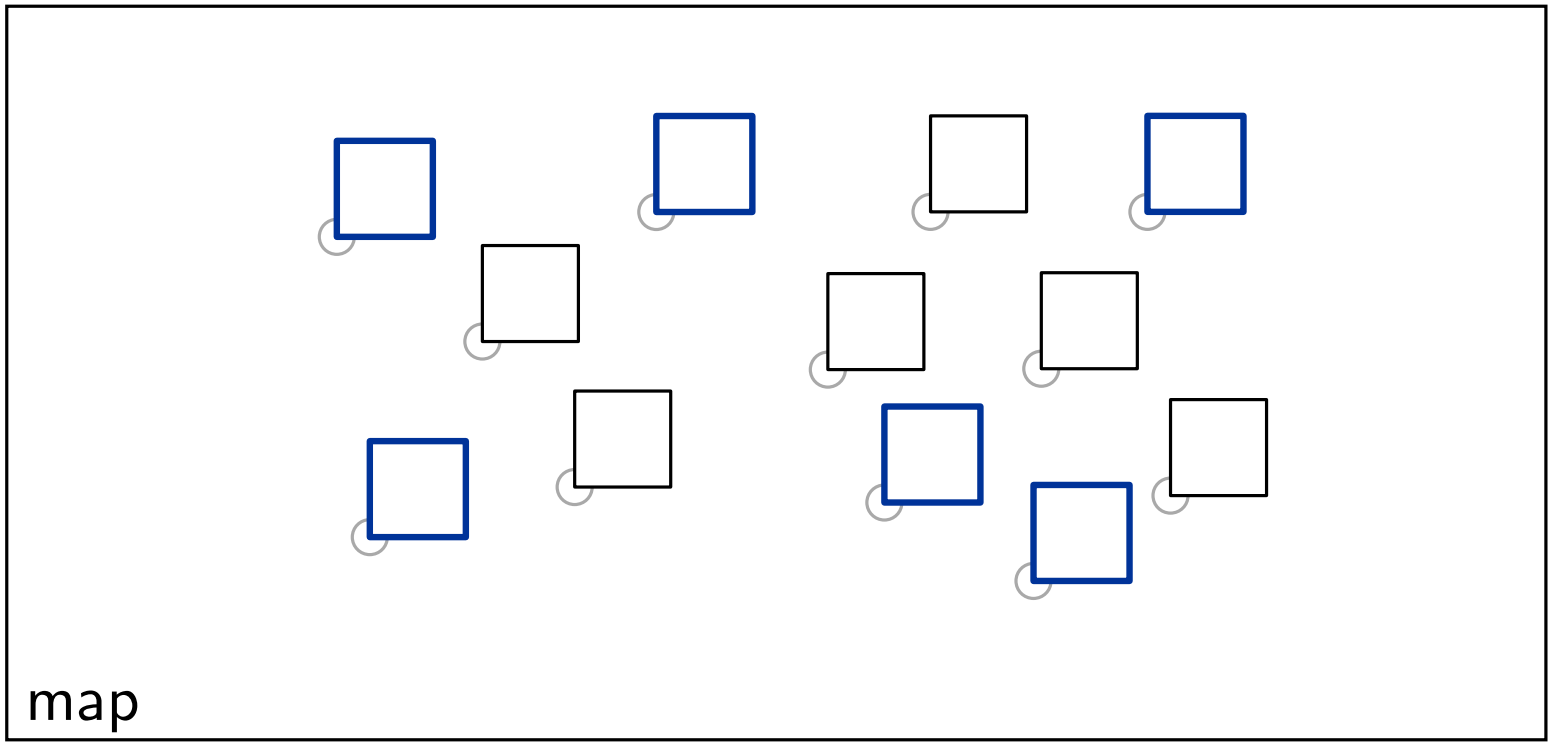

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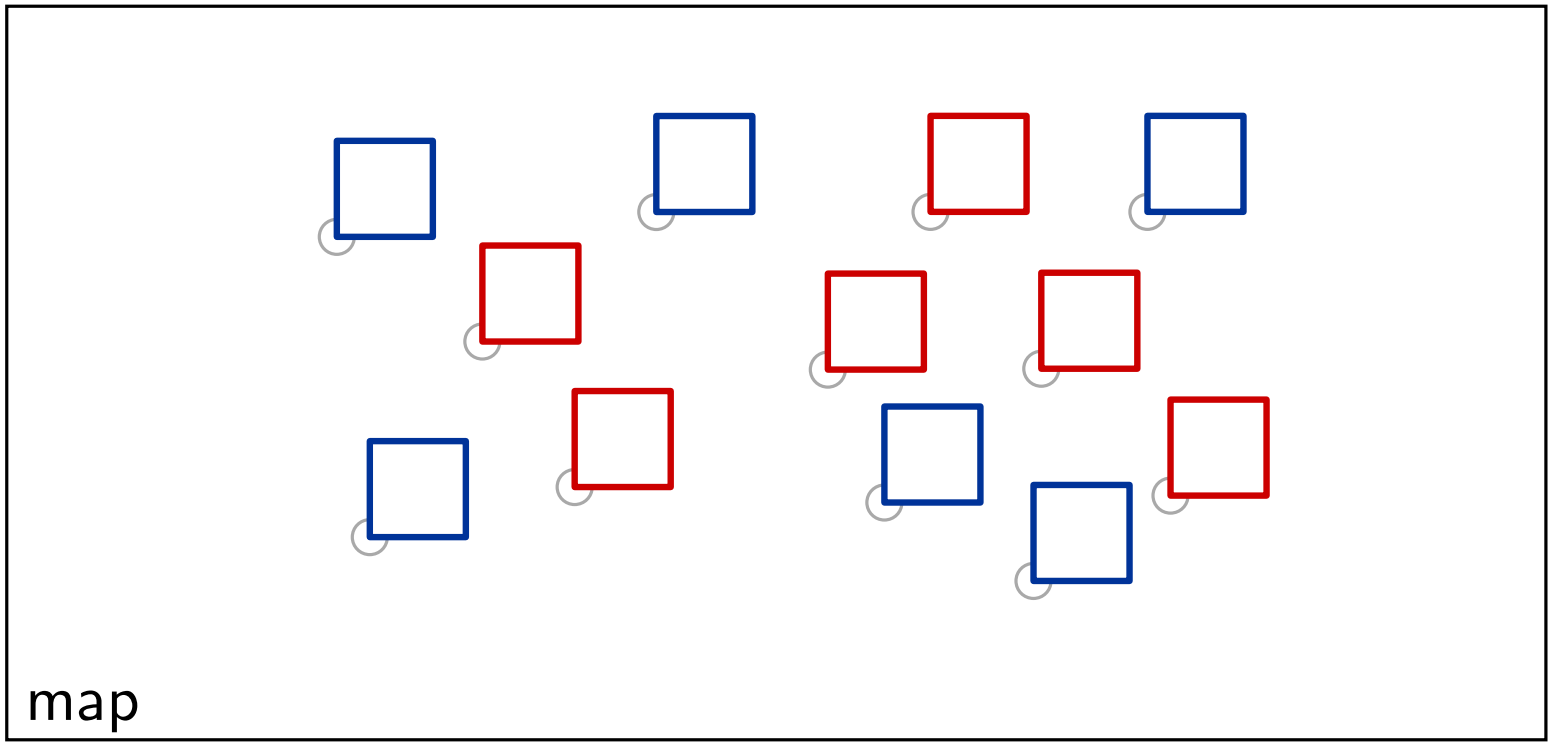

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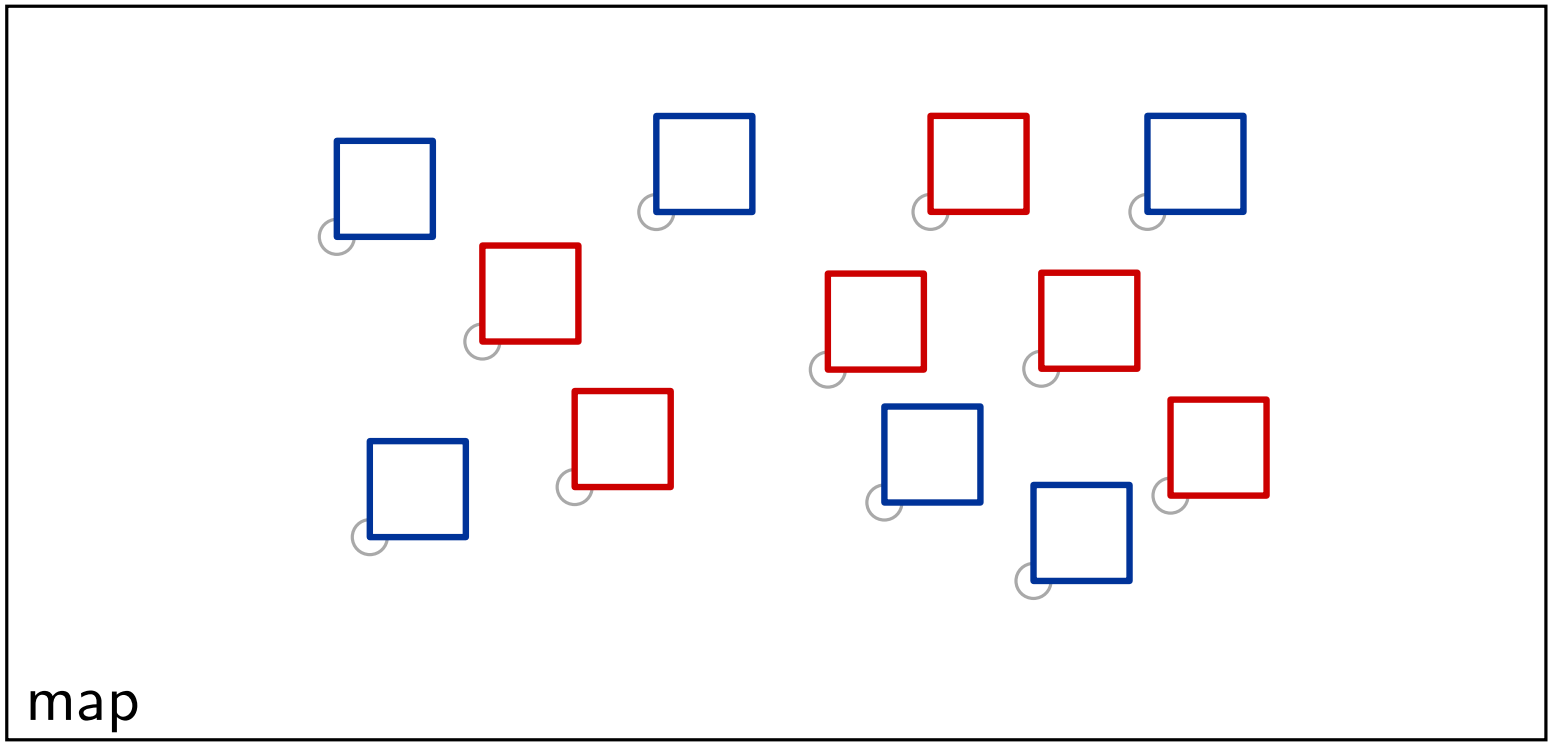

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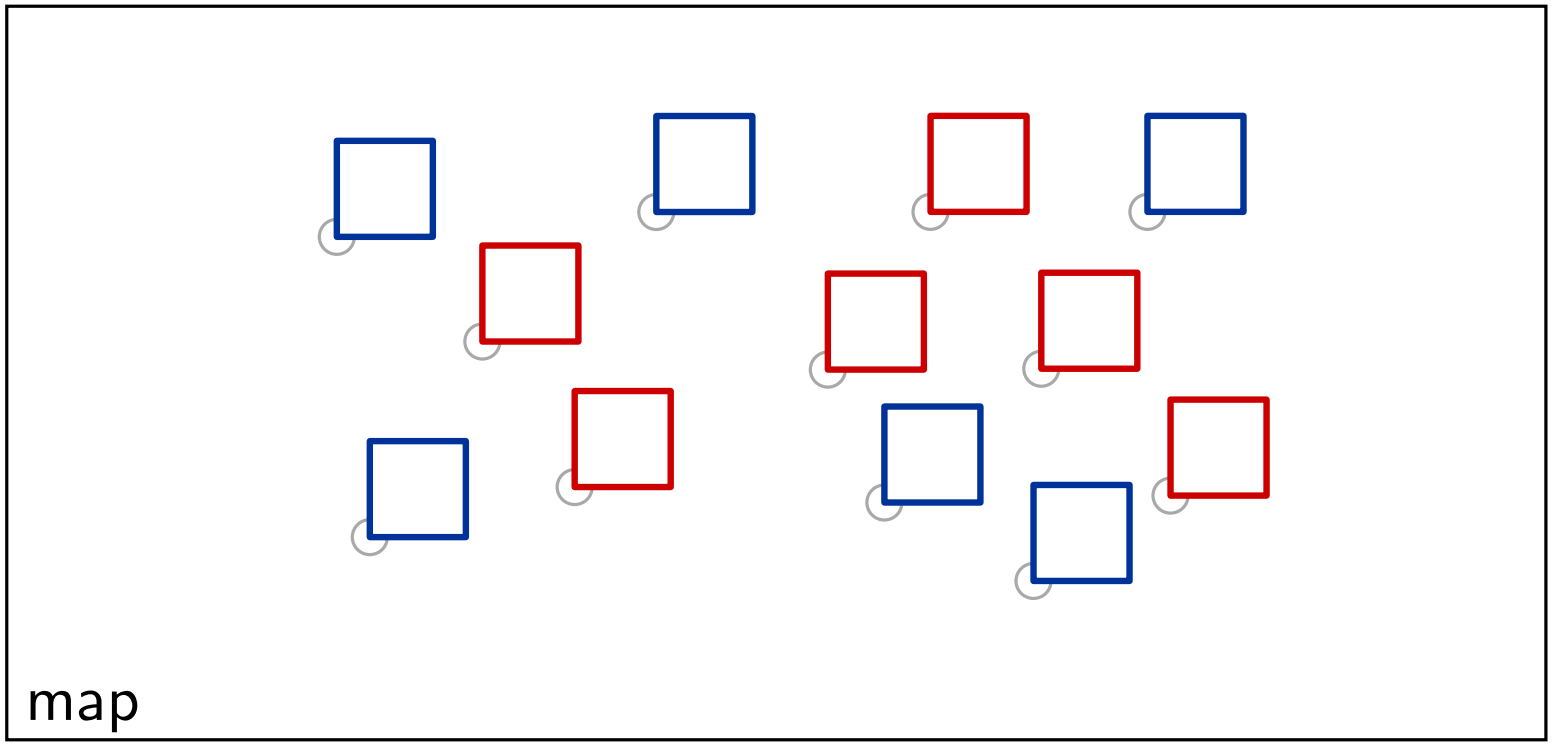

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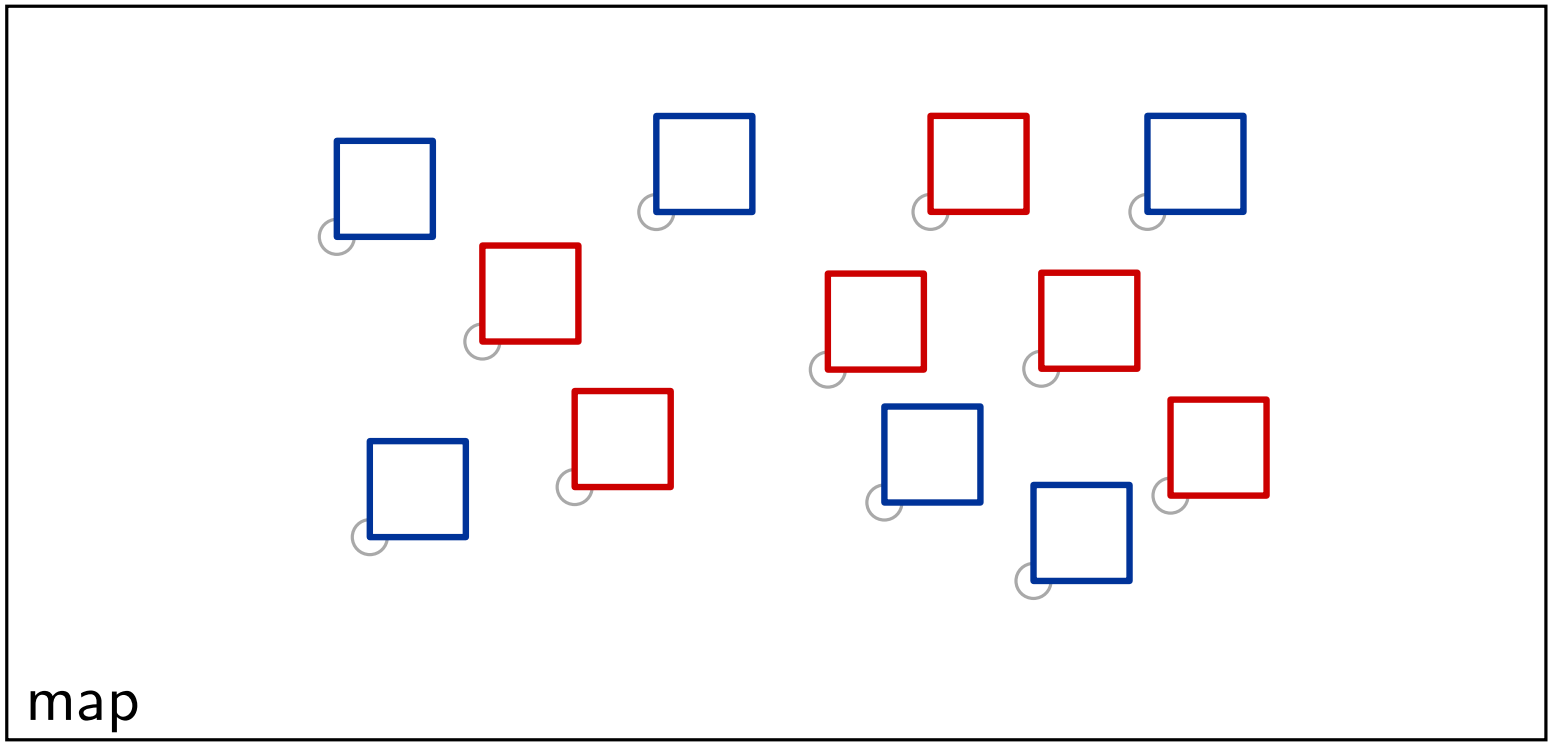

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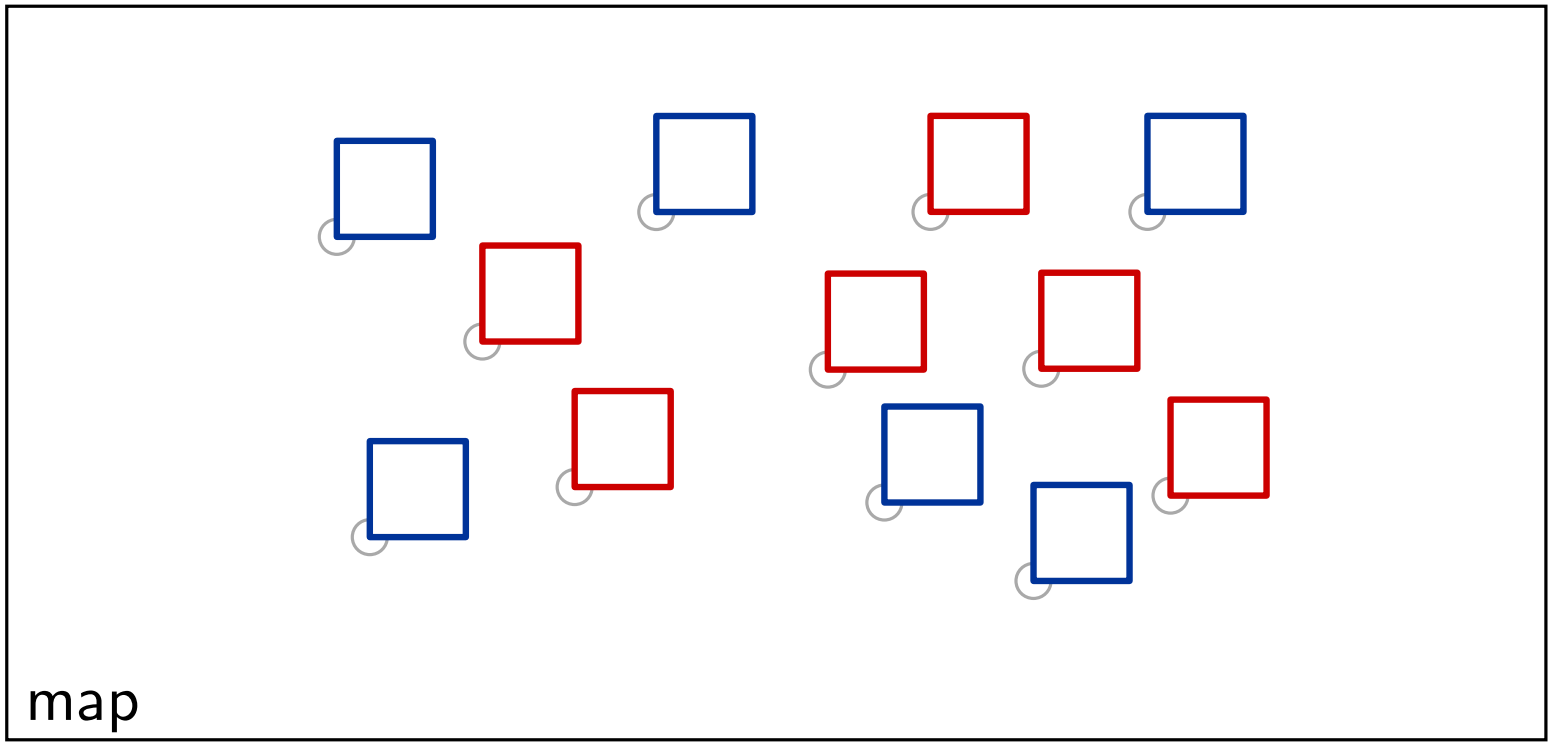

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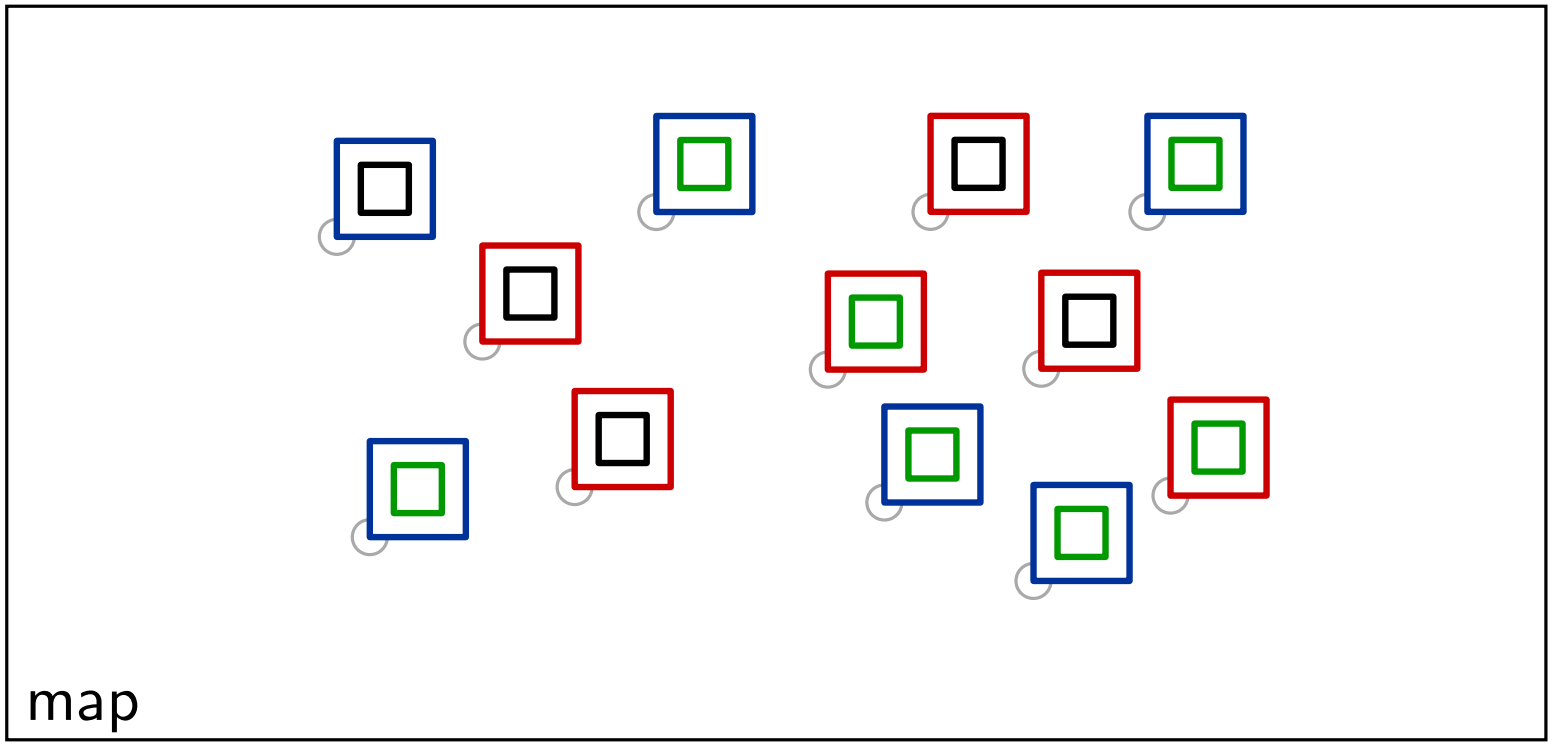

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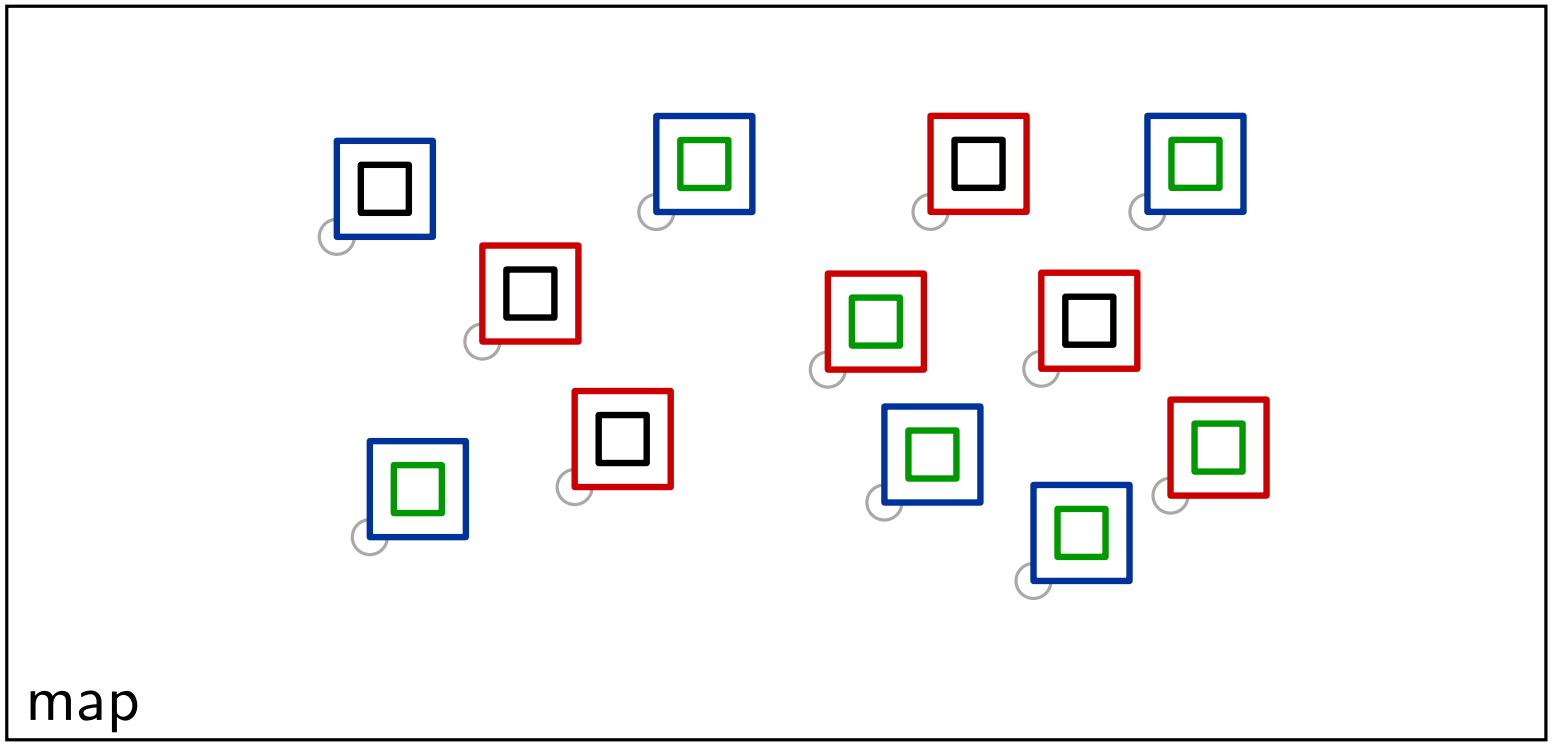
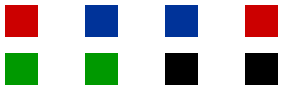


- split set of labels into **four** sets 
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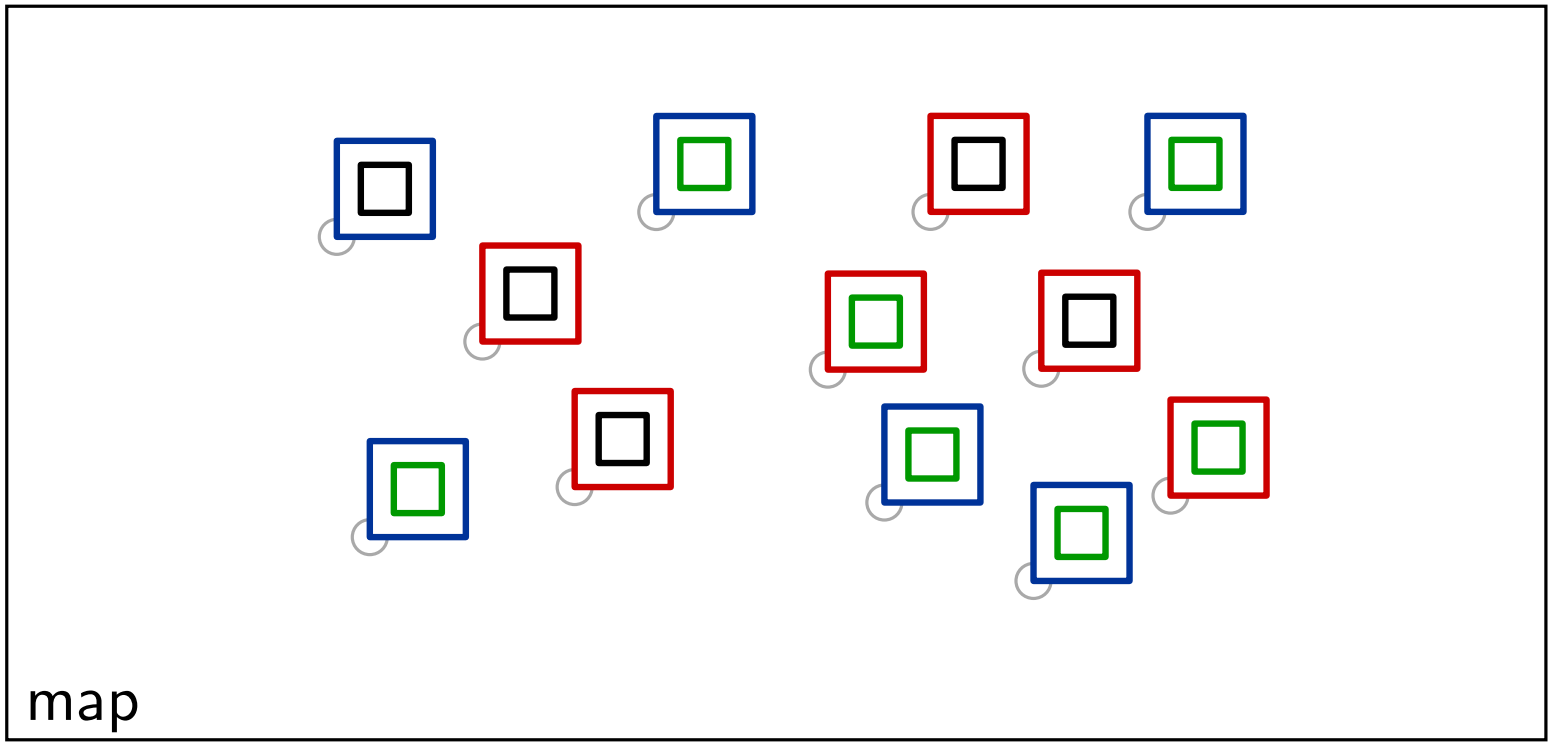
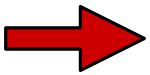
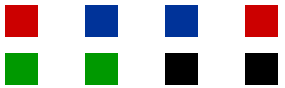




- split set of labels into **four** sets

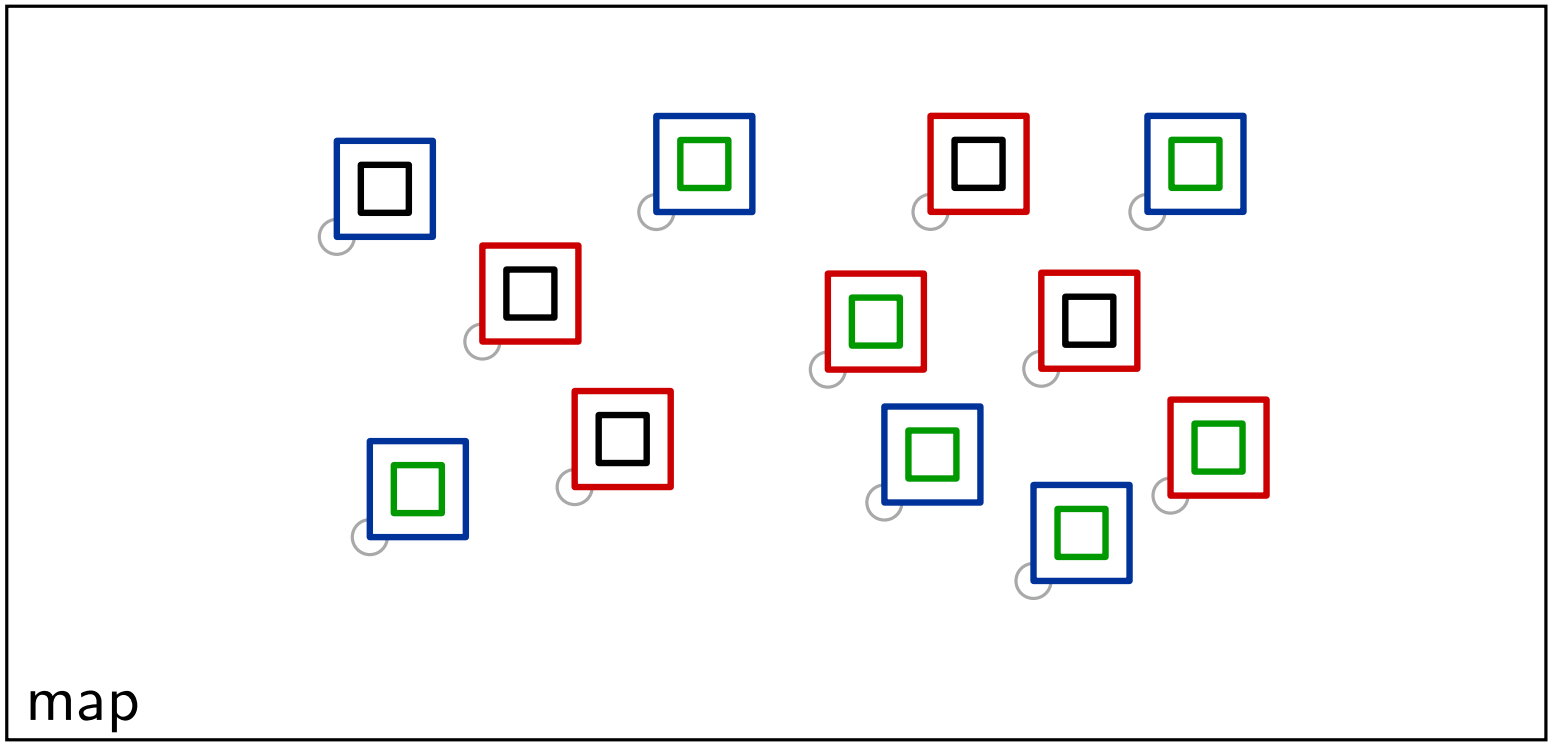


- find optimal solution for each set separately

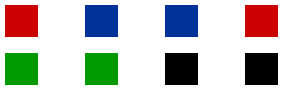
one of those solutions is a **1/4**-approximation

1/4-Approximation of MaxTotal

Observation 1:



- split set of labels into **four** sets



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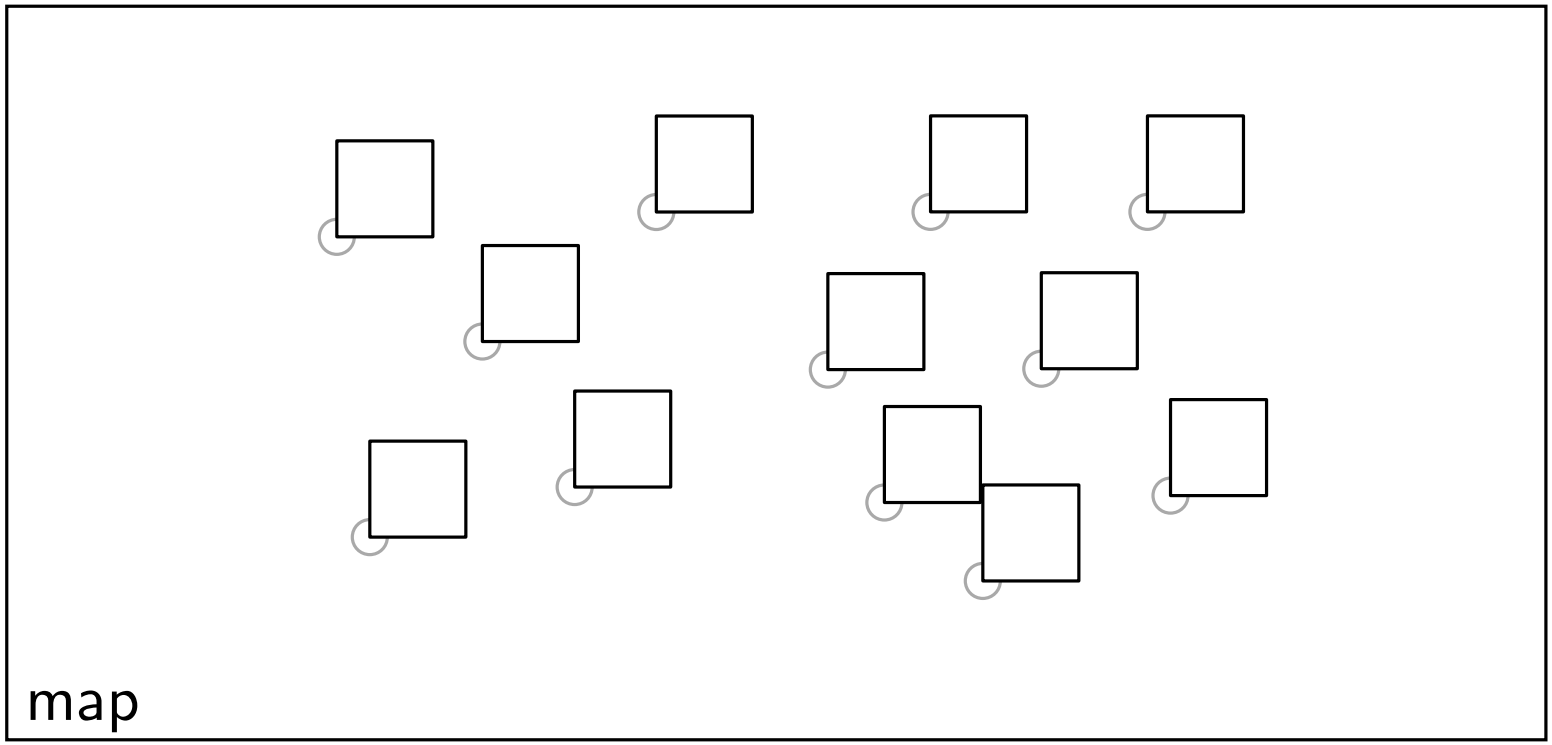
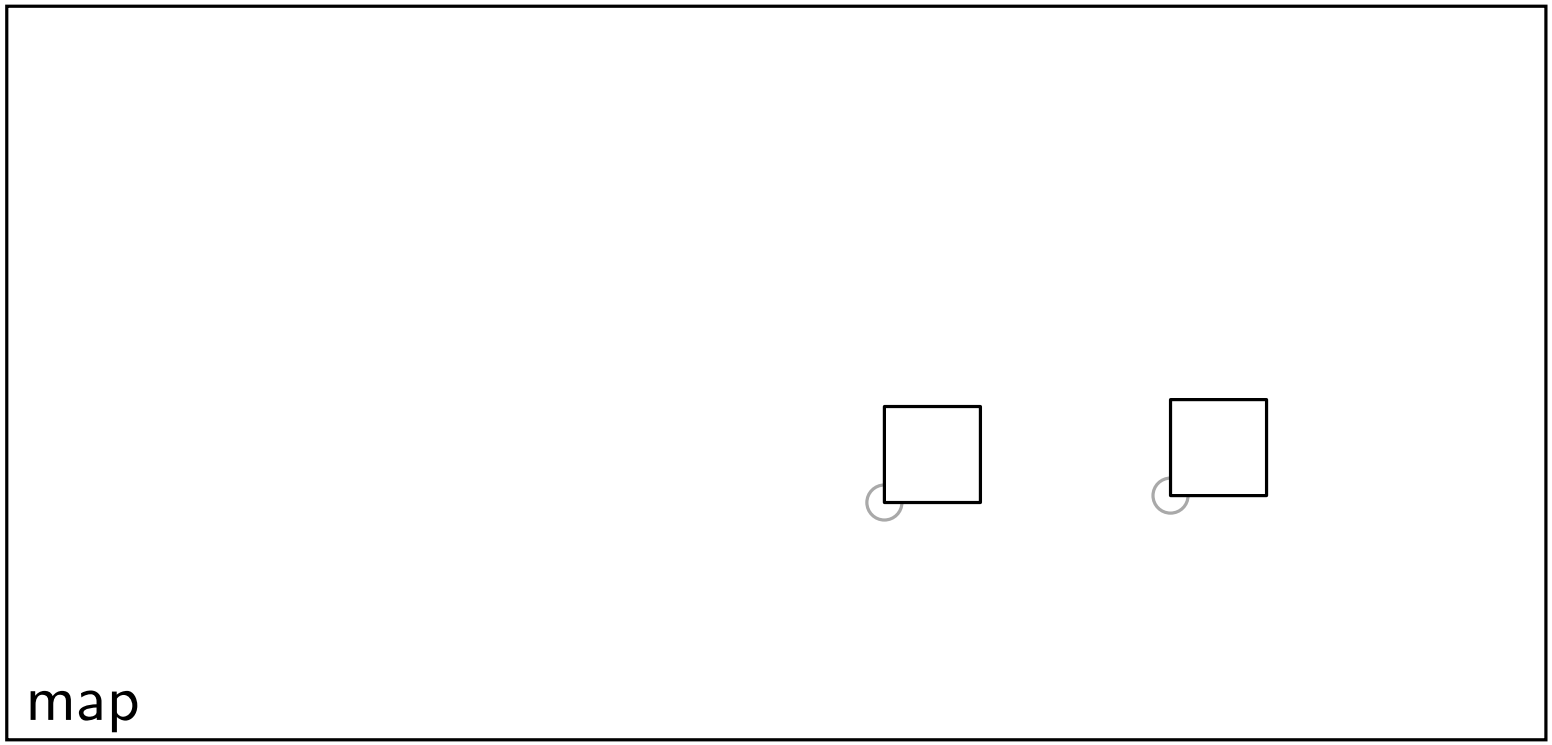
1/4-Approximation of MaxTotal

Observation 2:



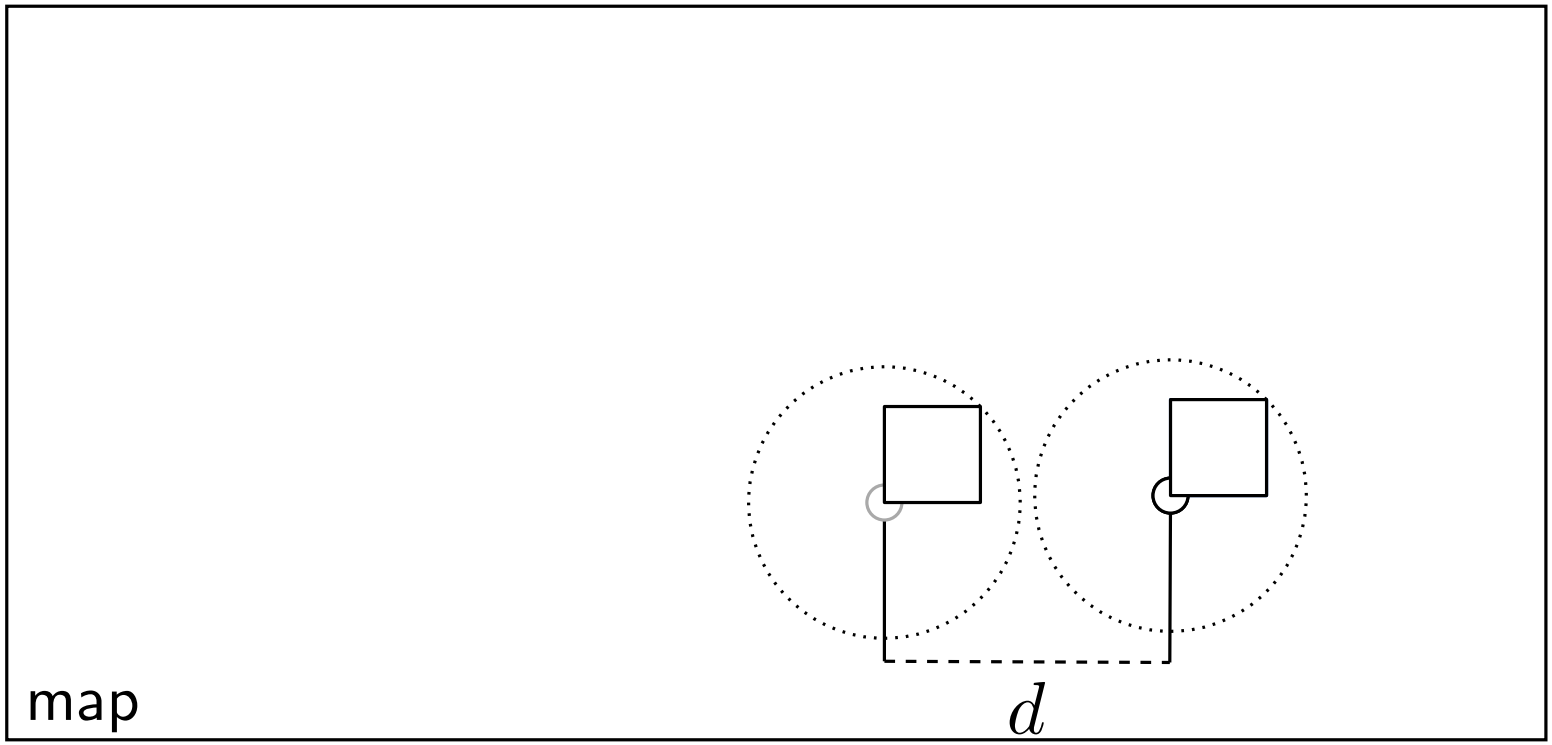
1/4-Approximation of MaxTotal

Observation 2:



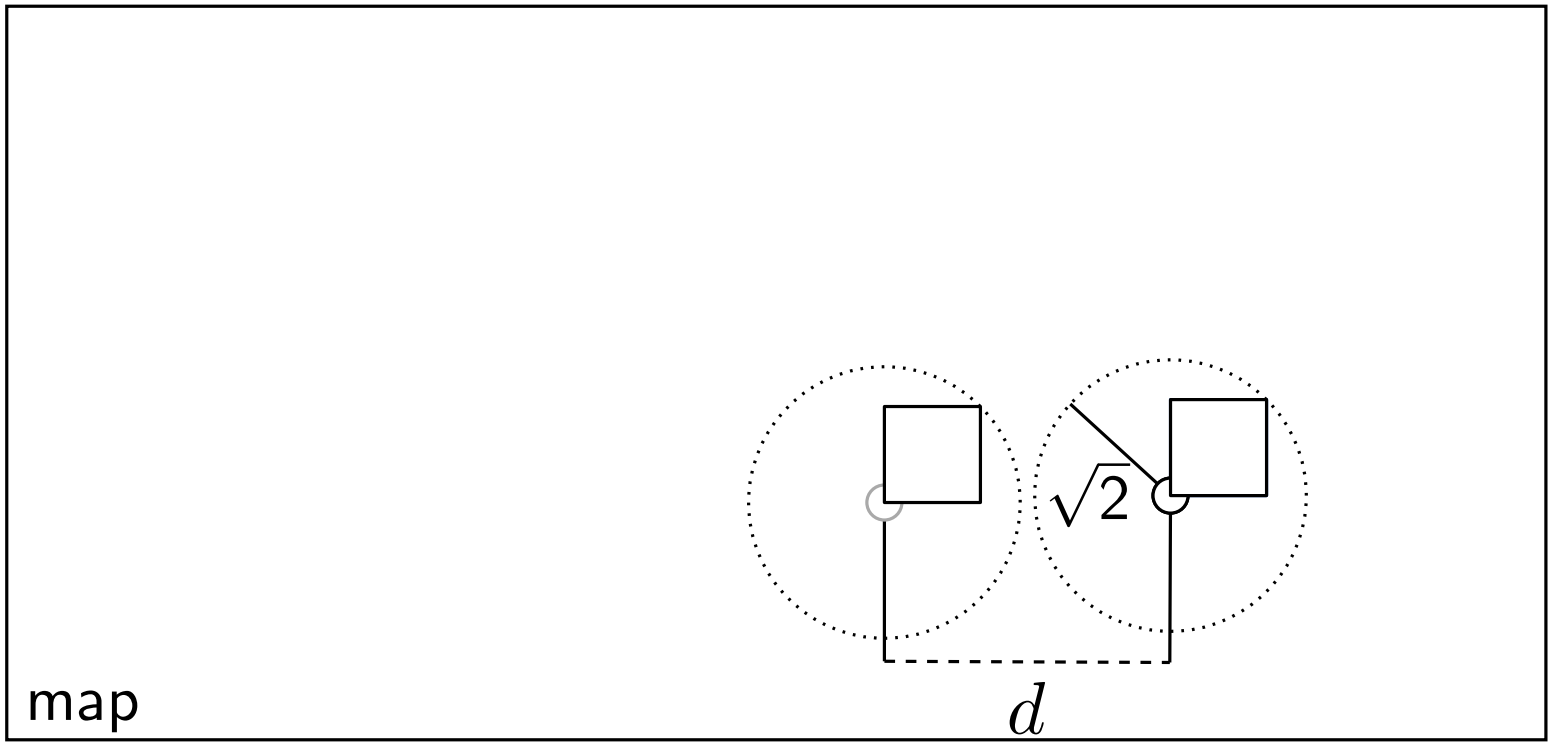
1/4-Approximation of MaxTotal

Observation 2:



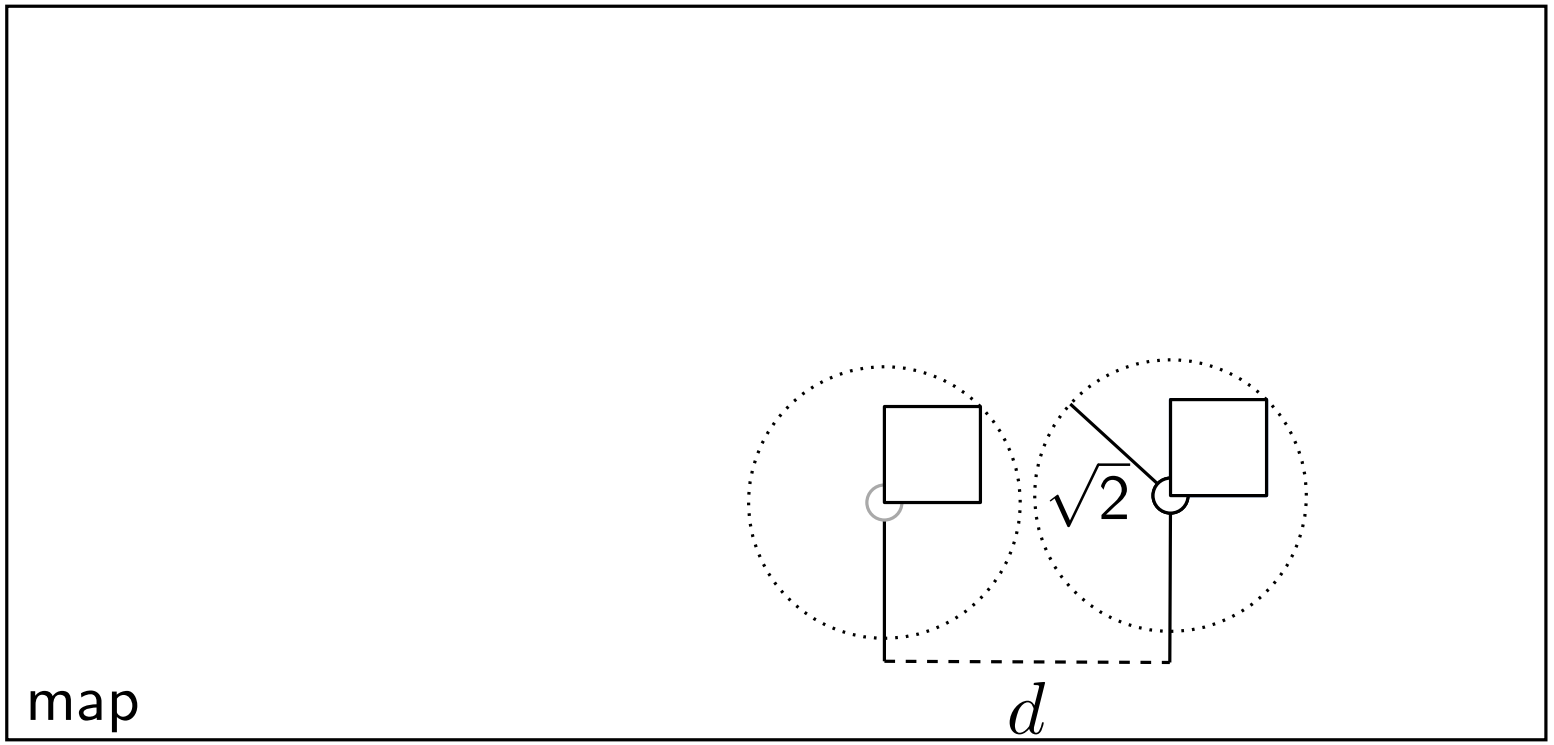
1/4-Approximation of MaxTotal

Observation 2:



1/4-Approximation of MaxTotal

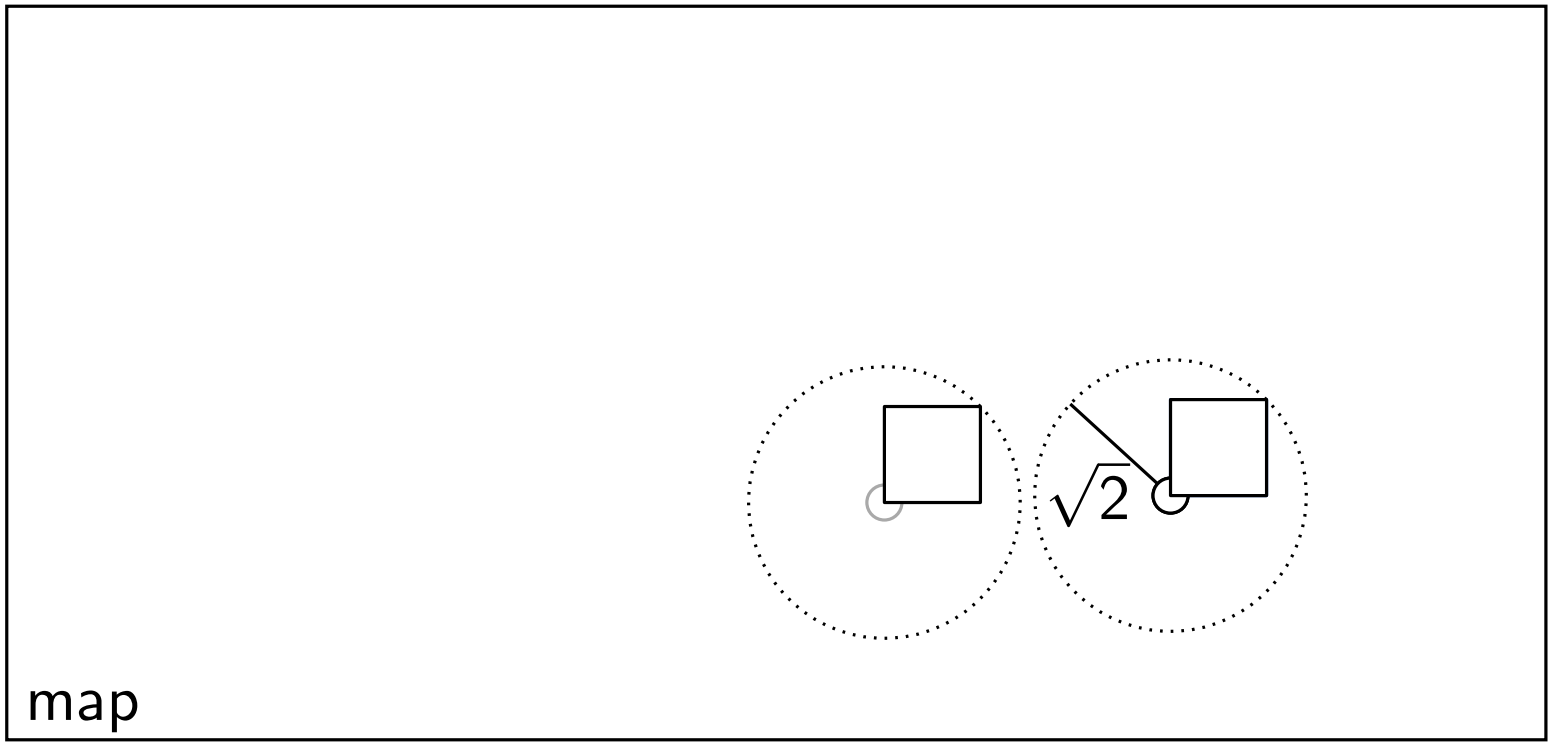
Observation 2:



if $d > 2\sqrt{2}$ then no conflict possible

1/4-Approximation of MaxTotal

Observation 2:



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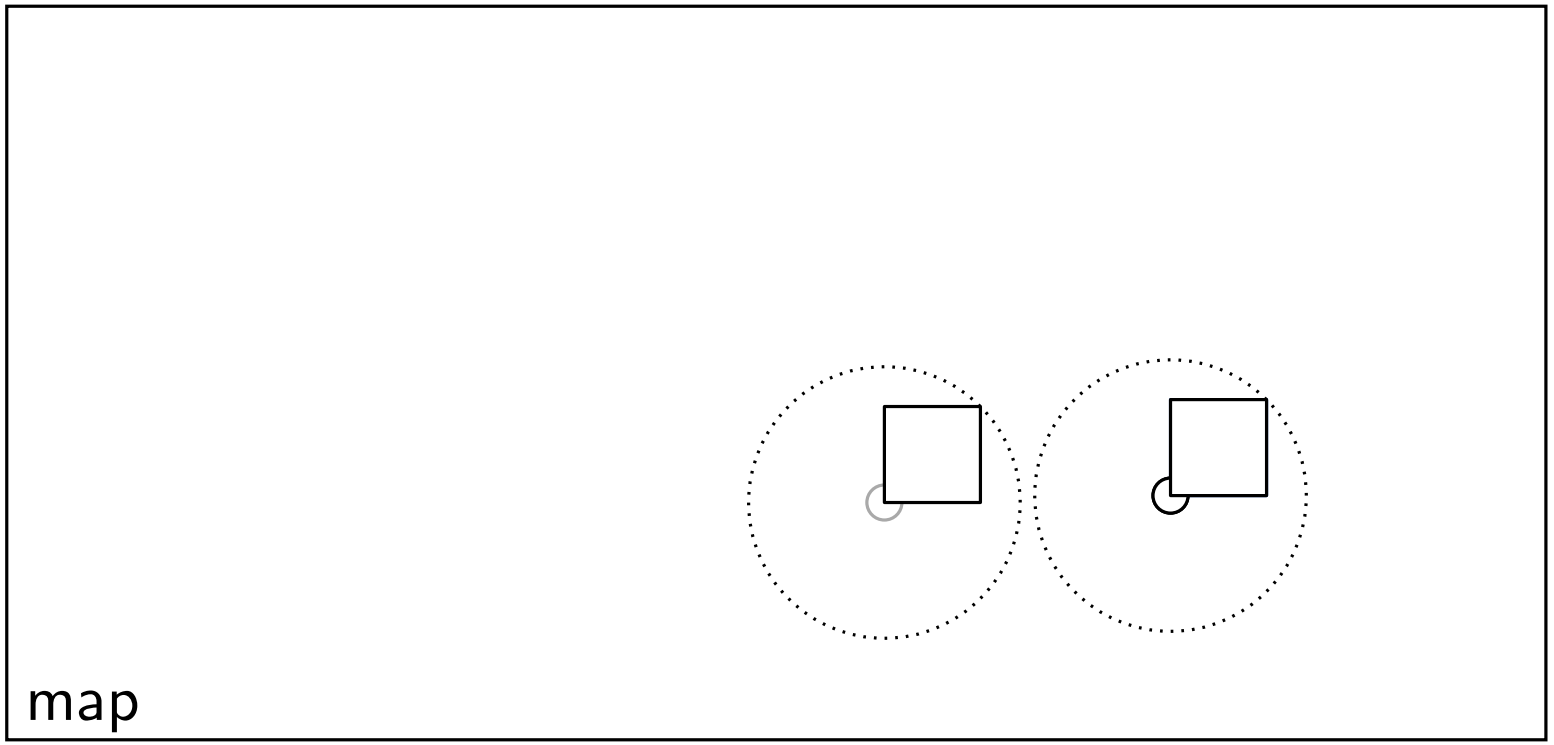
1/4-Approximation of MaxTotal

Observation 2:



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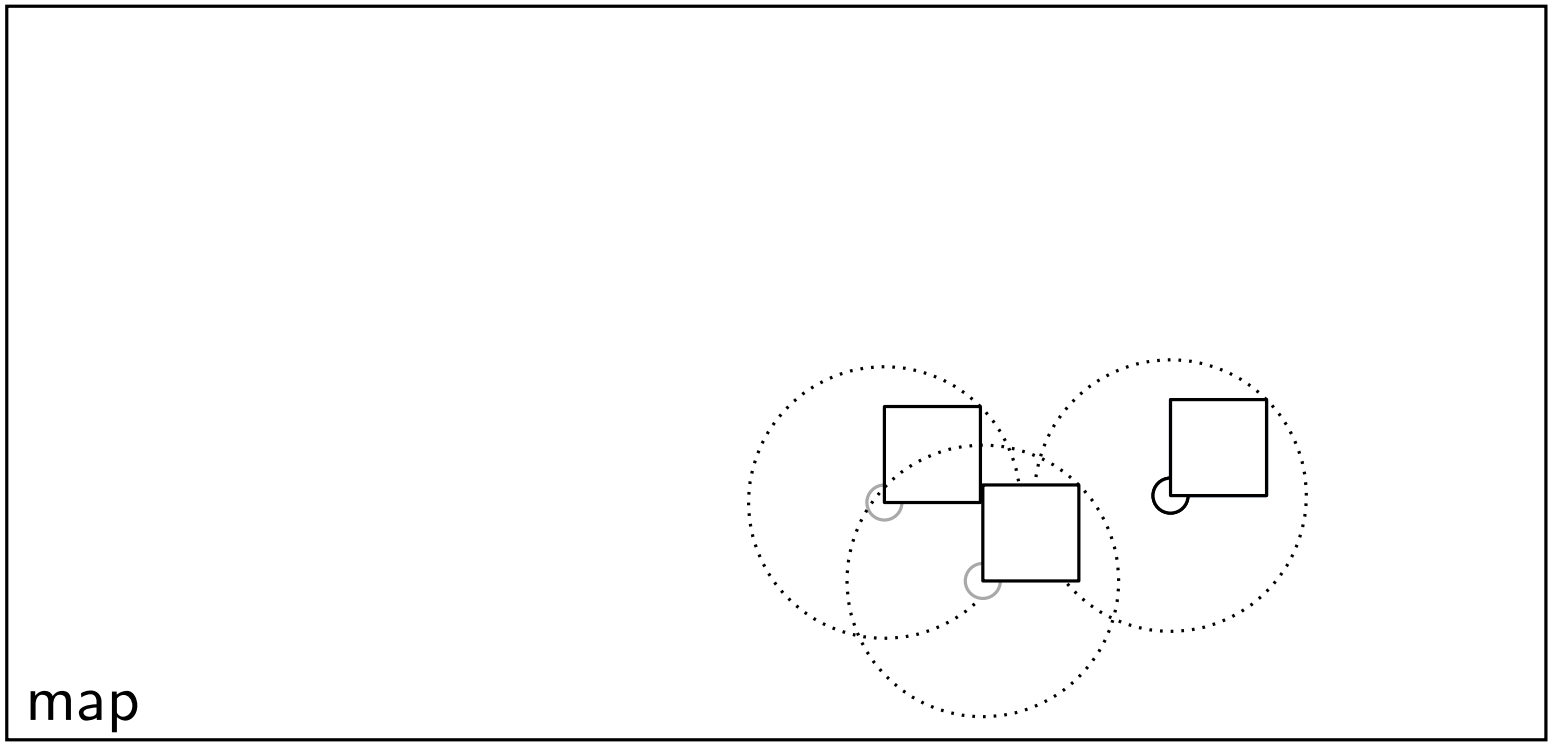
1/4-Approximation of MaxTotal

Observation 2:



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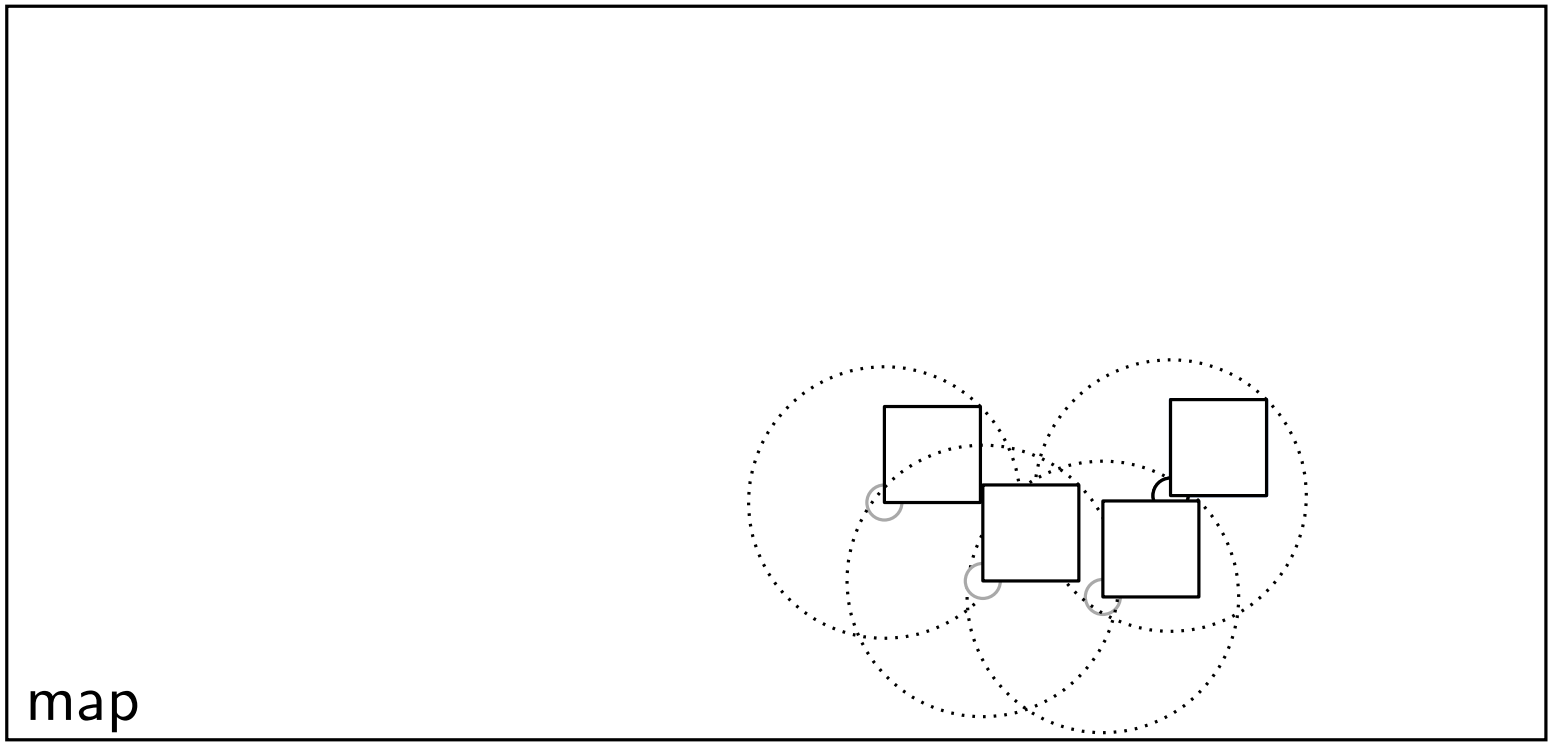
1/4-Approximation of MaxTotal

Observation 2:



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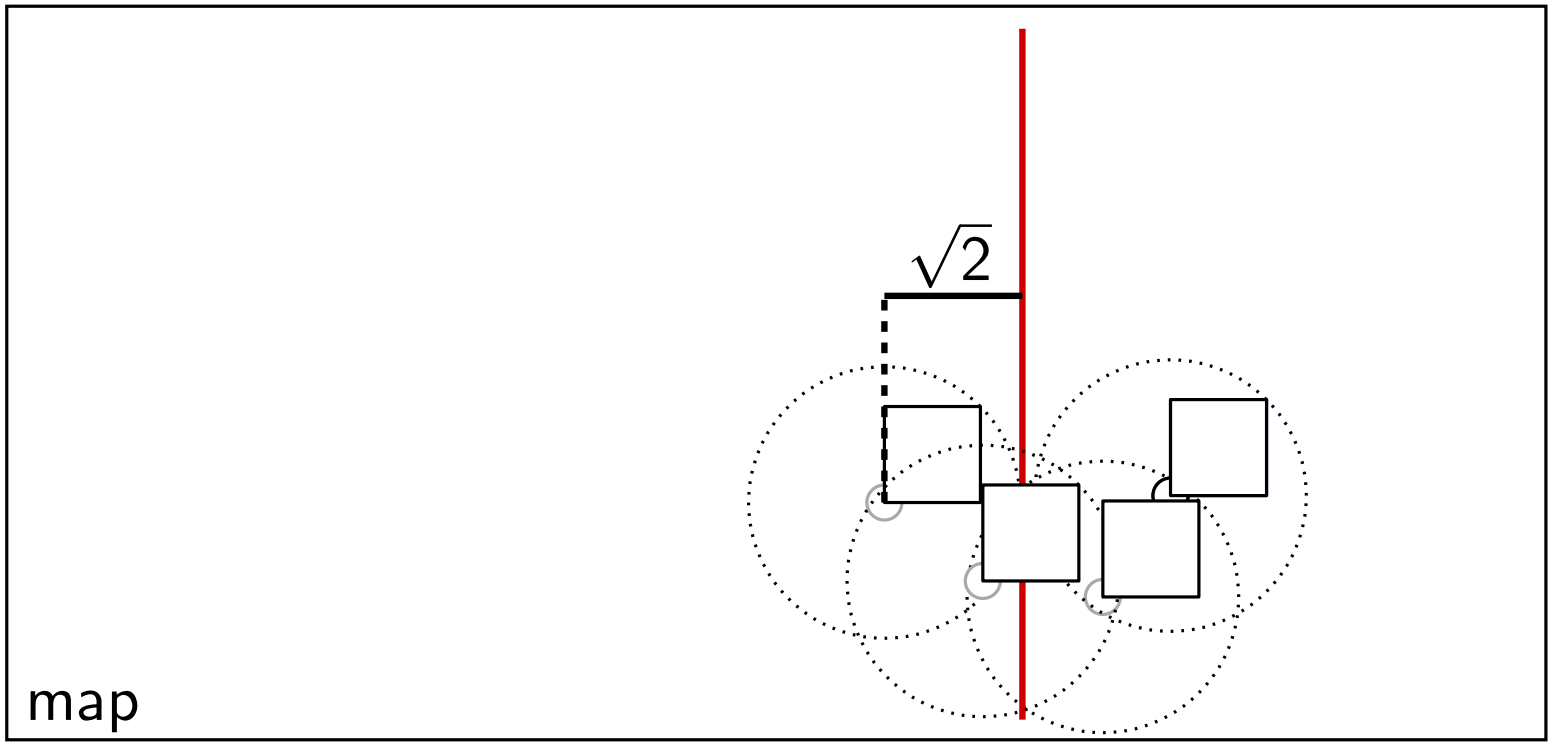
1/4-Approximation of MaxTotal

Observation 2:



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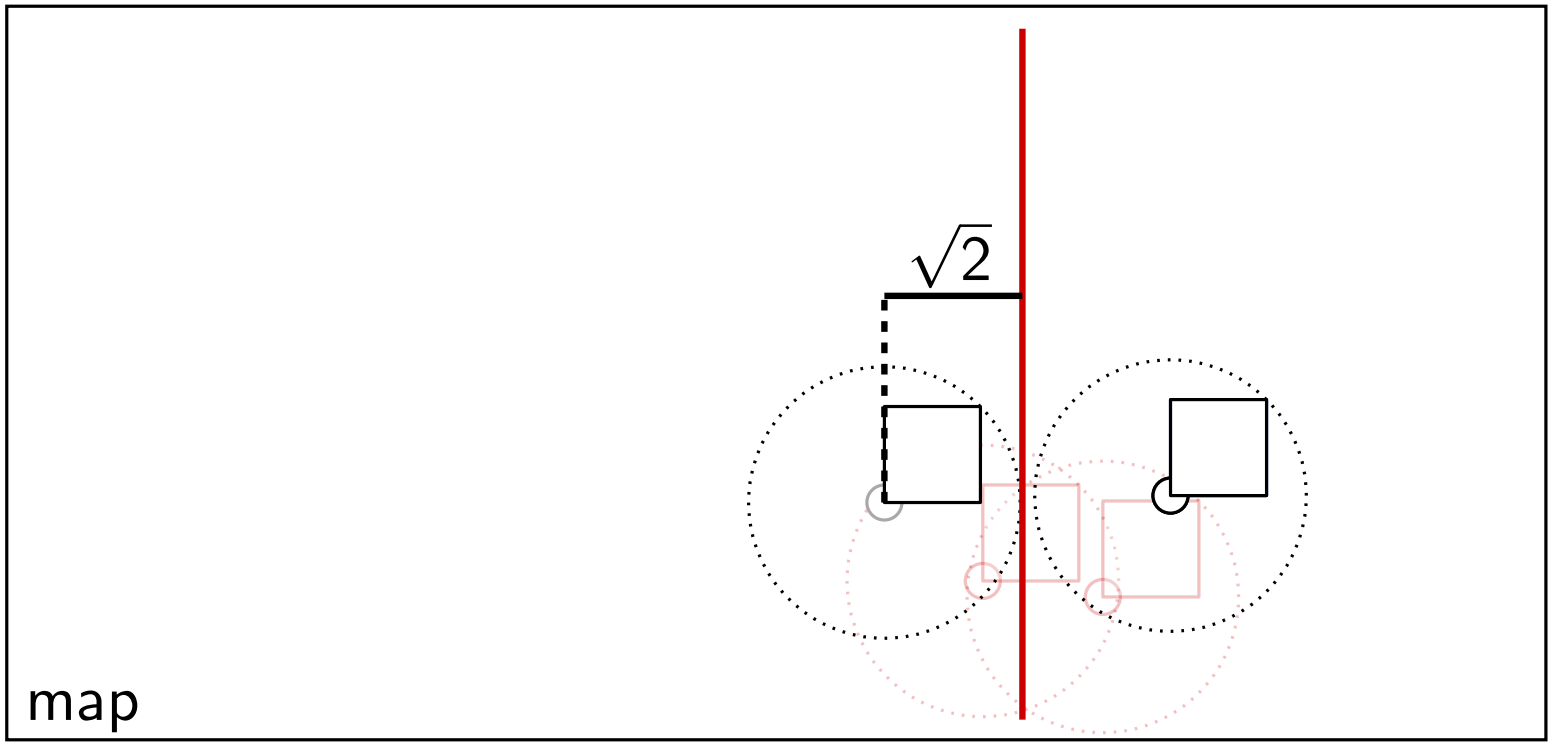
1/4-Approximation of MaxTotal

Observation 2:



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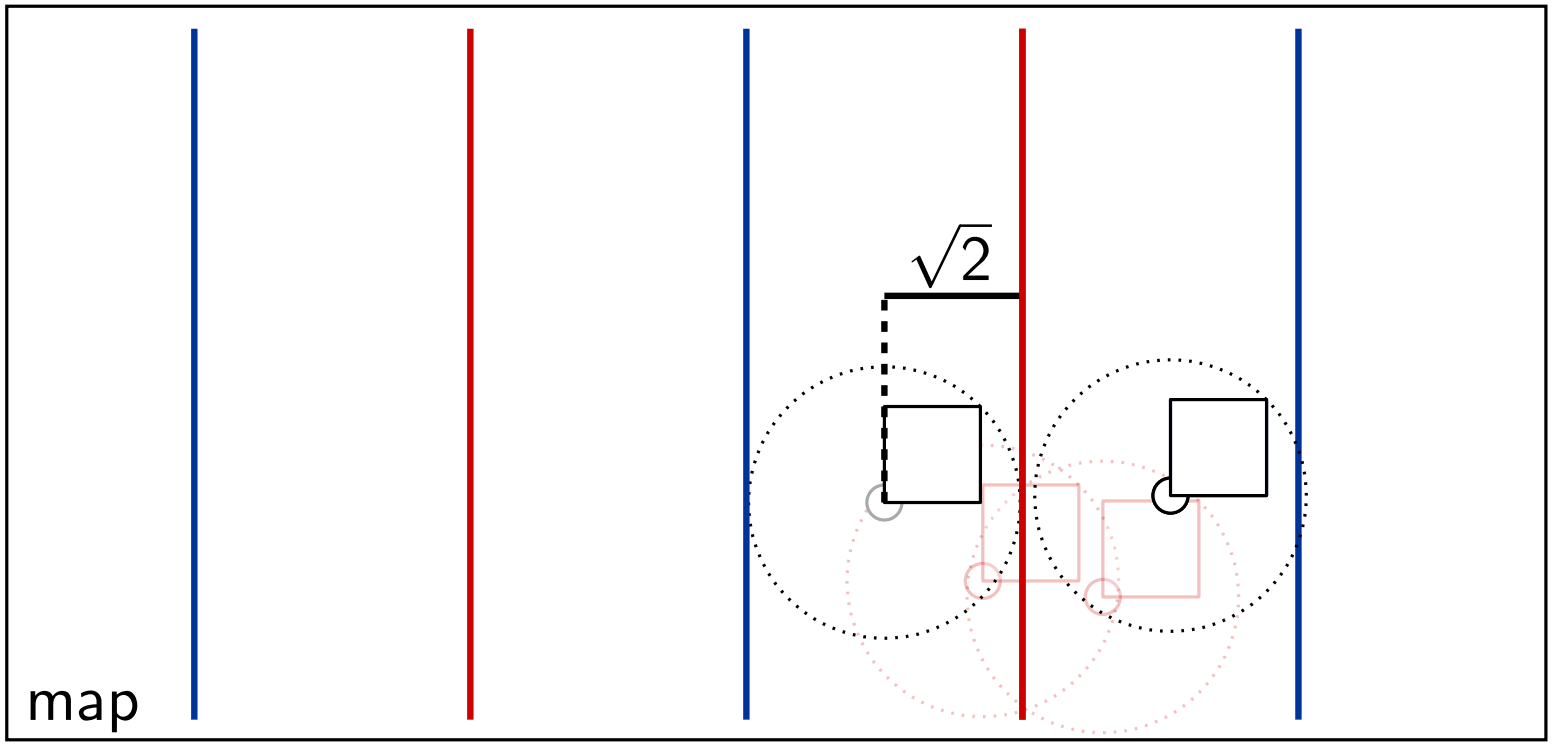
Observation 2:



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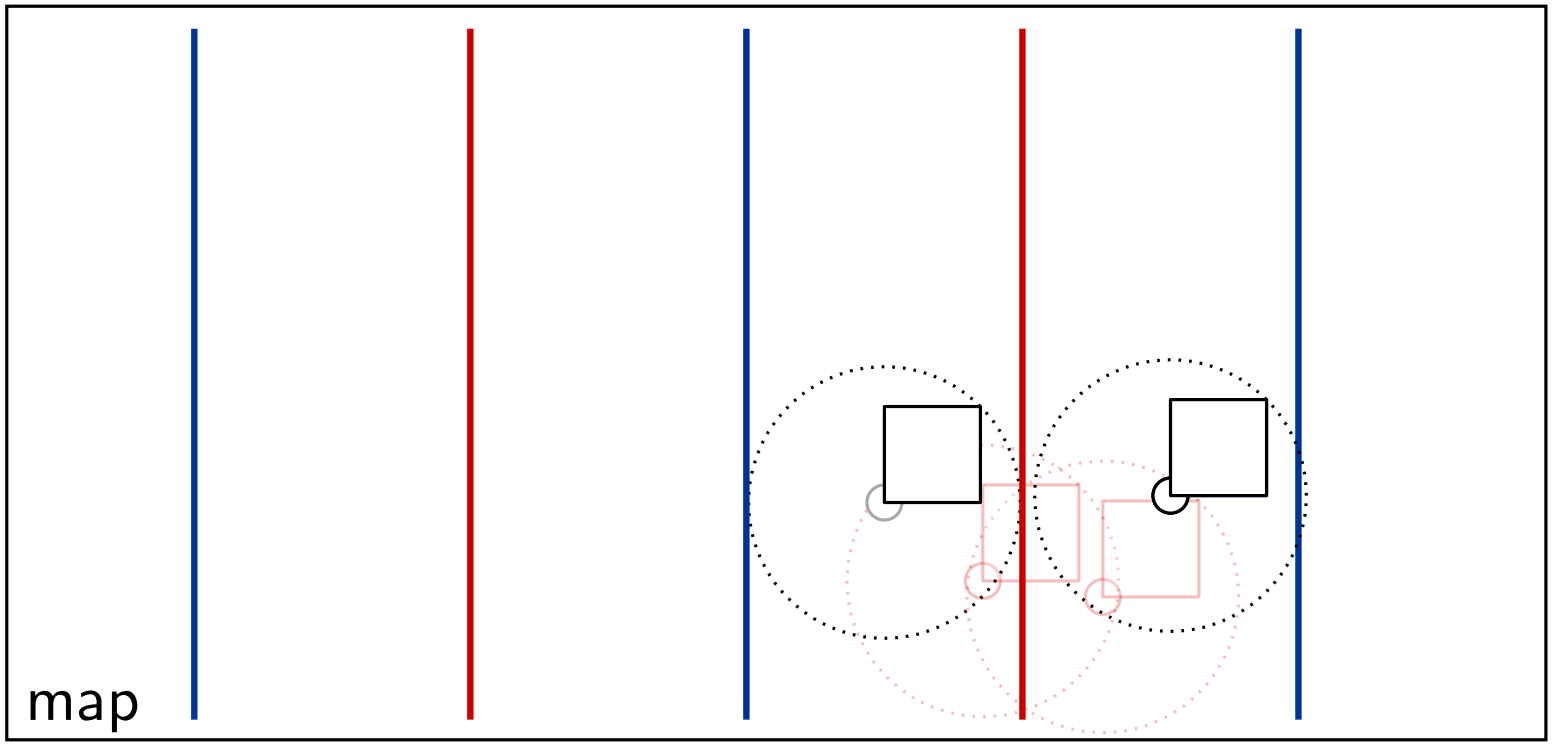
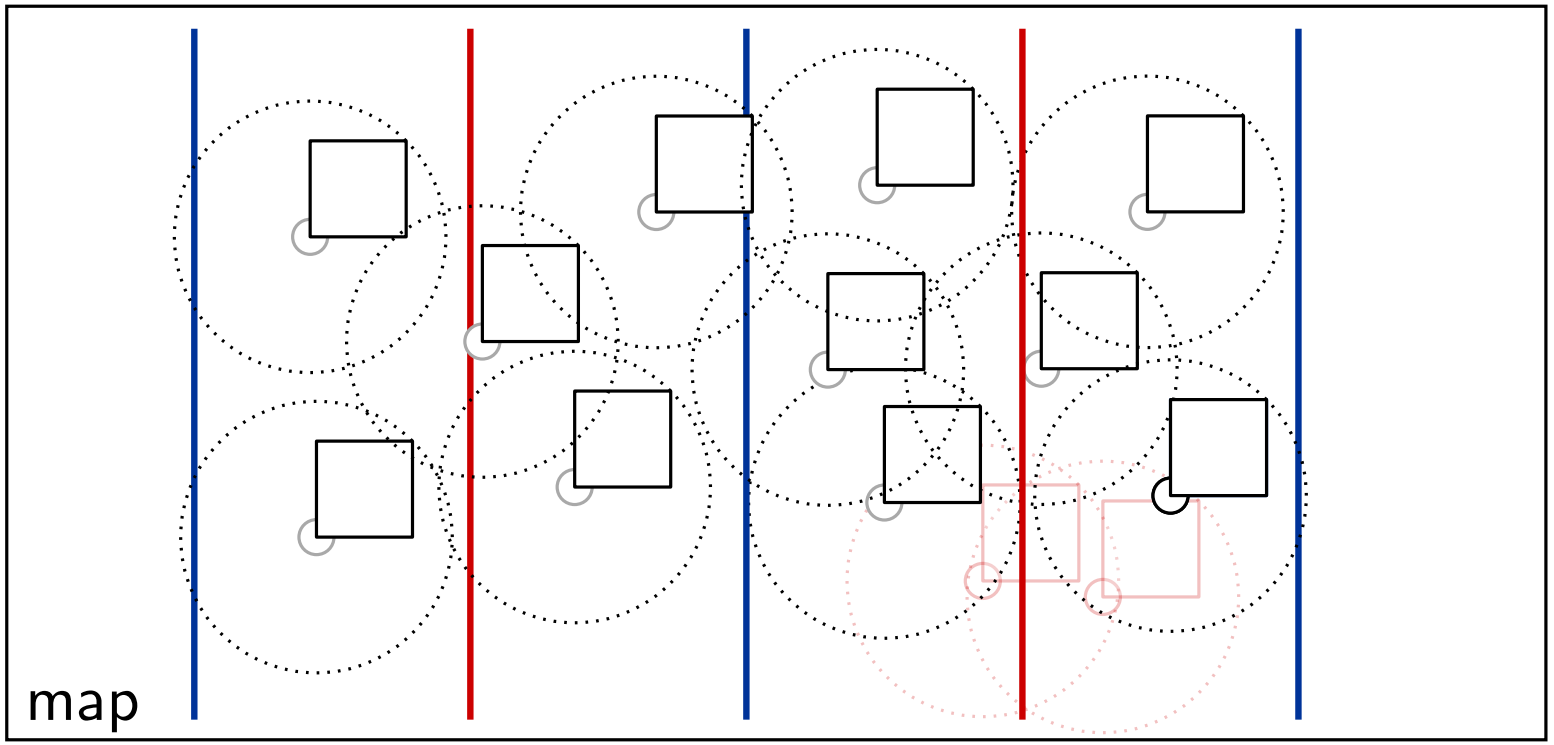
1/4-Approximation of MaxTotal

Observation 2:



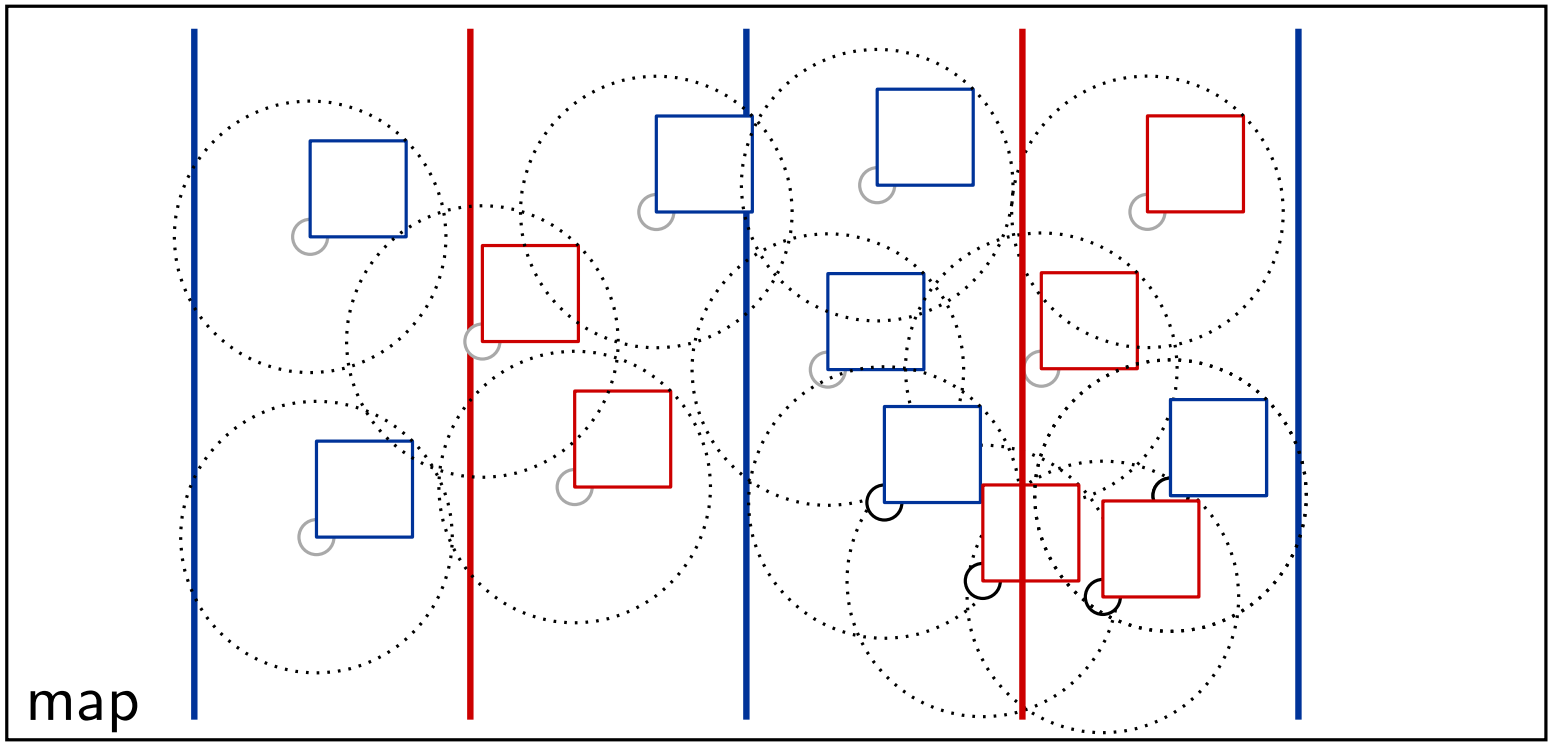
1/4-Approximation of MaxTotal

Observation 2:



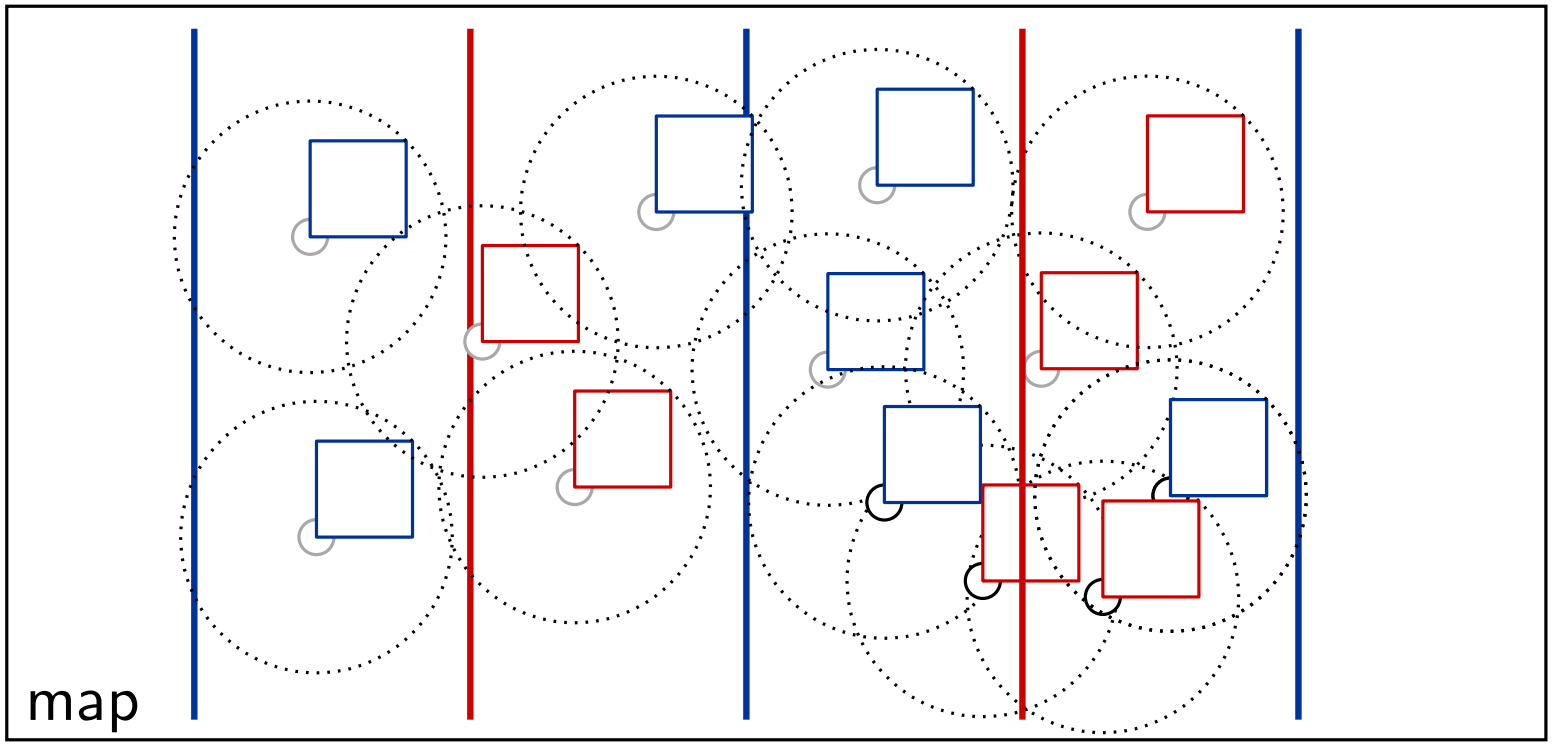
1/4-Approximation of MaxTotal

Observation 2:



1/4-Approximation of MaxTotal

Observation 2:



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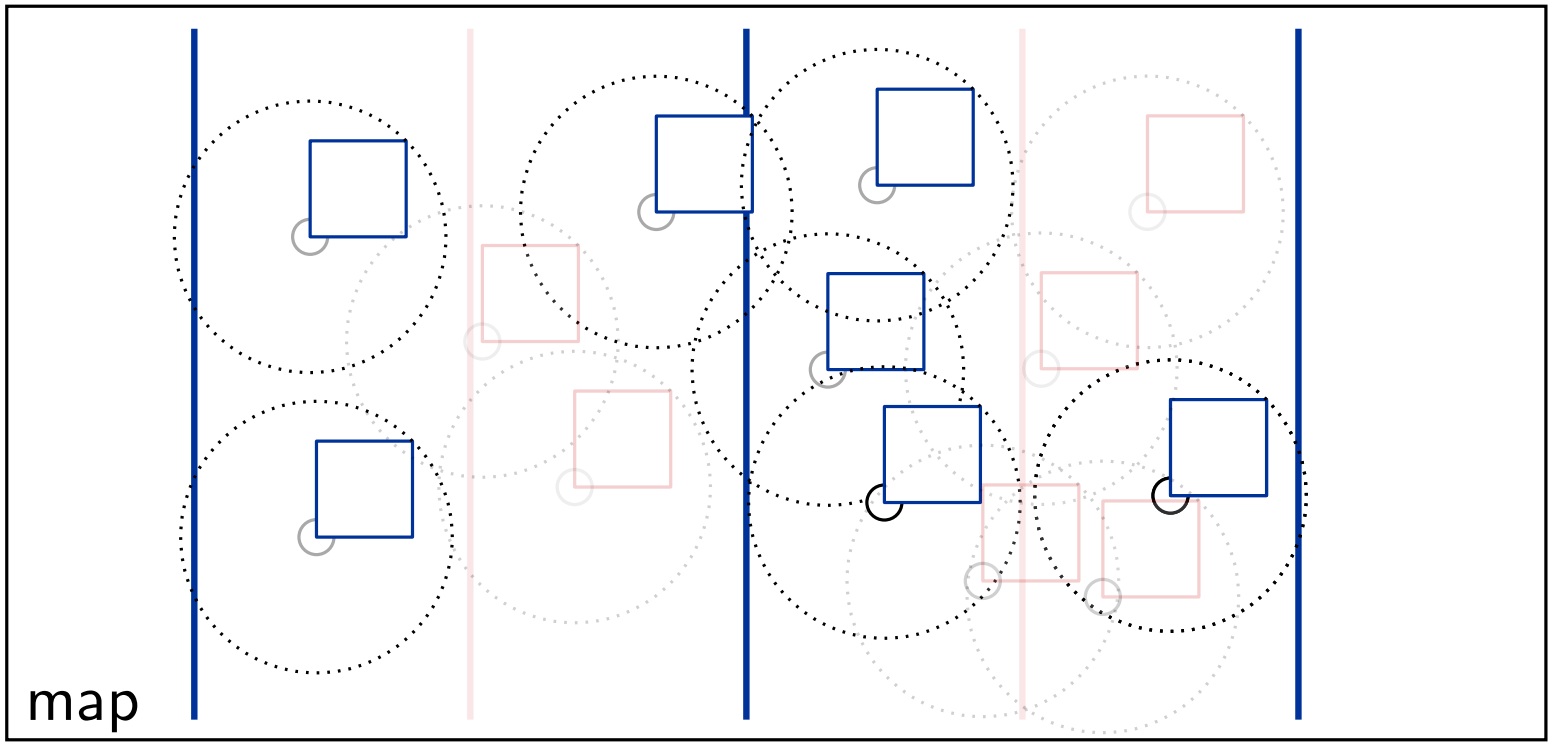
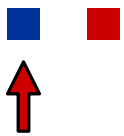
1/4-Approximation of MaxTotal

Observation 2:

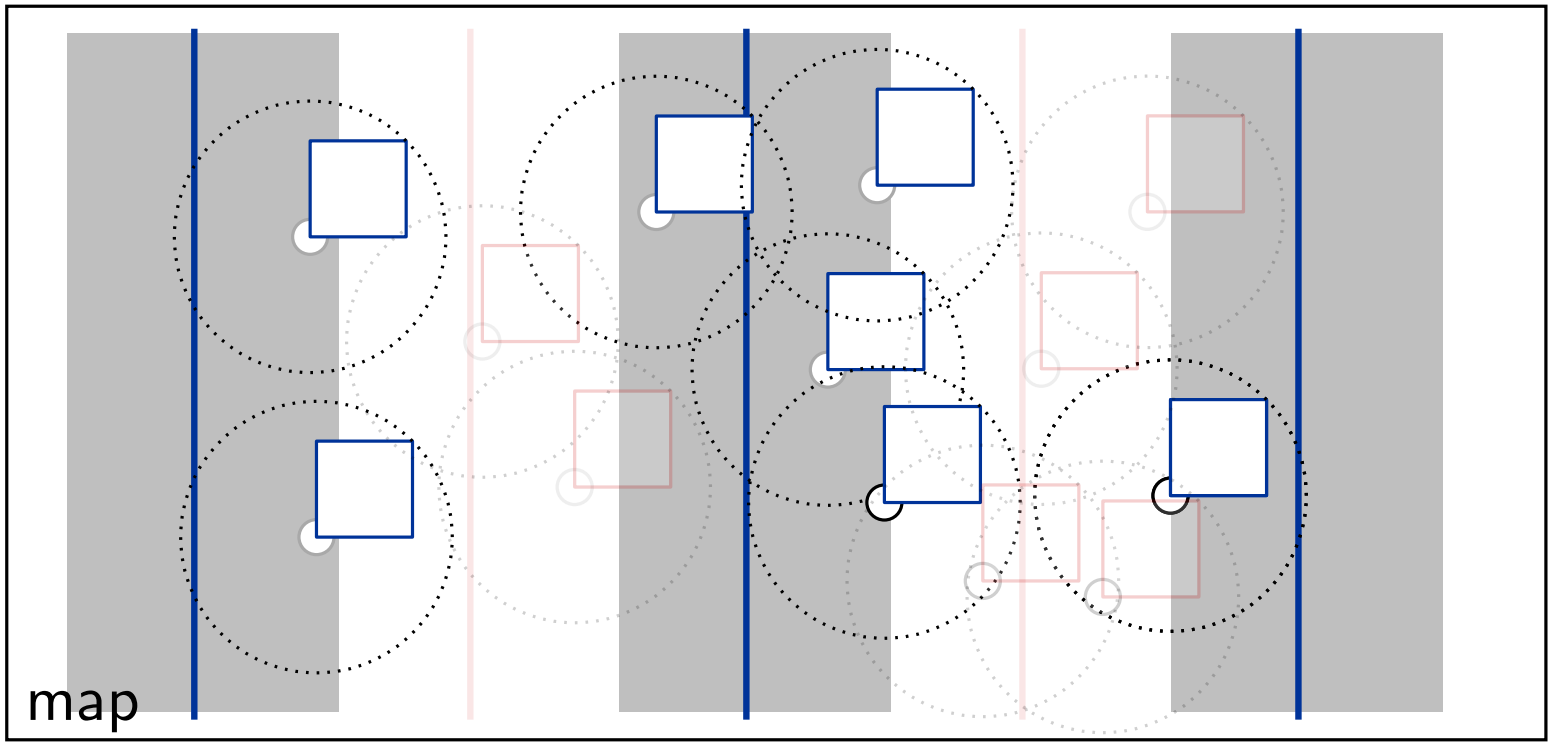


- split set of labels into two sets

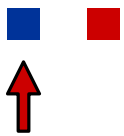


1/4-Approximation of MaxTotal

Observation 2:



- split set of labels into two sets



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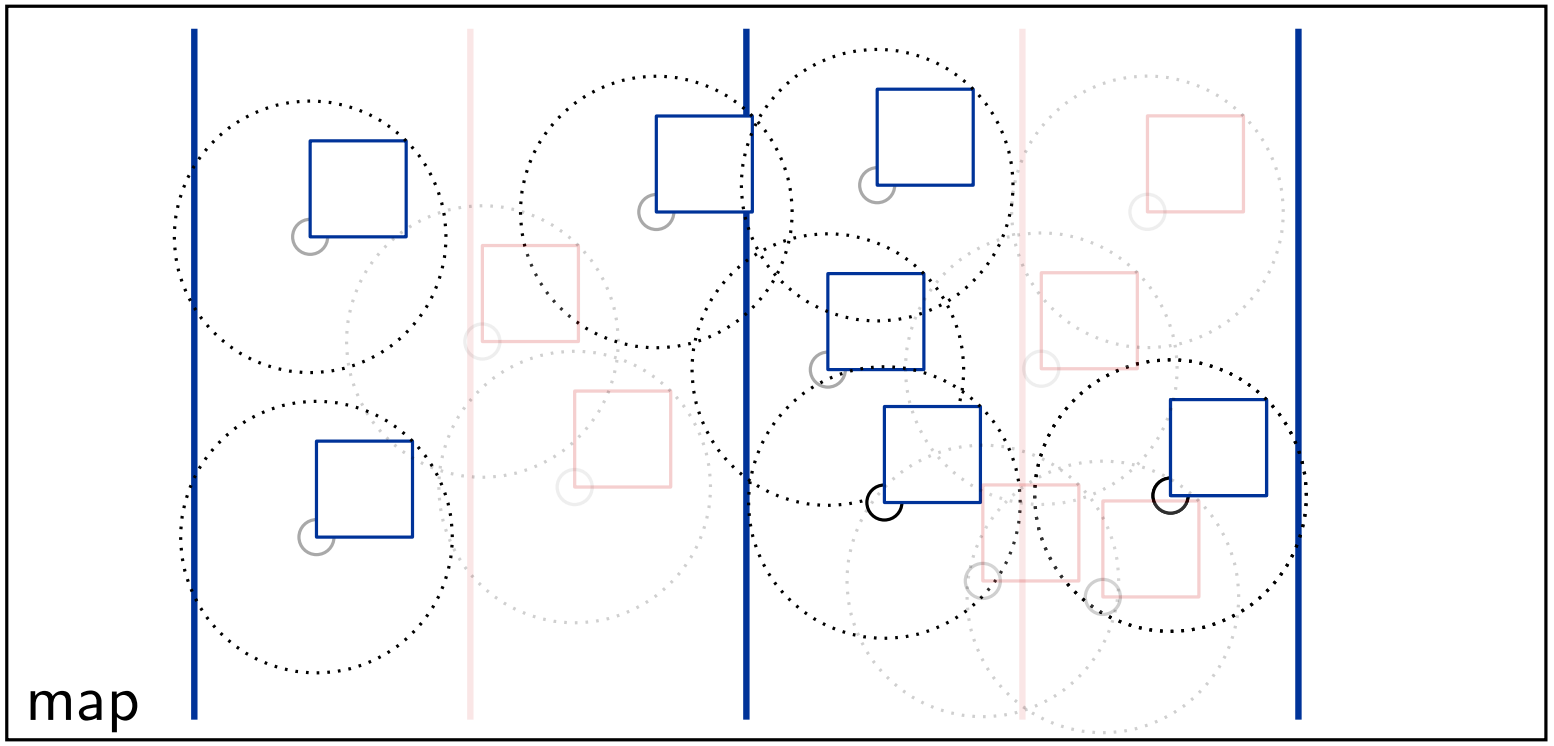
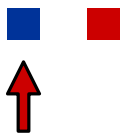
Observation 2:



- split set of labels into two sets



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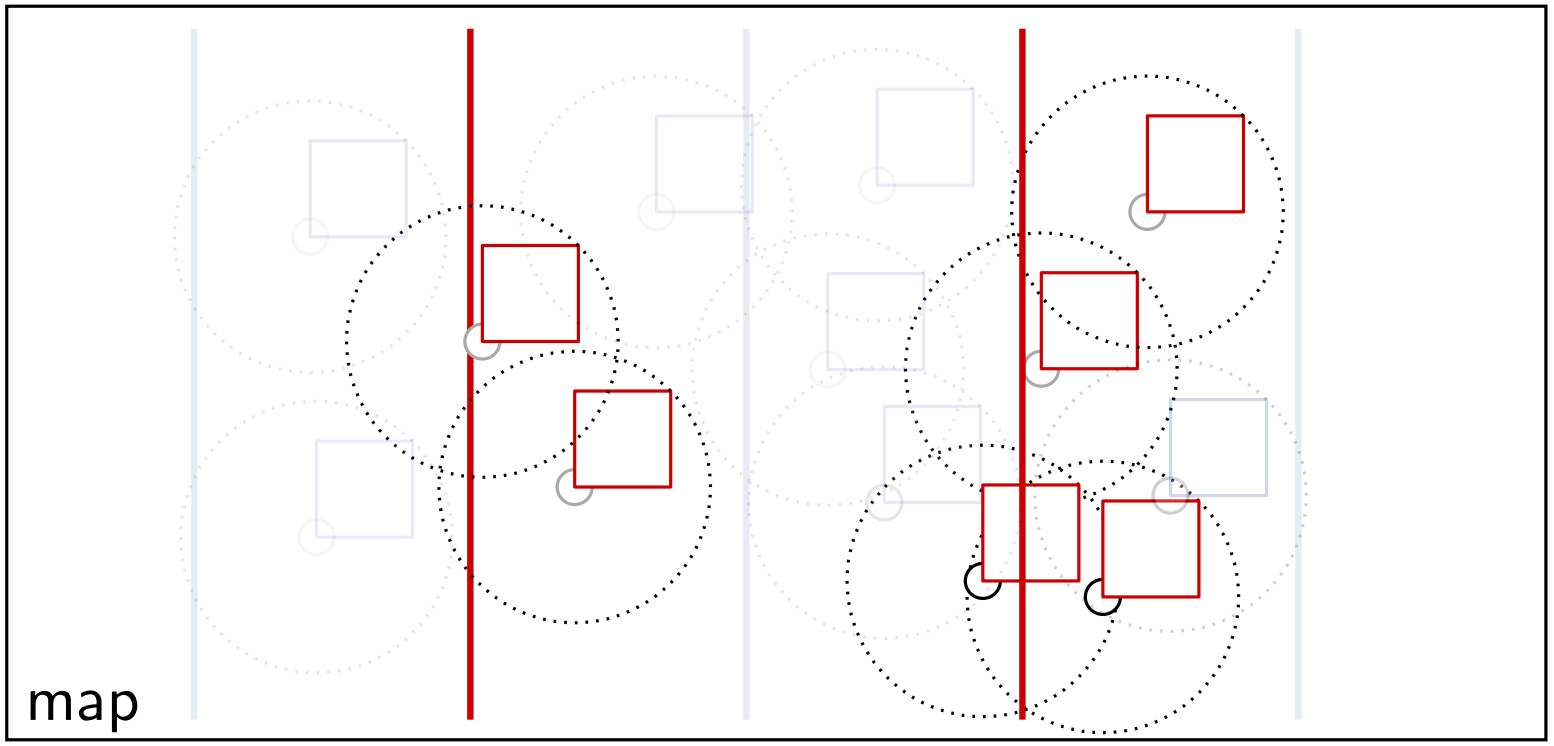
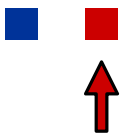
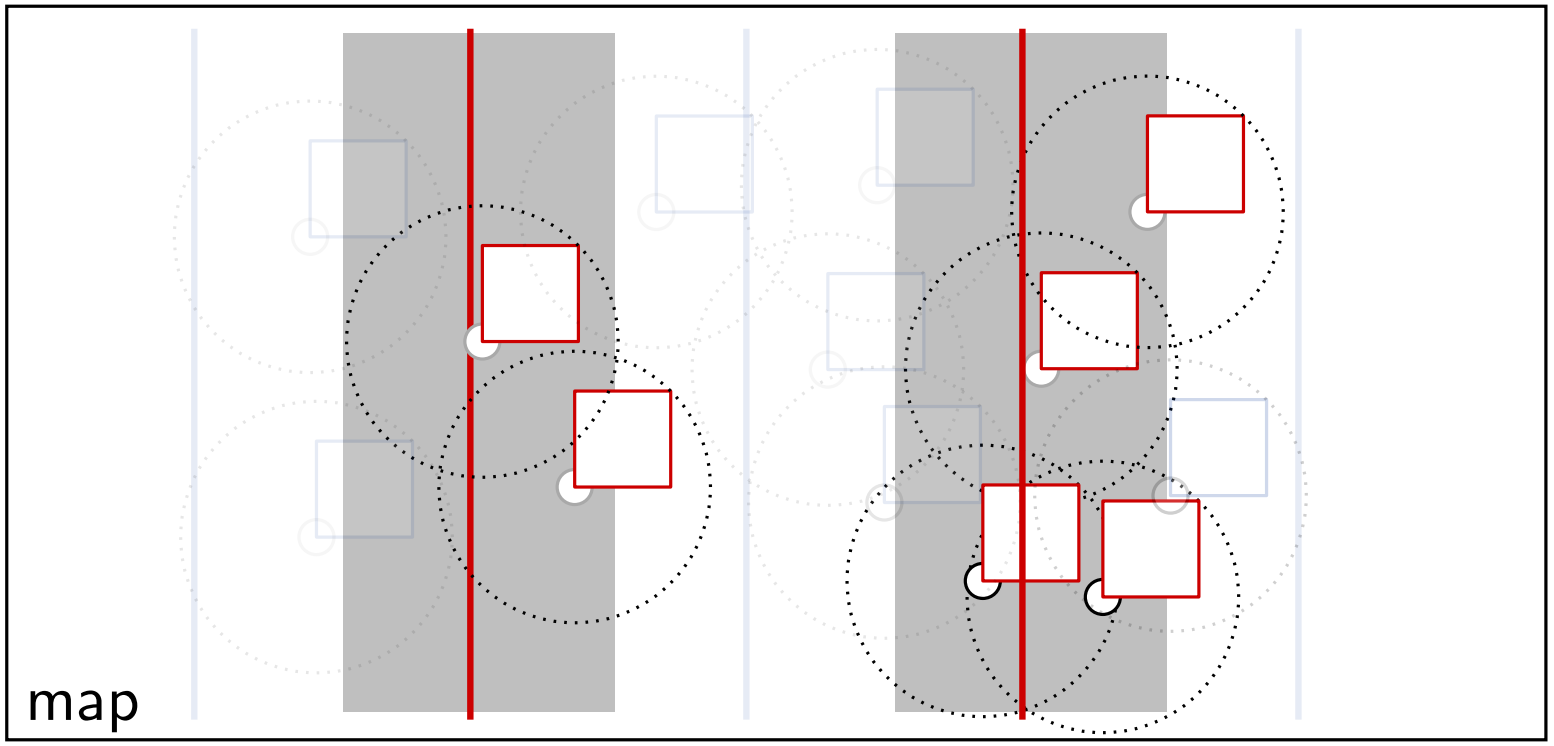


- split set of labels into two sets



1/4-Approximation of MaxTotal

Observation 2:



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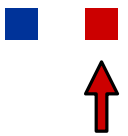

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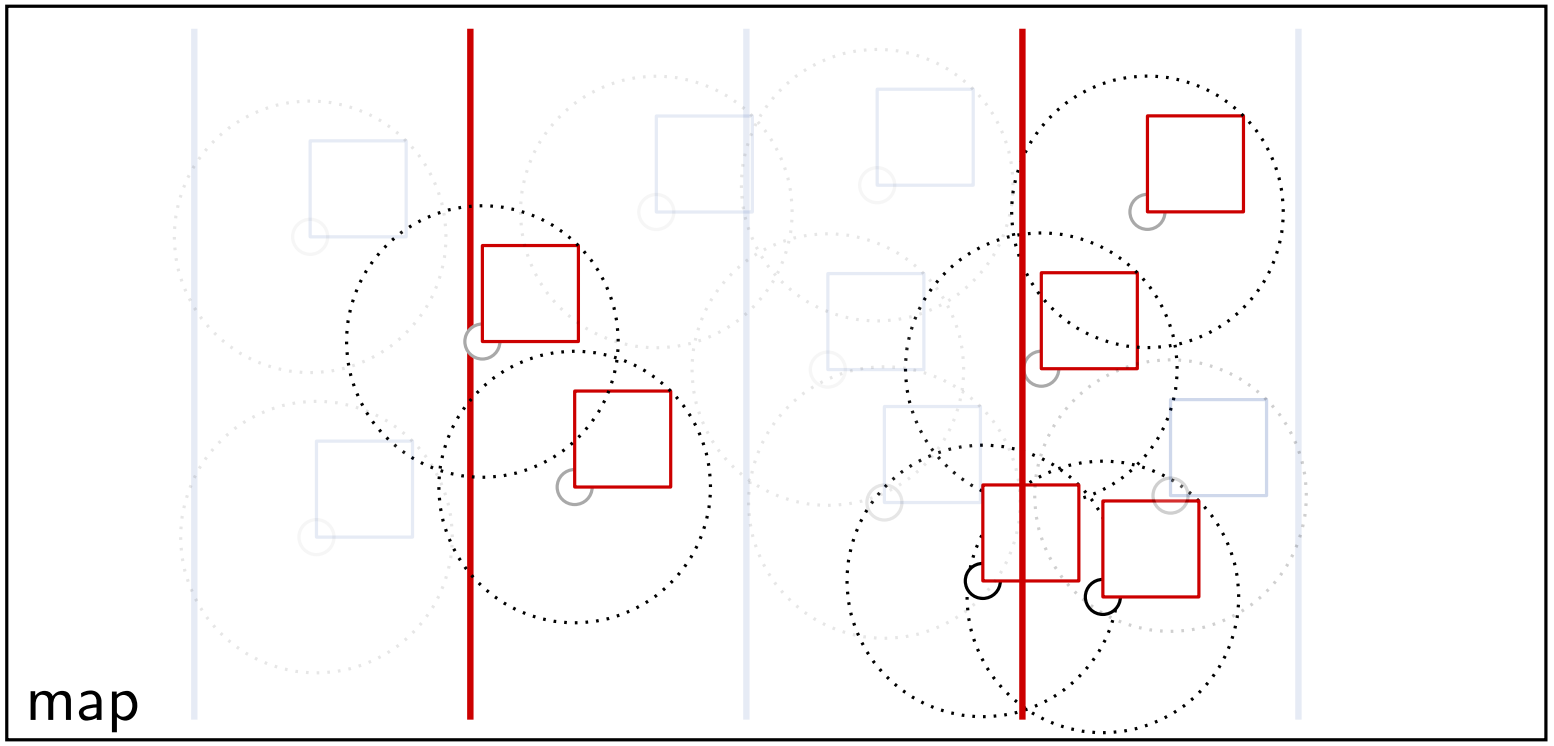

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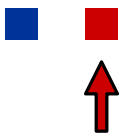

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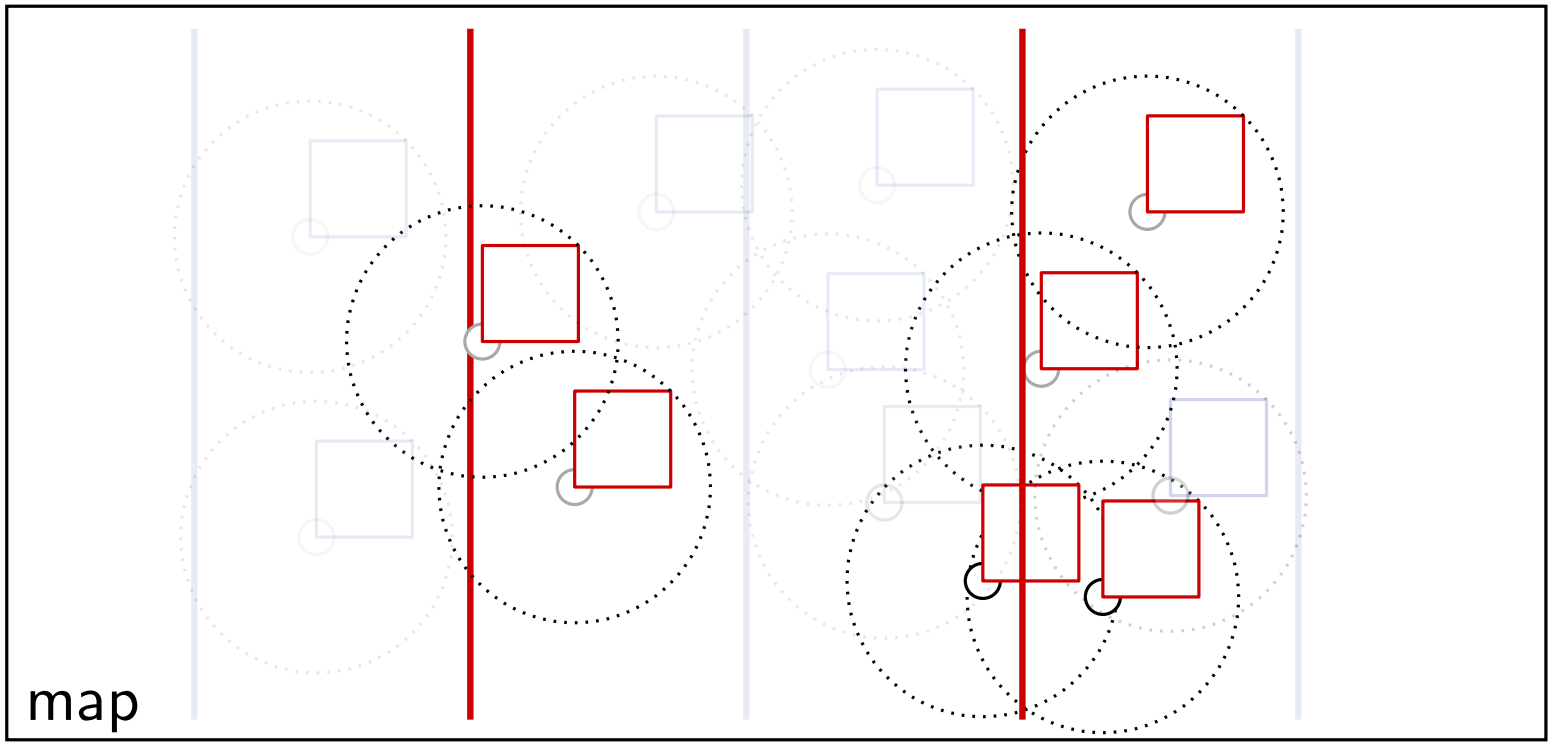
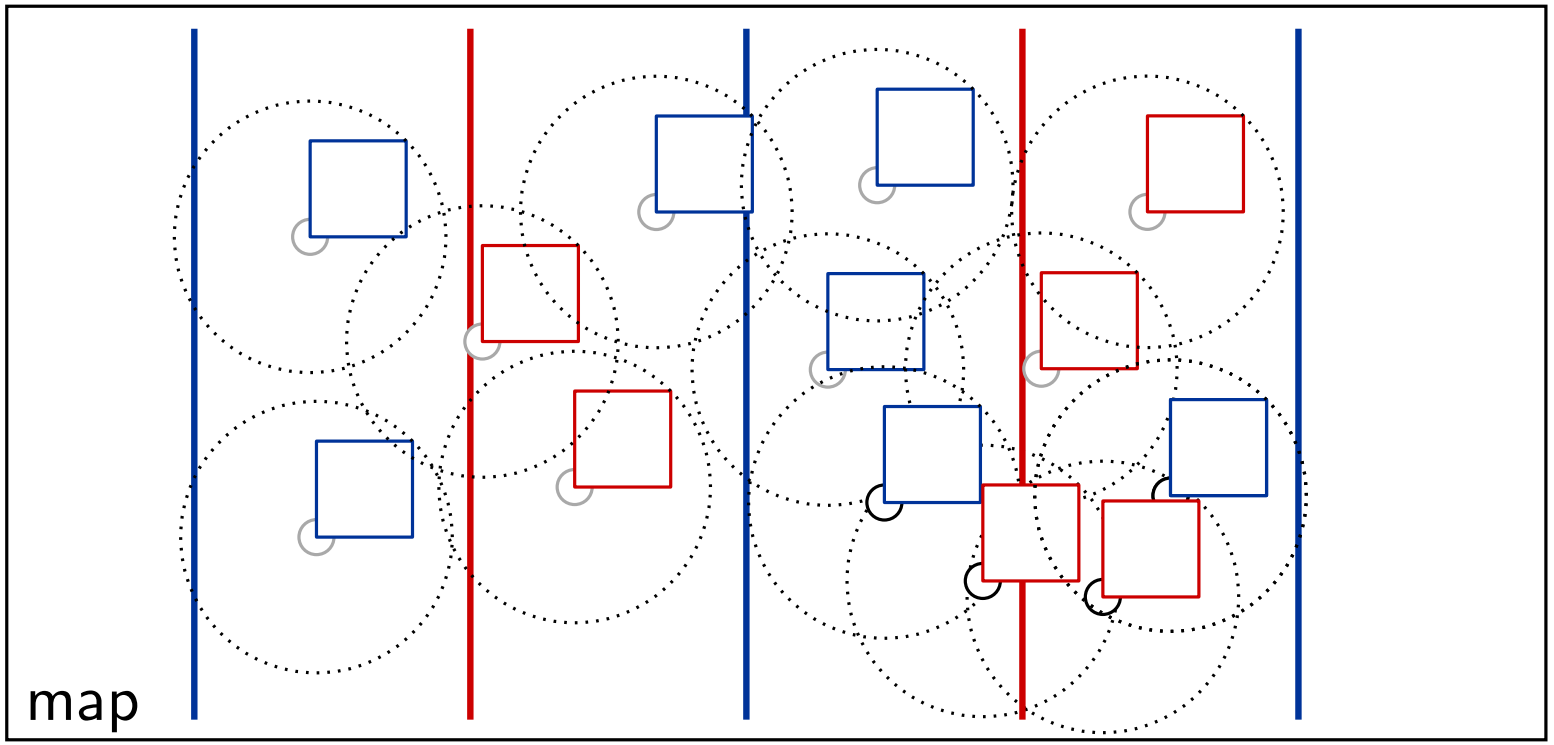


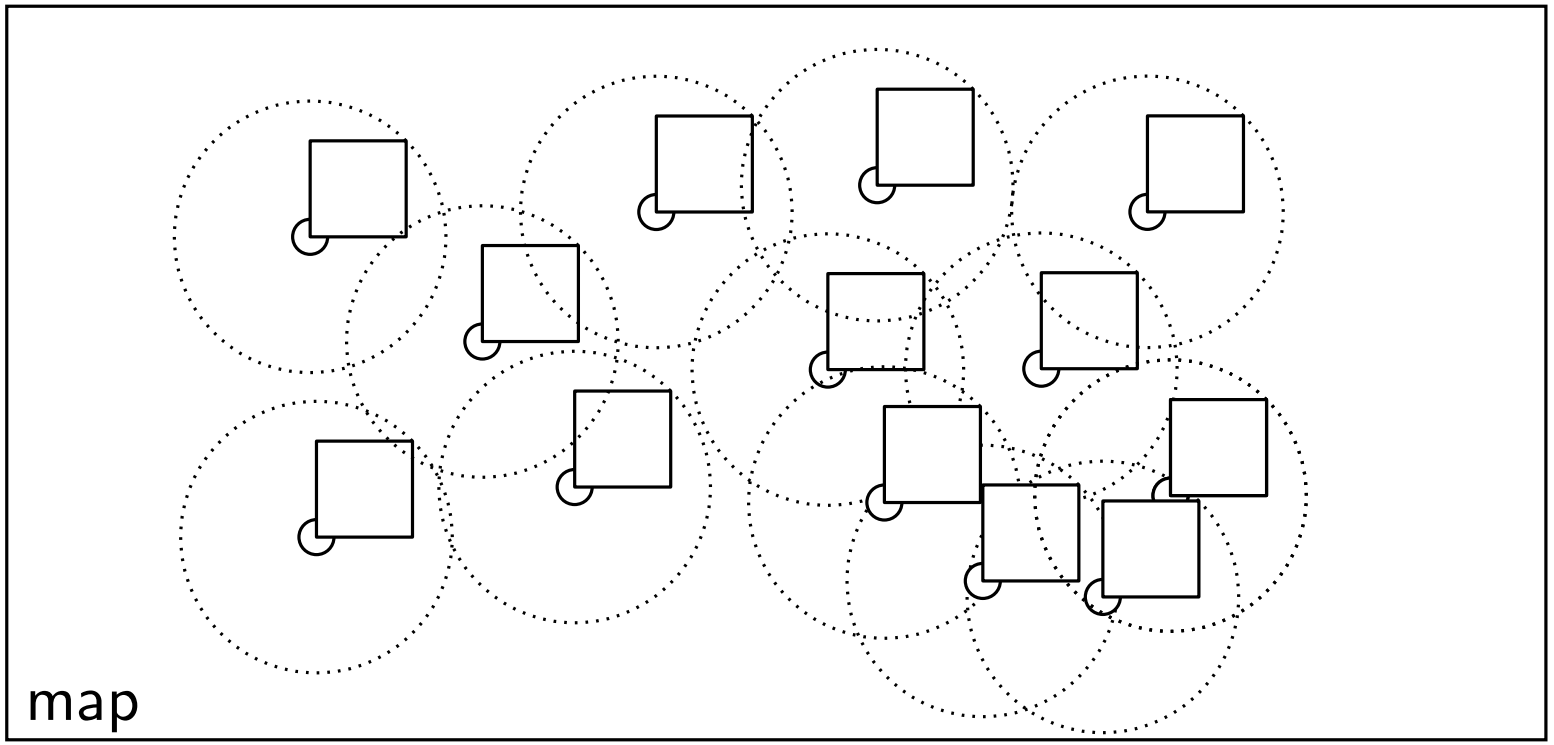
- split set of labels into two sets
- find optimal solution for each set separately

one of those solutions is 1/2 approximation

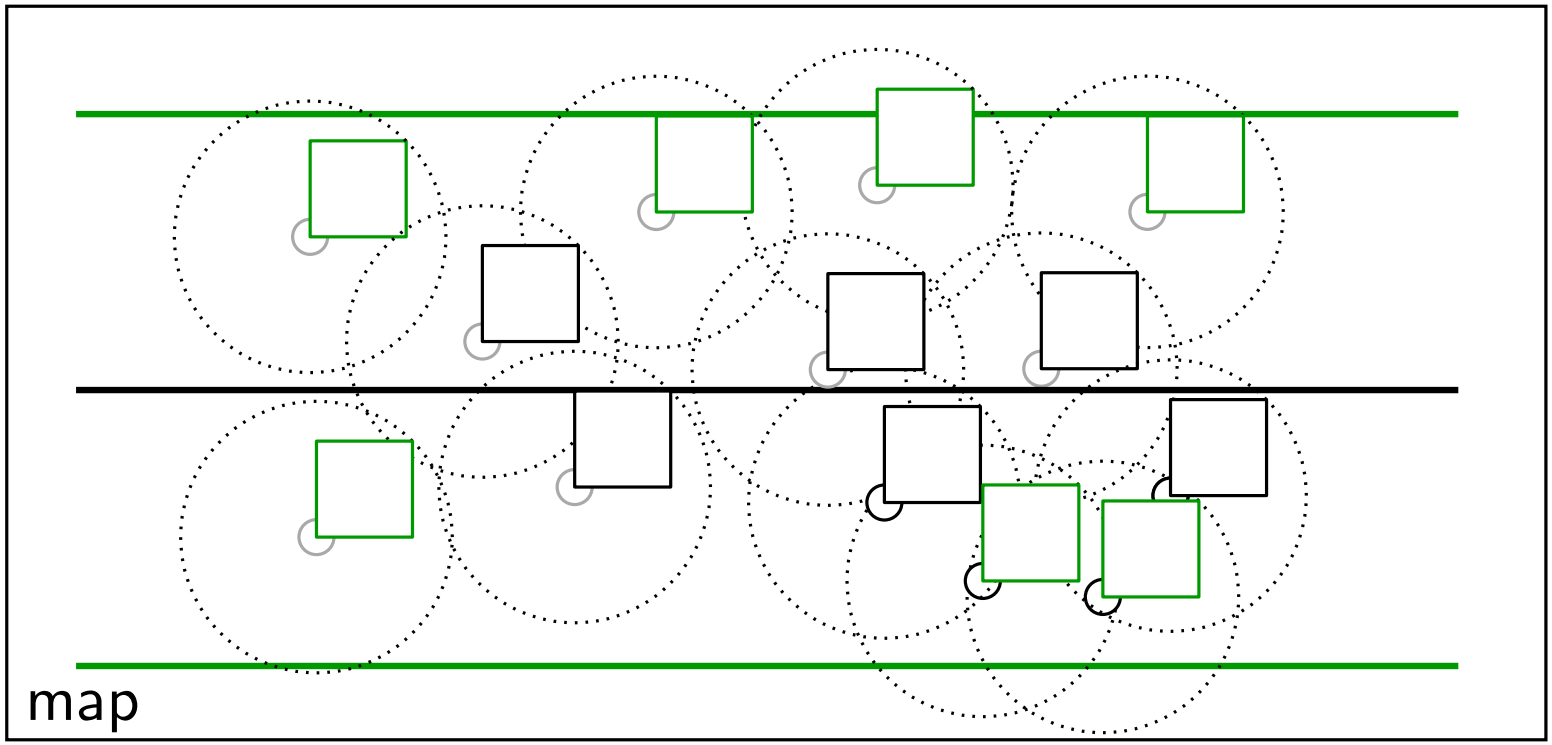
1/4-Approximation of MaxTotal



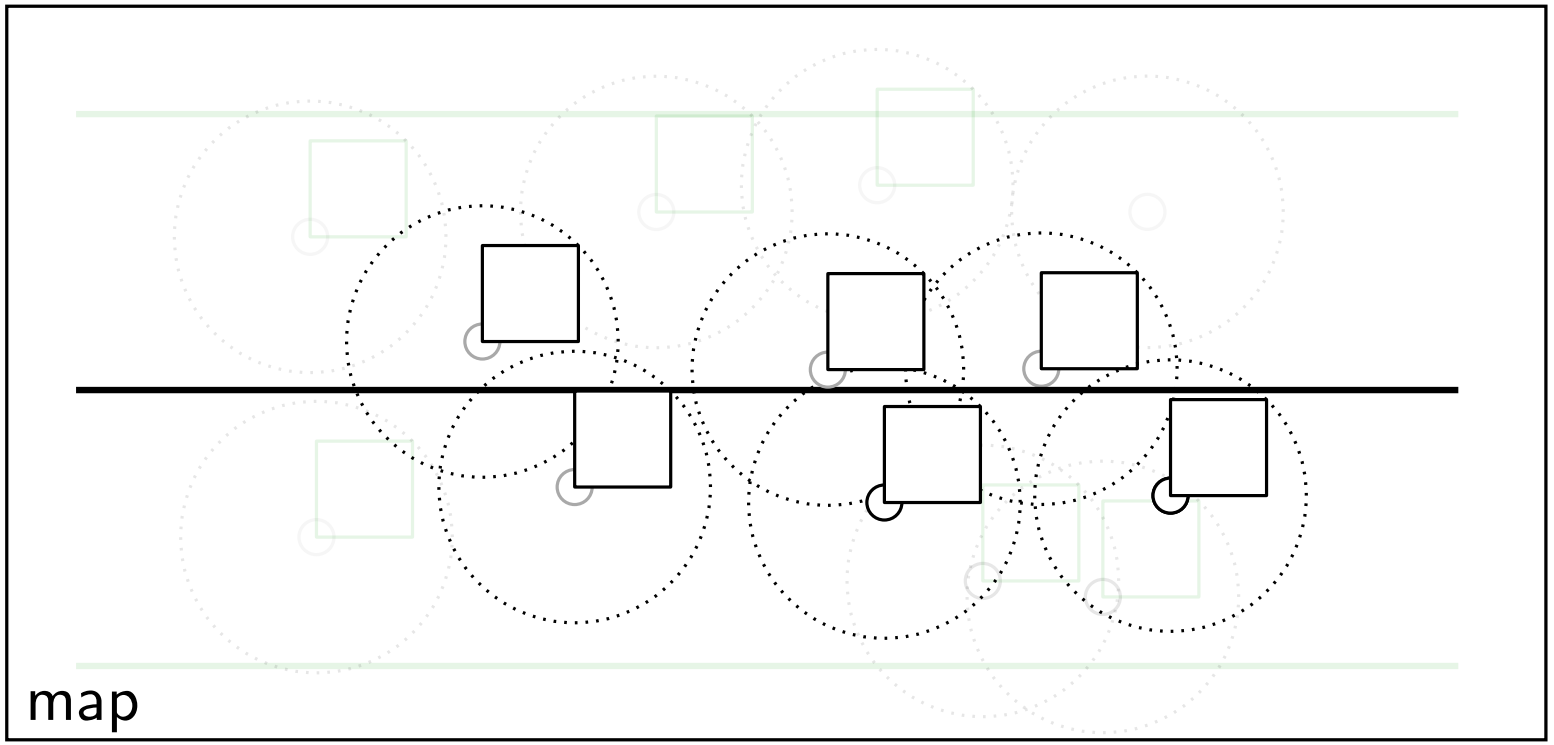
1/4-Approximation of MaxTotal



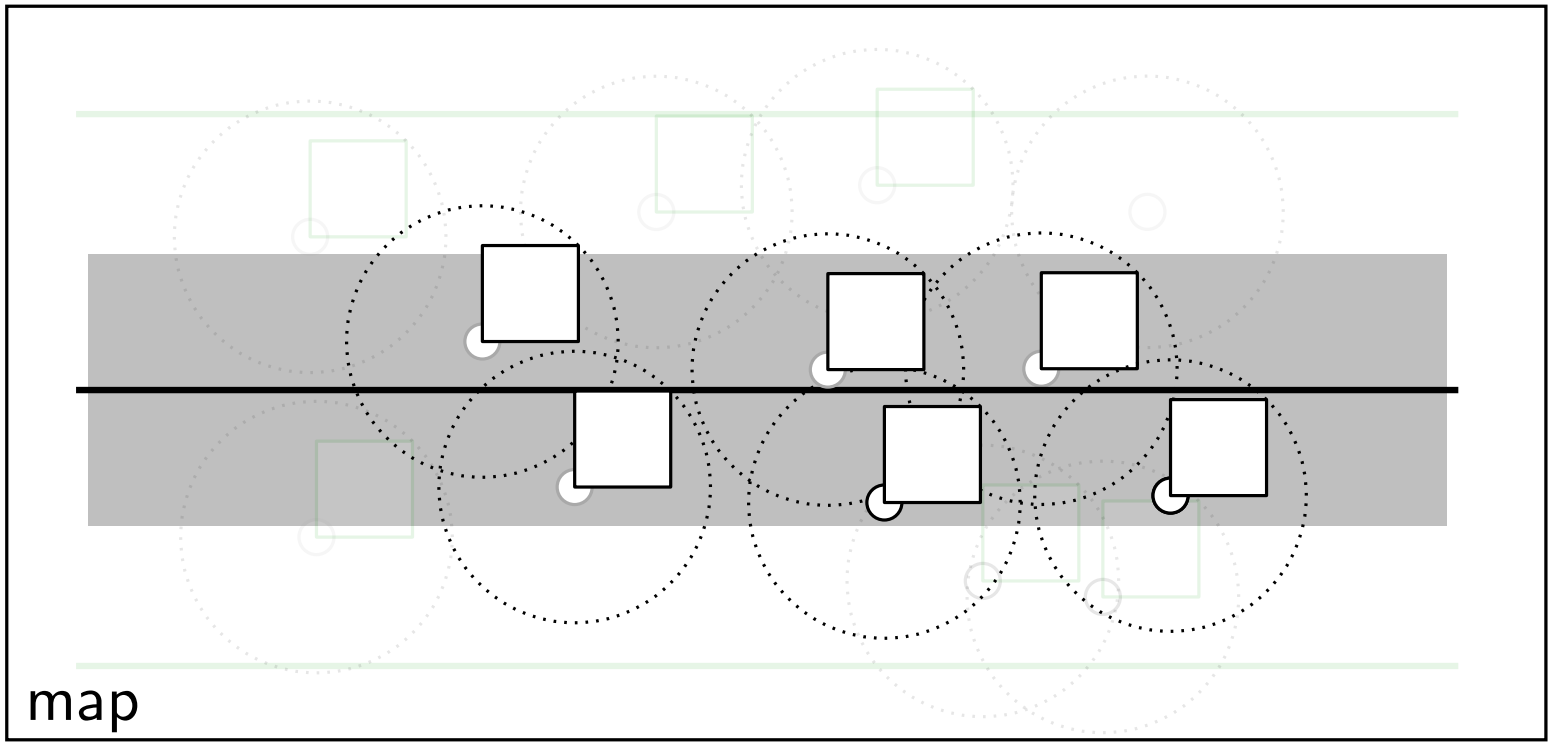
1/4-Approximation of MaxTotal



1/4-Approximation of MaxTotal



1/4-Approximation of MaxTotal



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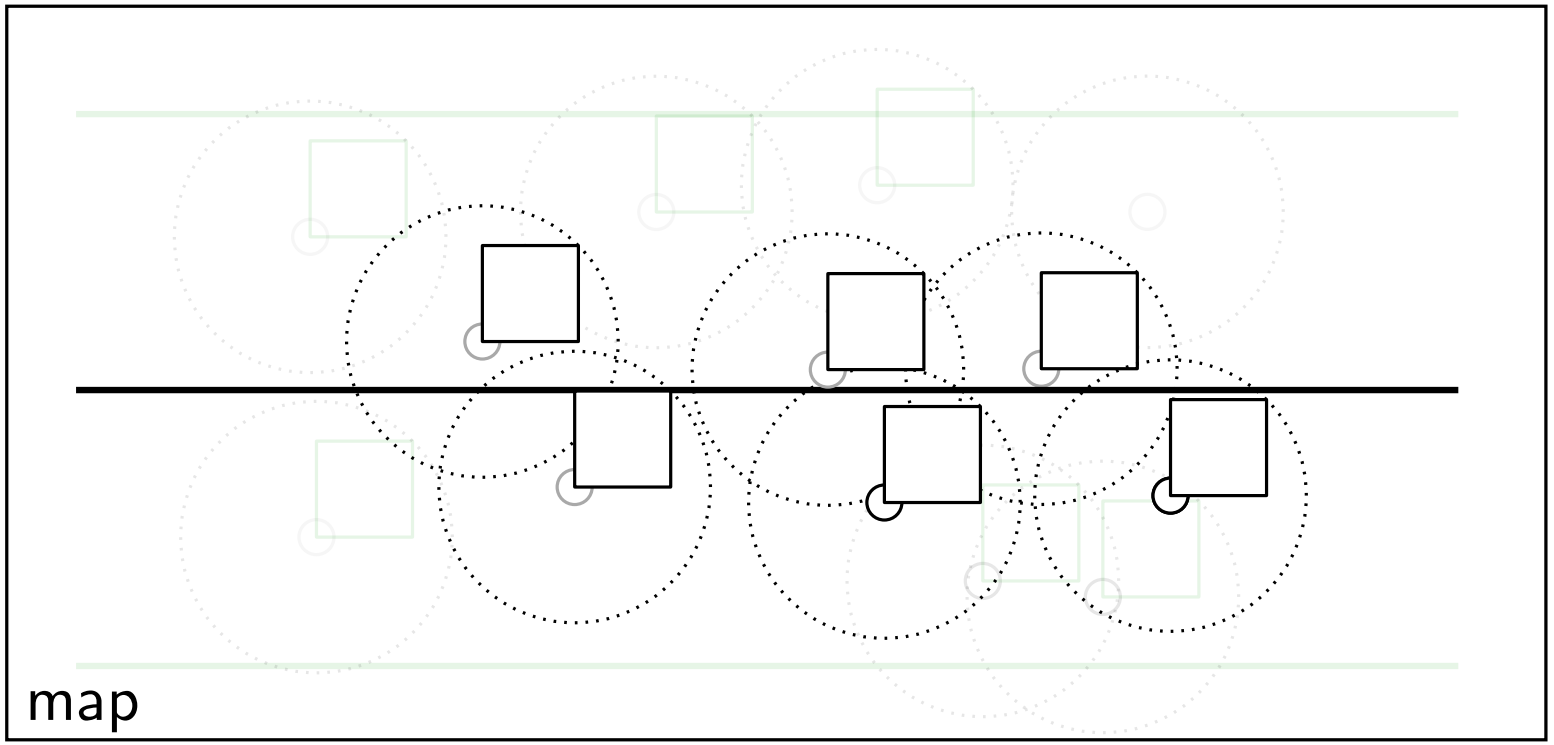

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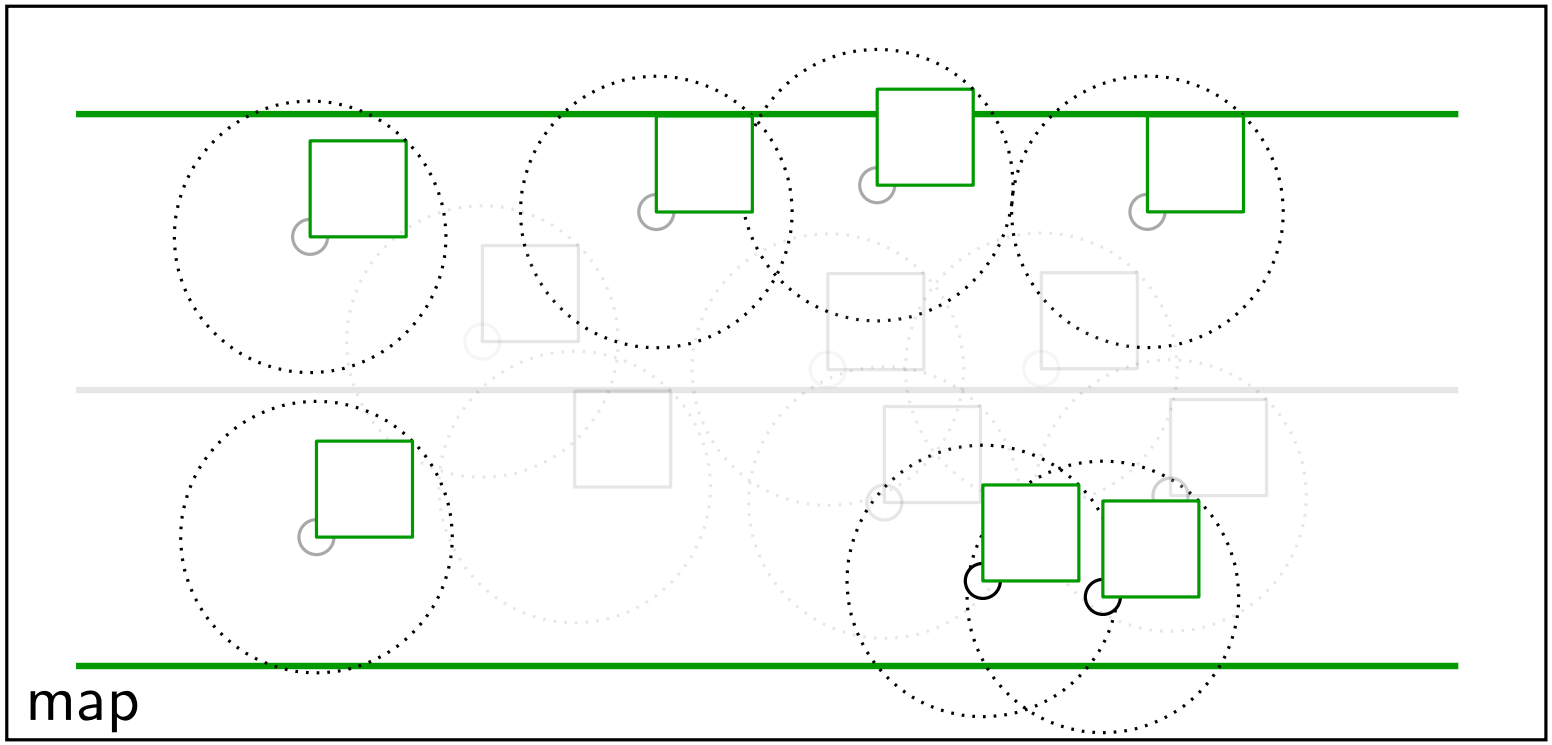

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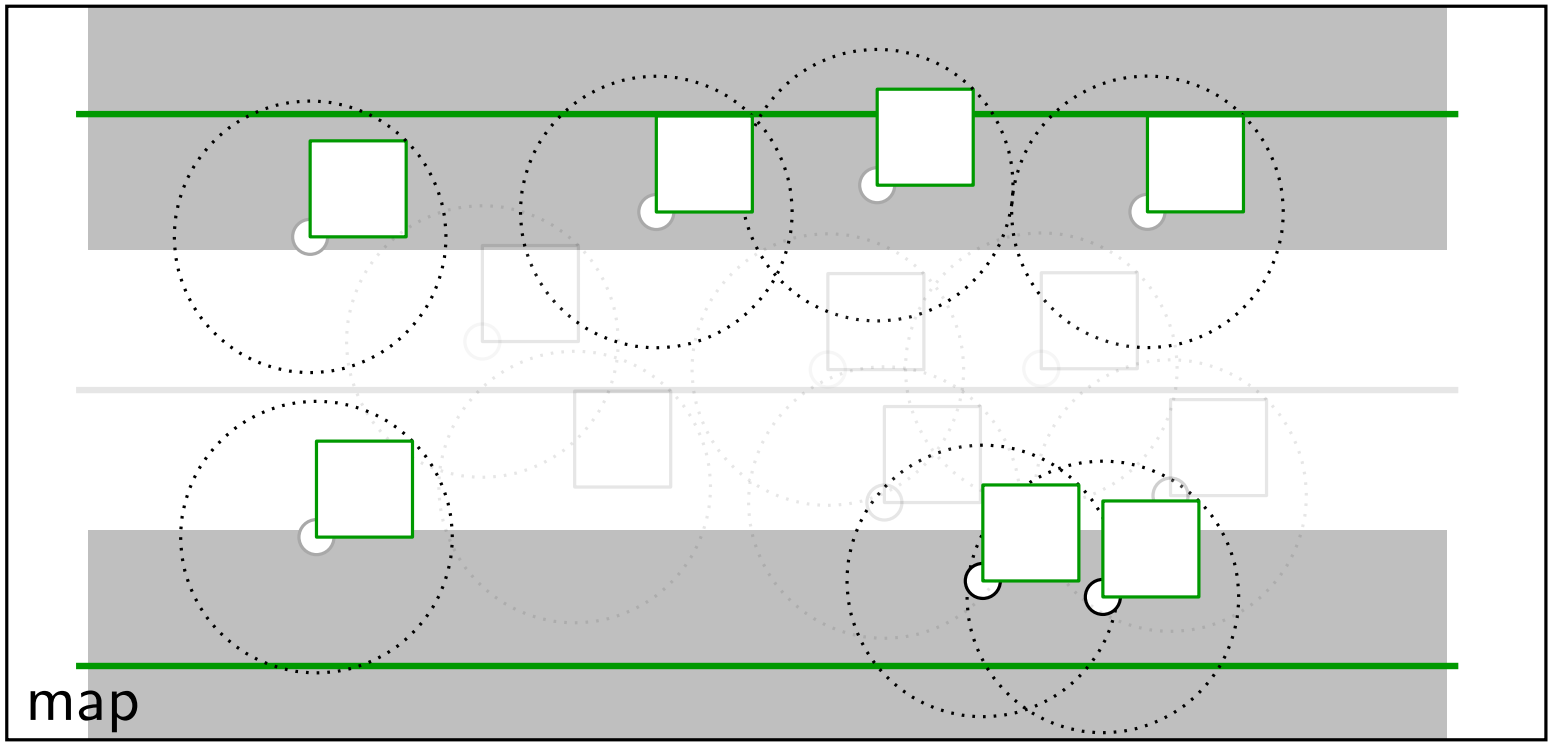

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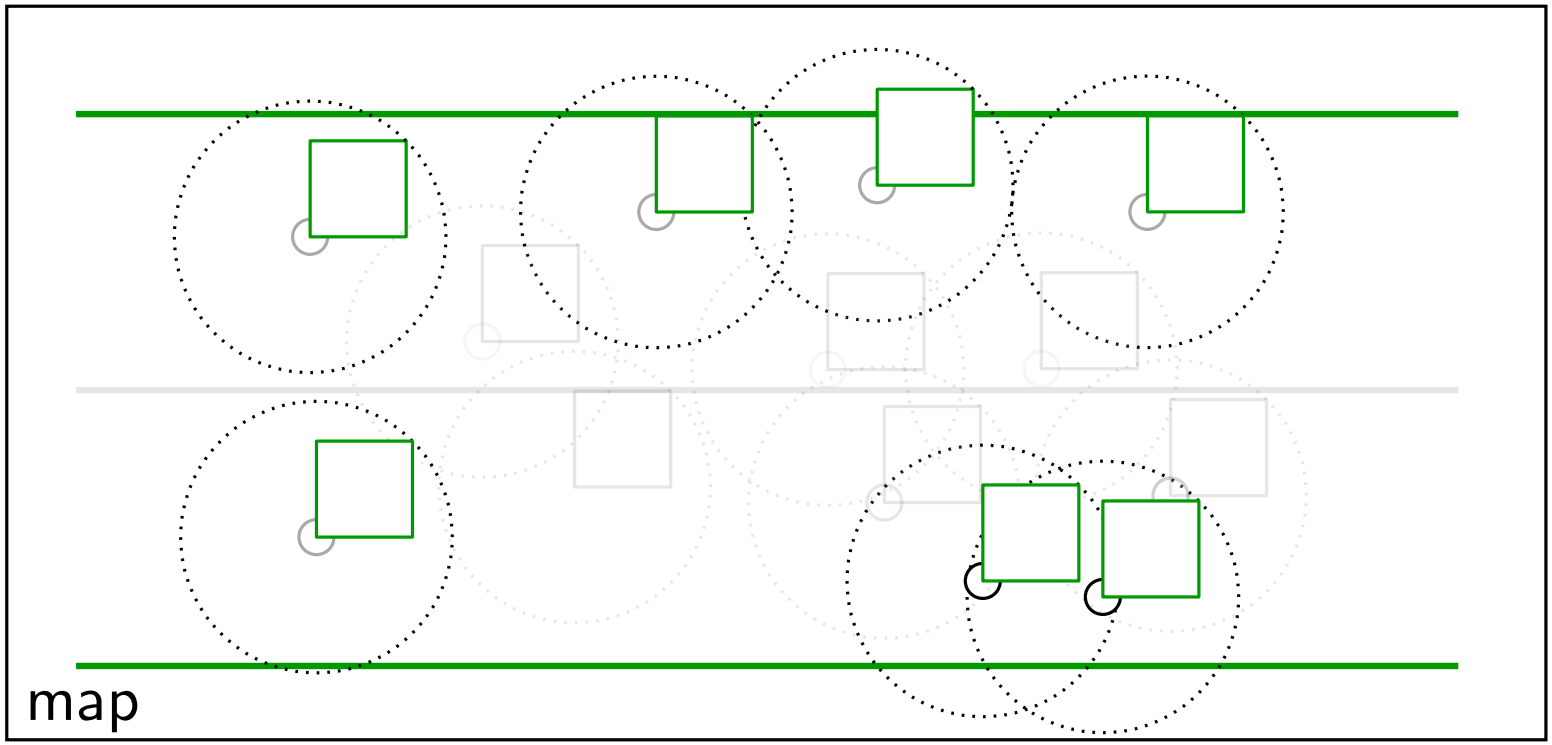

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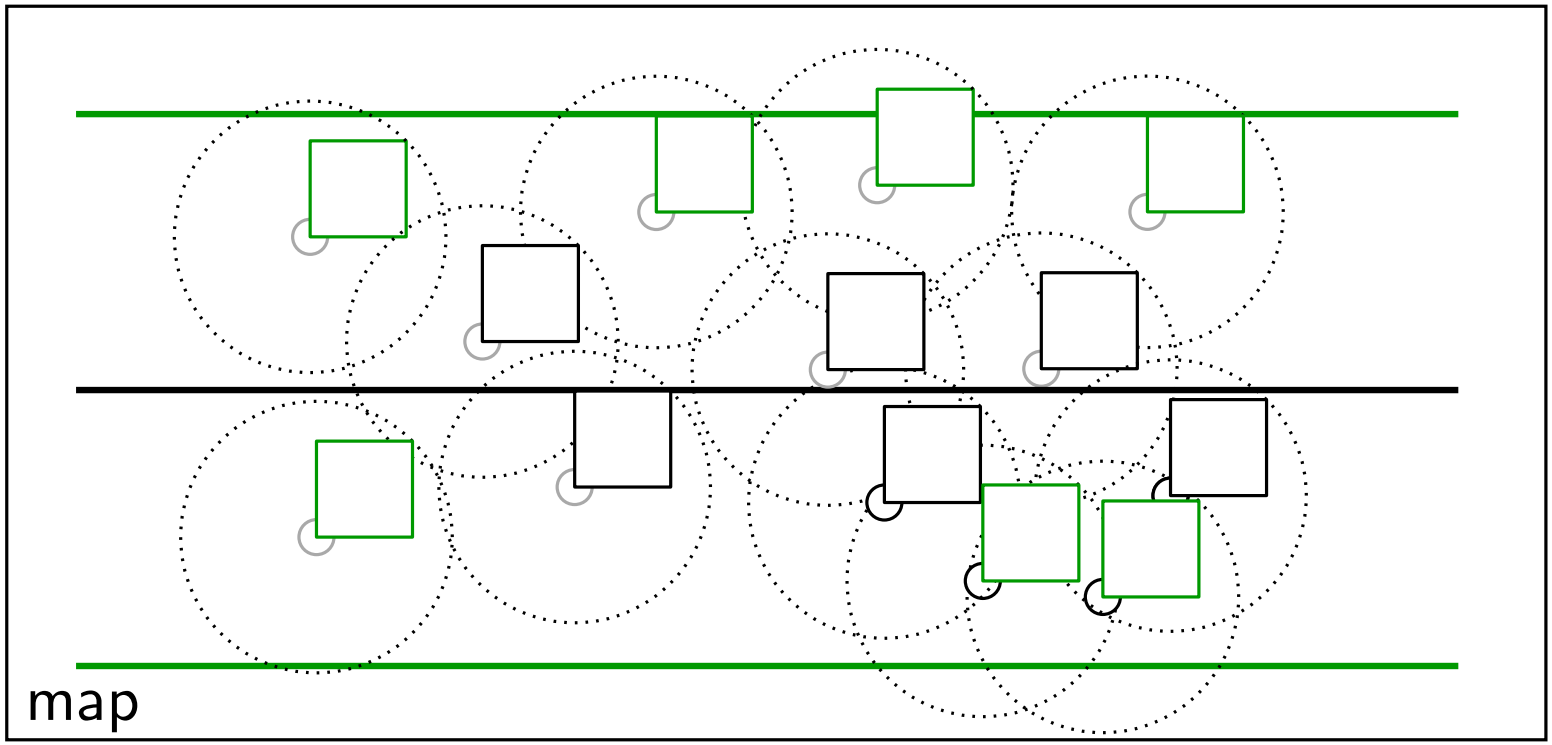

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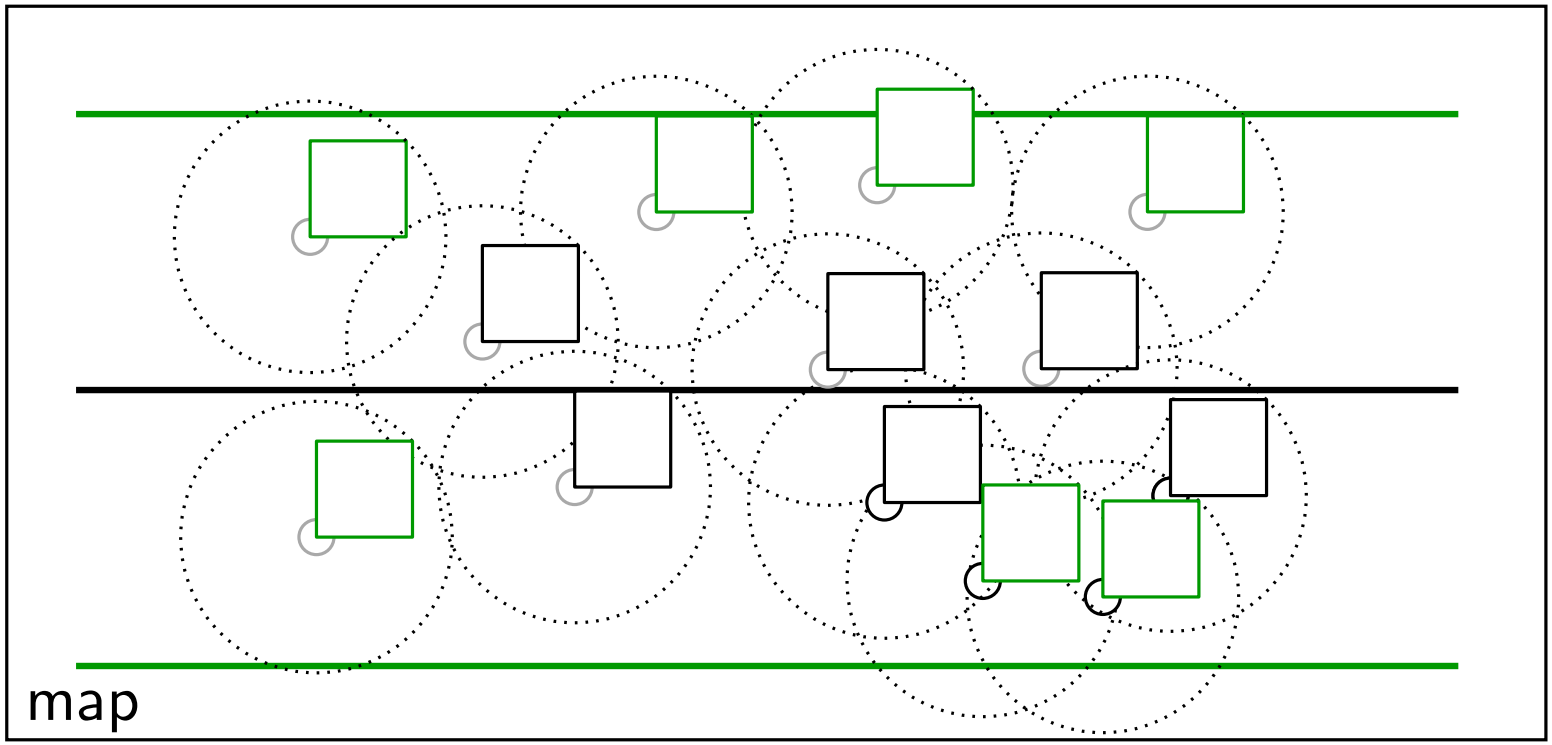
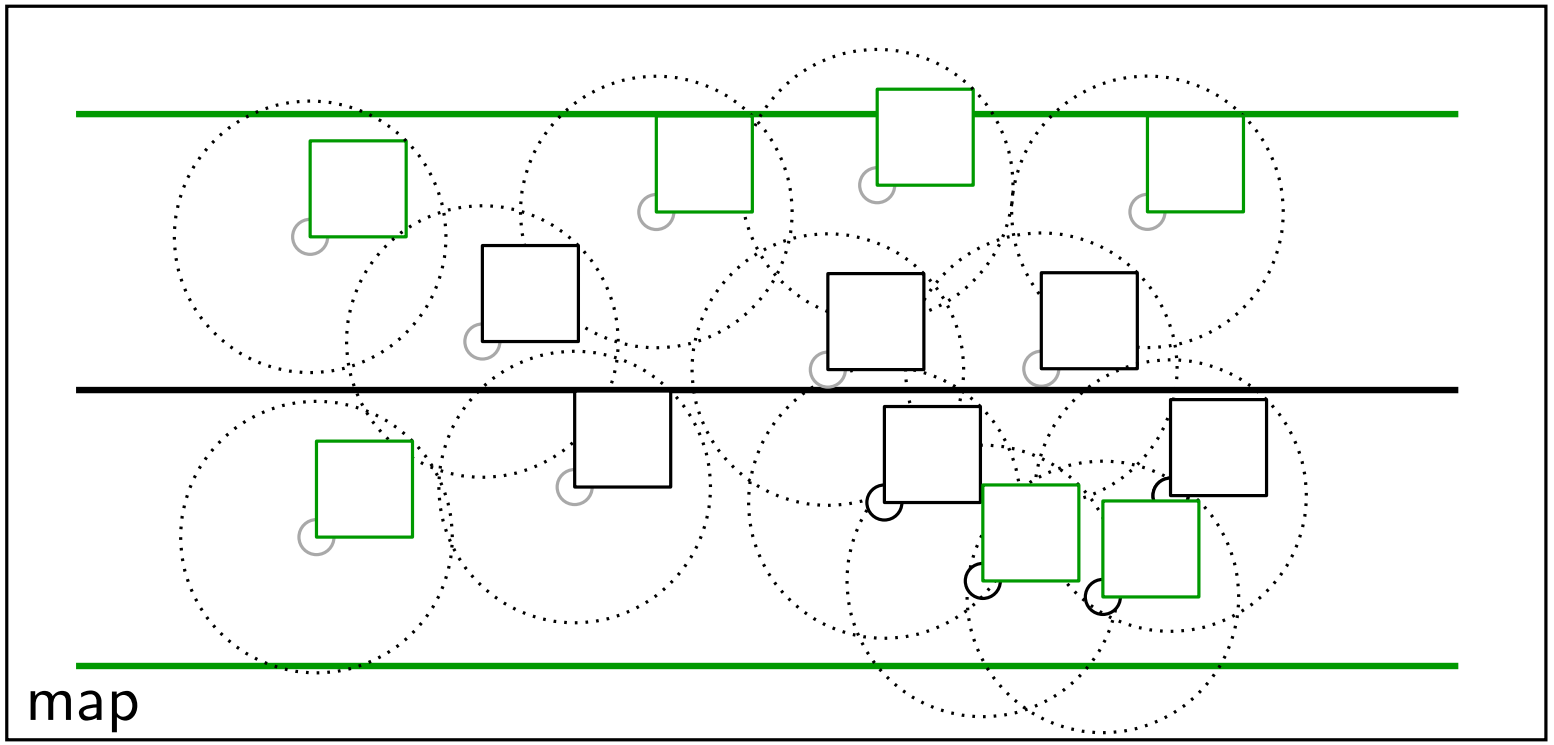


- split set of labels into **four** sets

1/4-Approximation of MaxTotal



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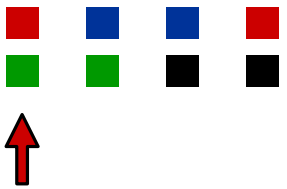
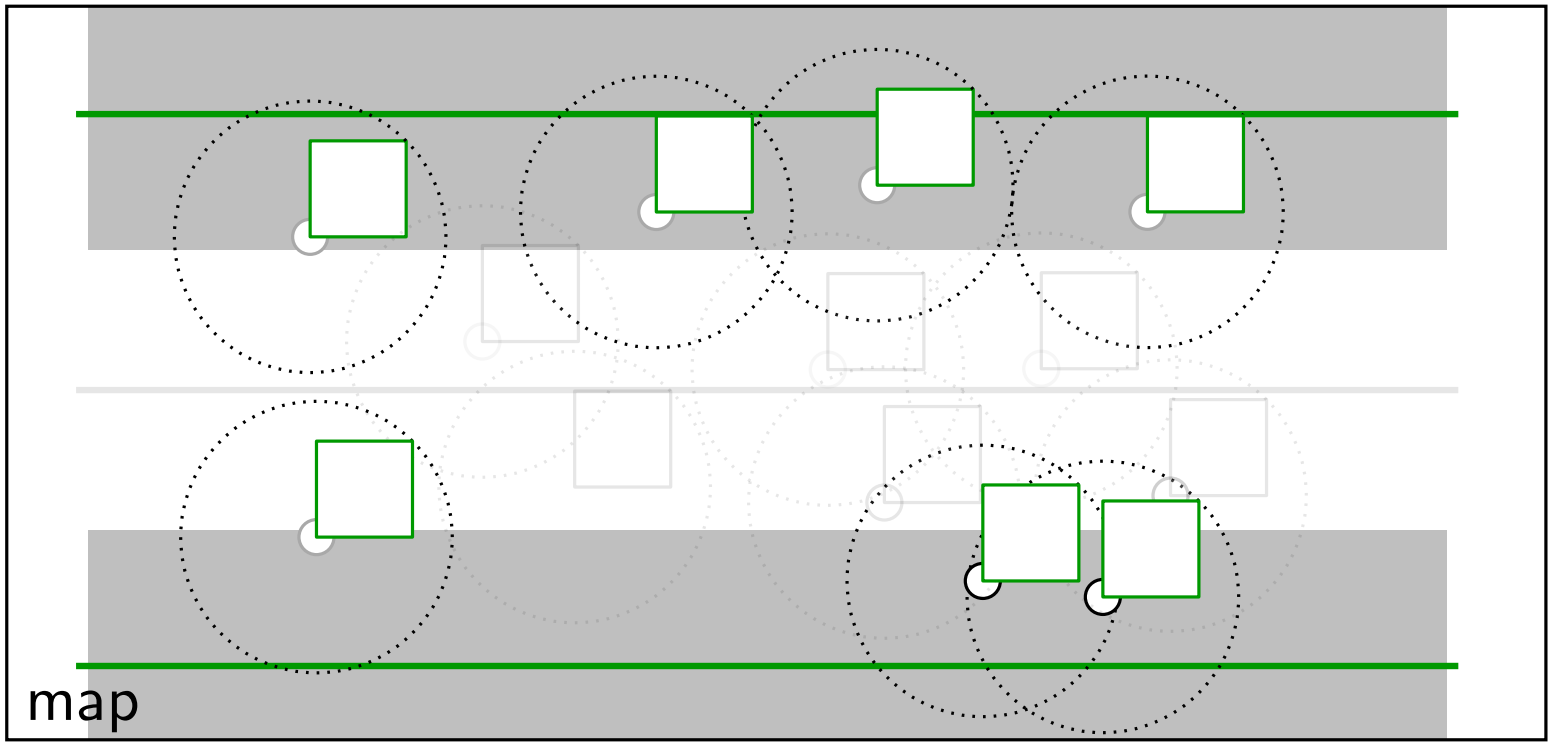


1/4-Approximation of MaxTotal



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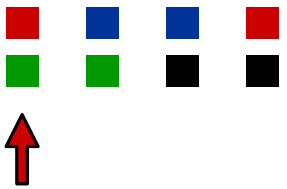
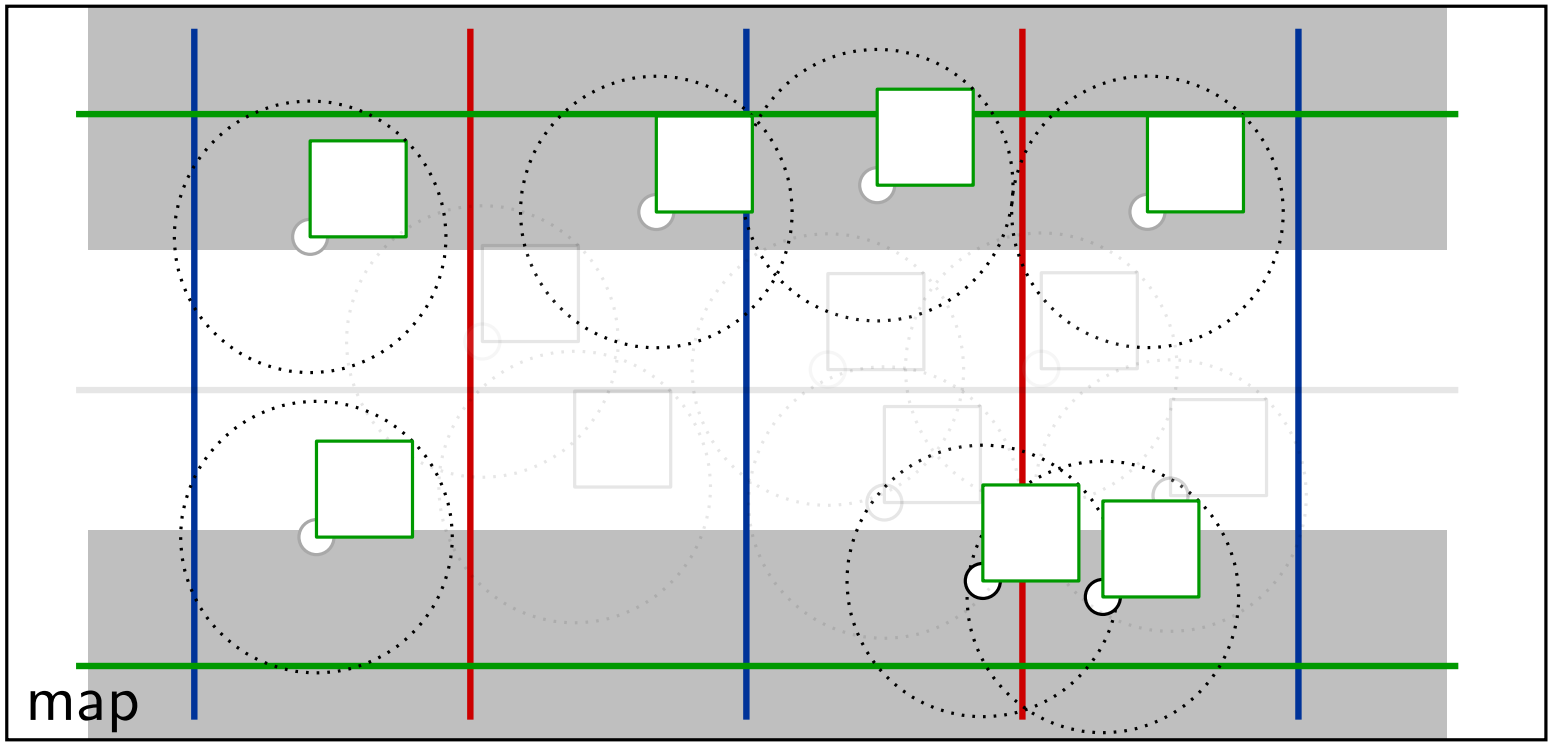


1/4-Approximation of MaxTotal



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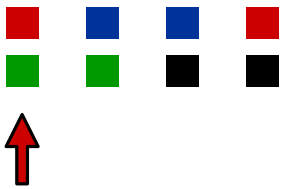
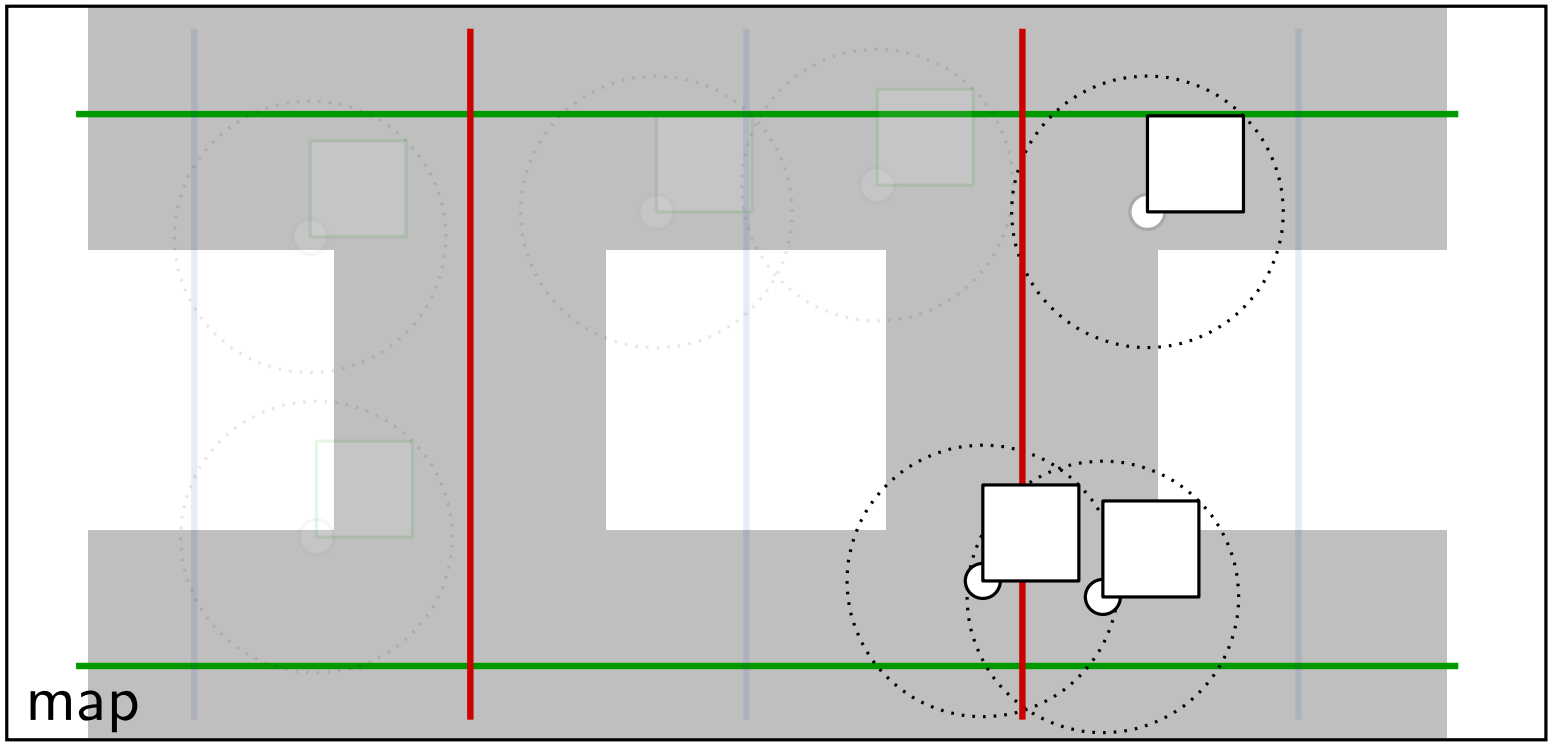
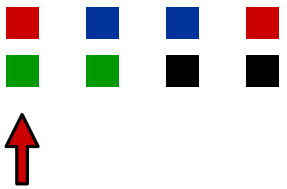


1/4-Approximation of MaxTotal



- split set of labels into **four** sets



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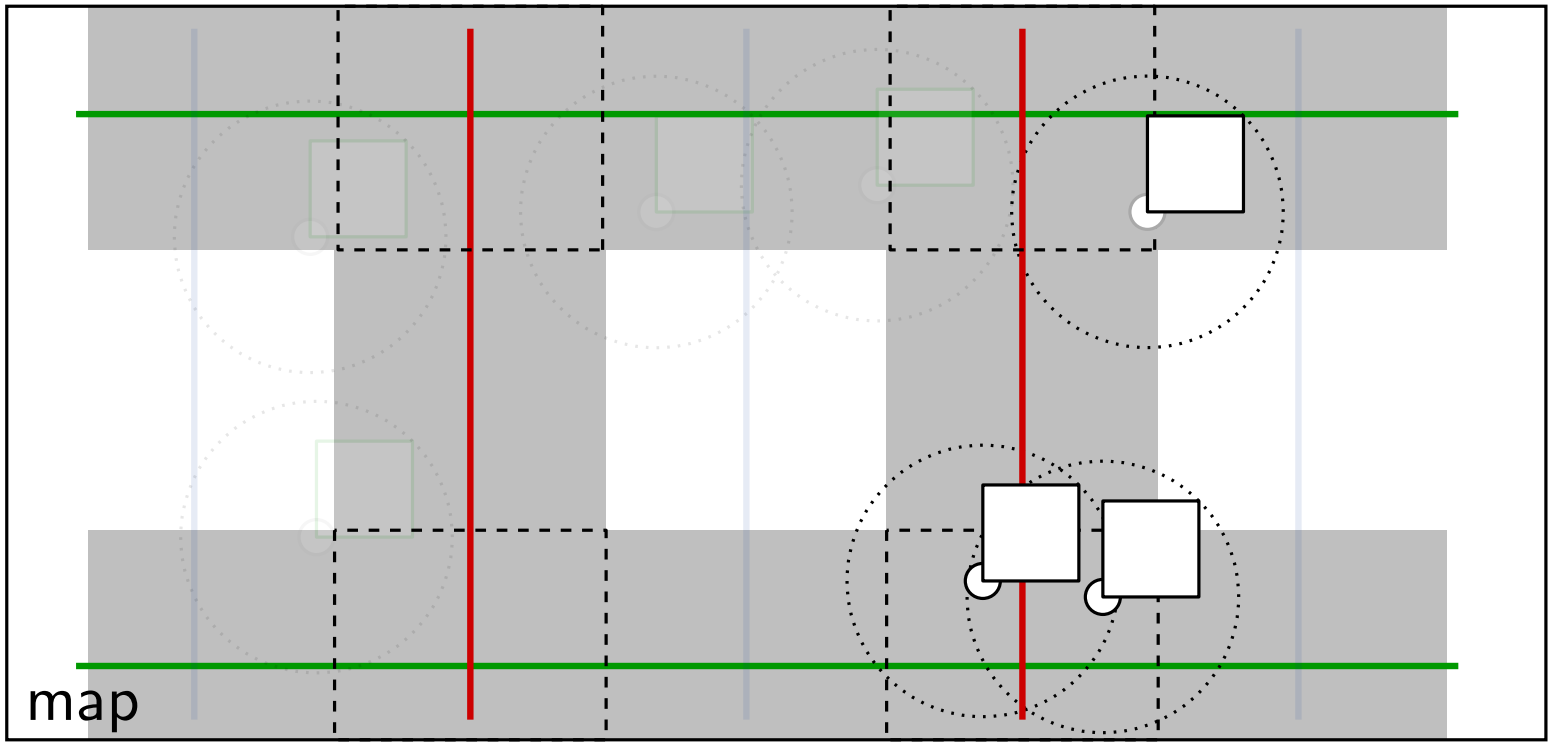

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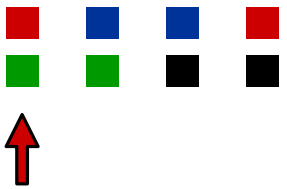
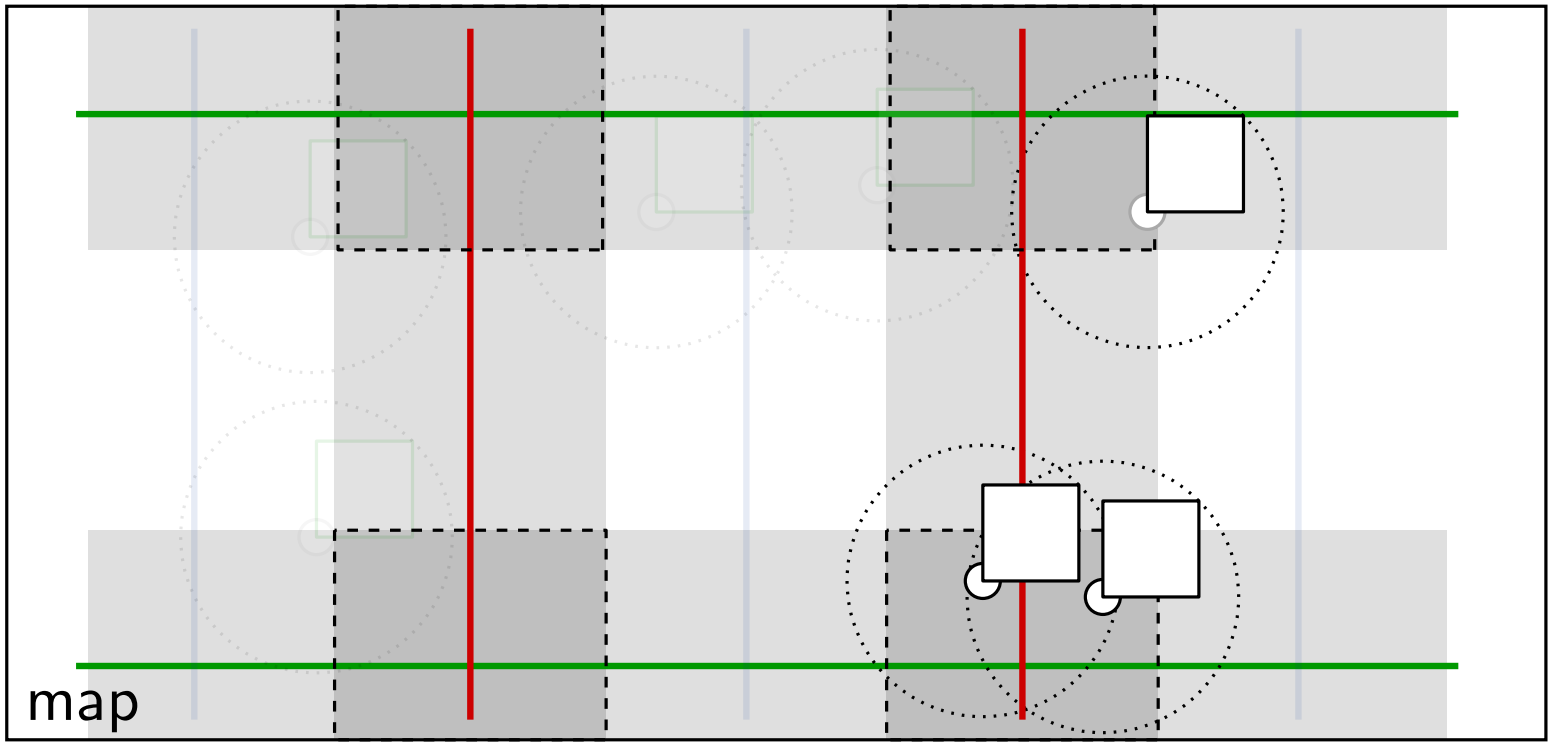
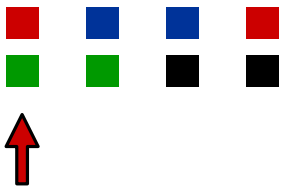


1/4-Approximation of MaxTotal



- split set of labels into **four** sets



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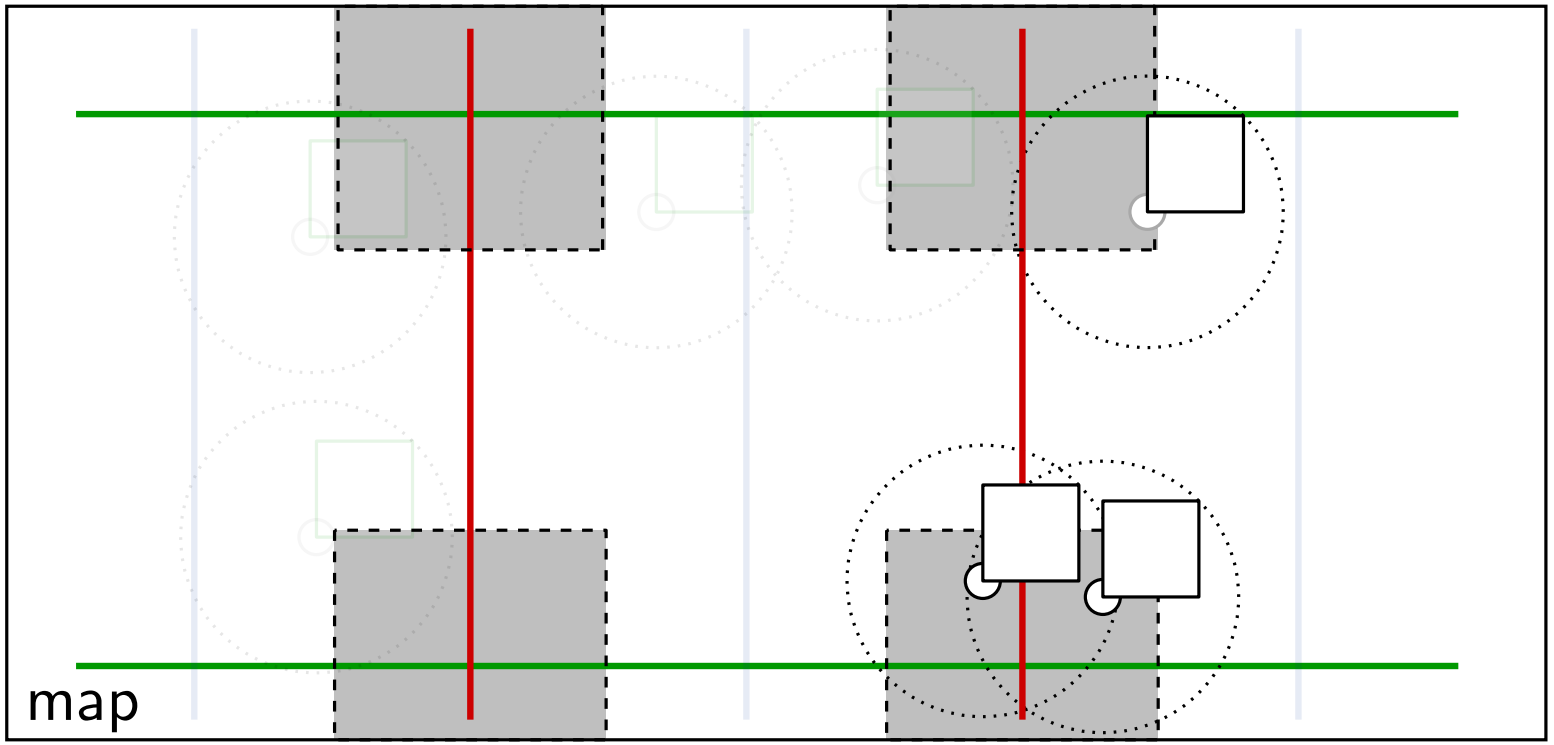

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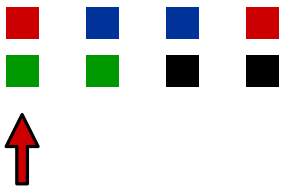

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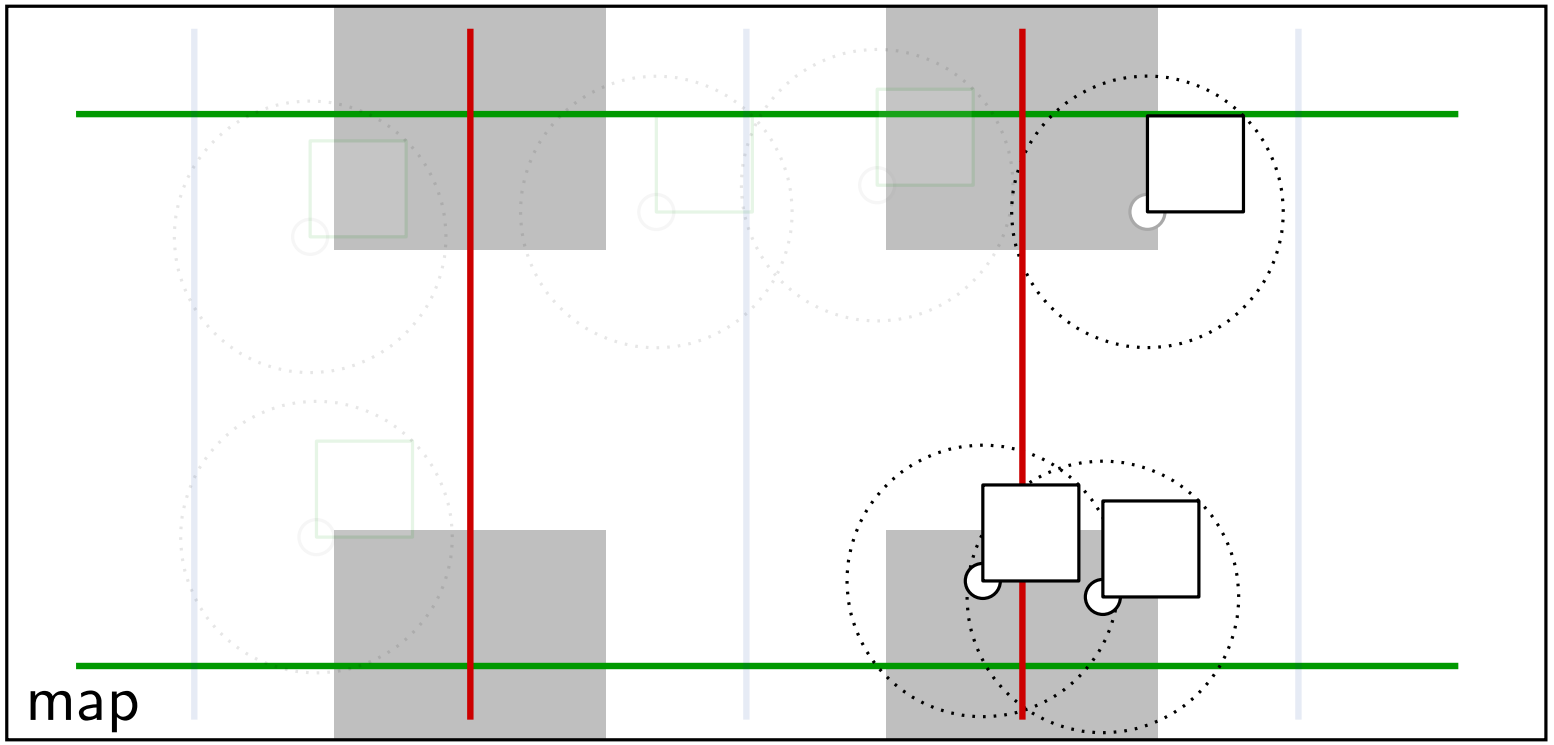

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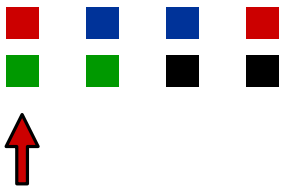

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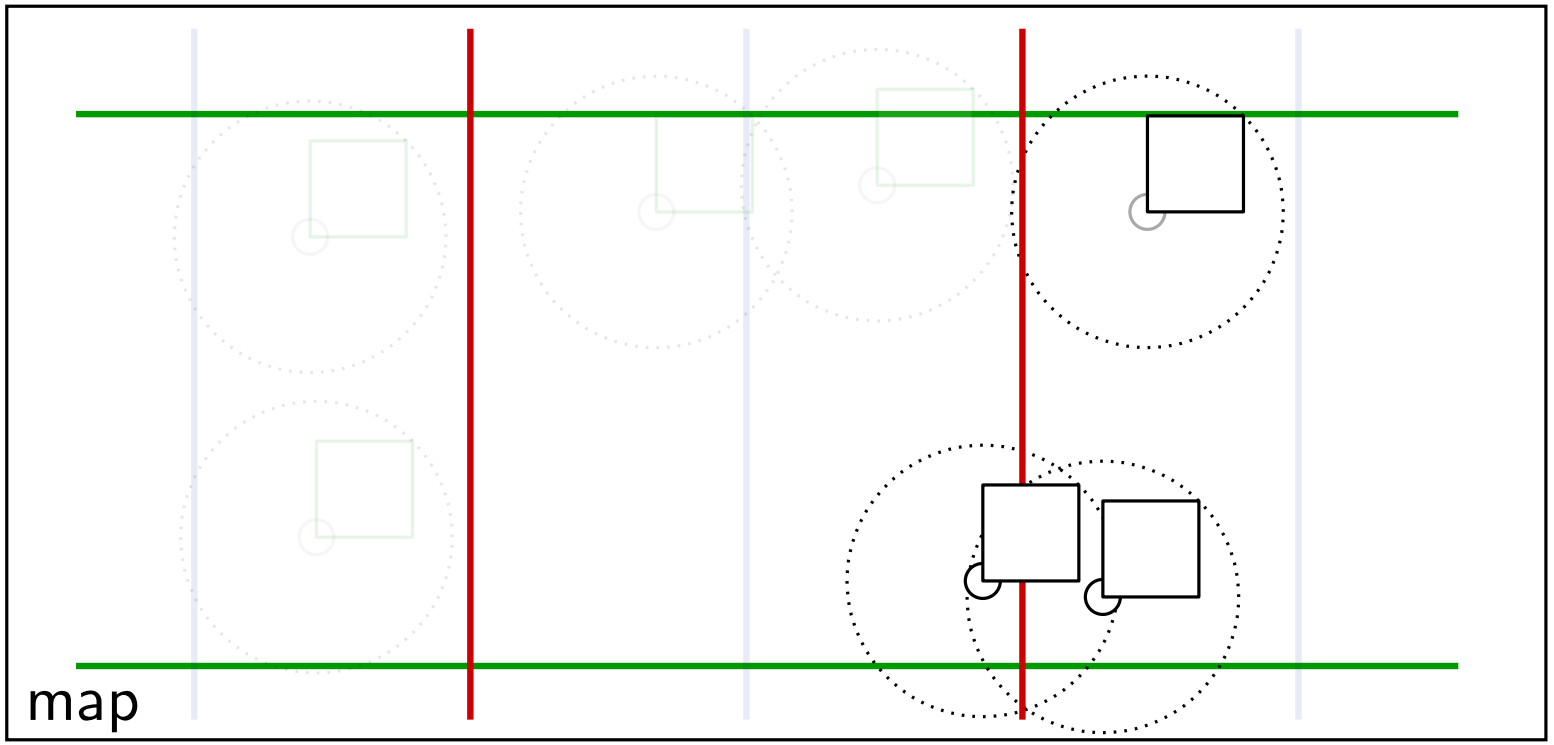

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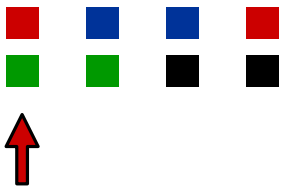

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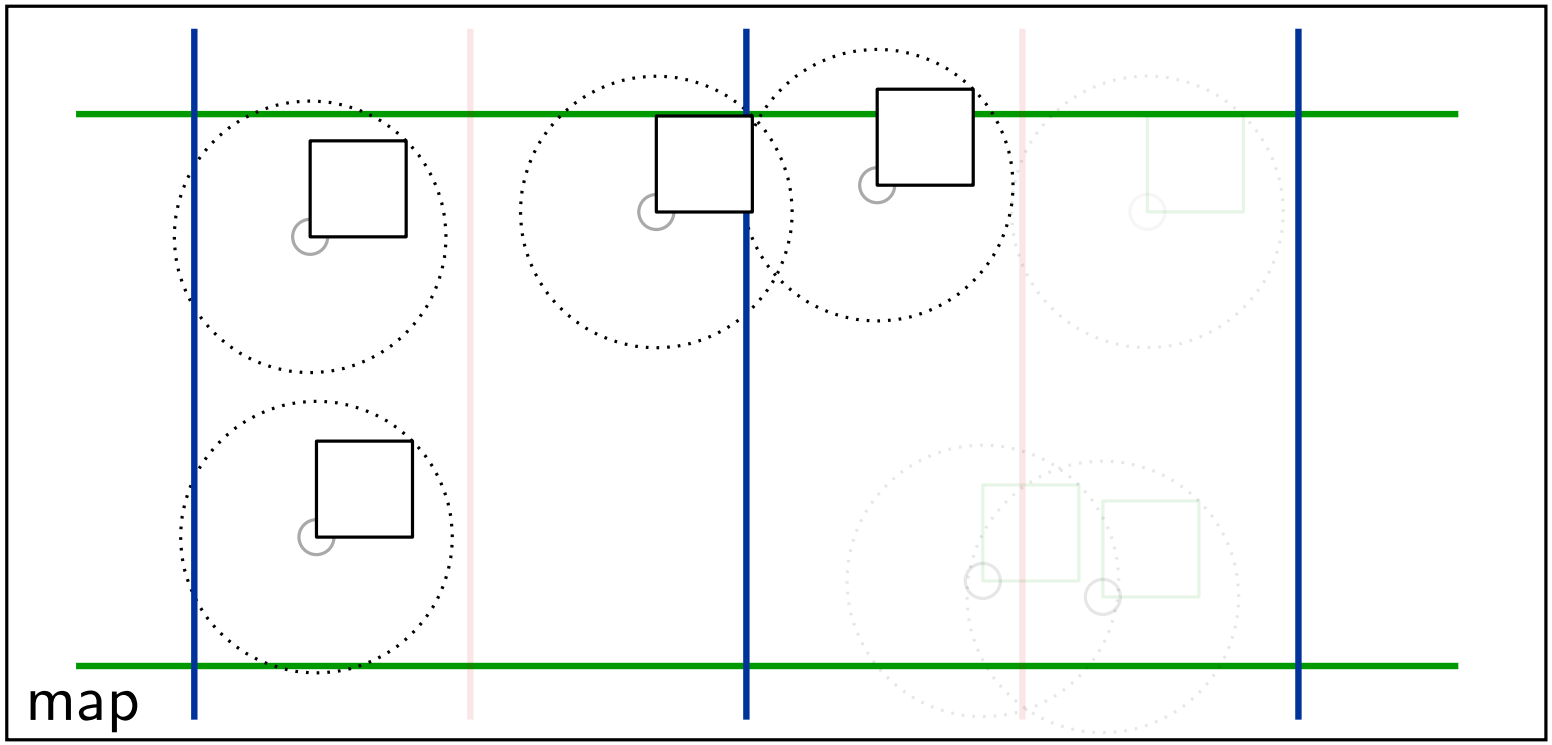

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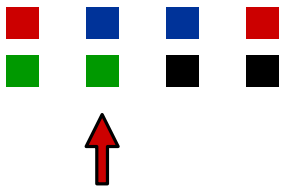

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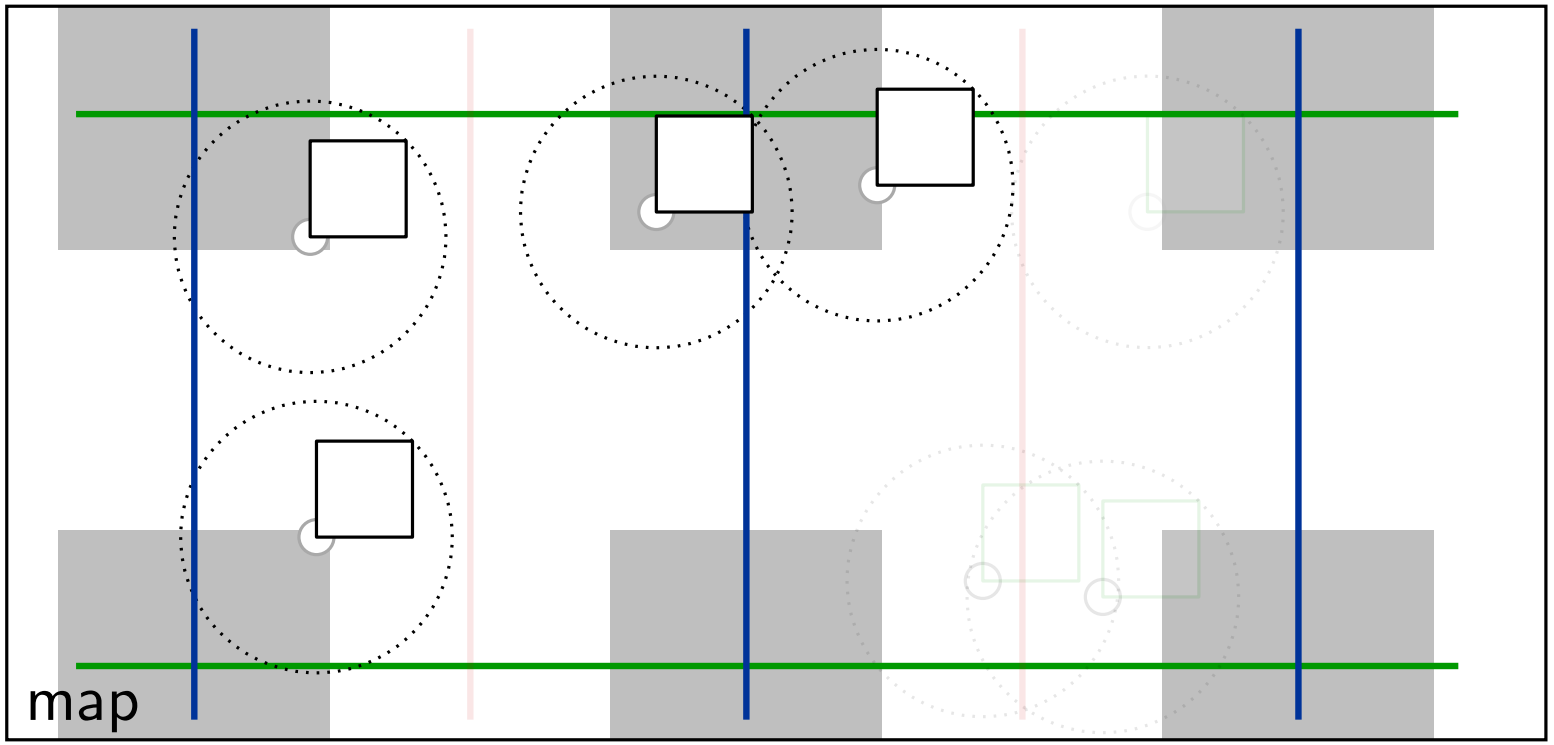

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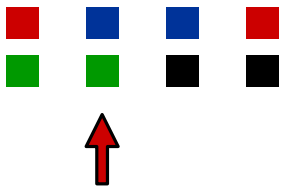

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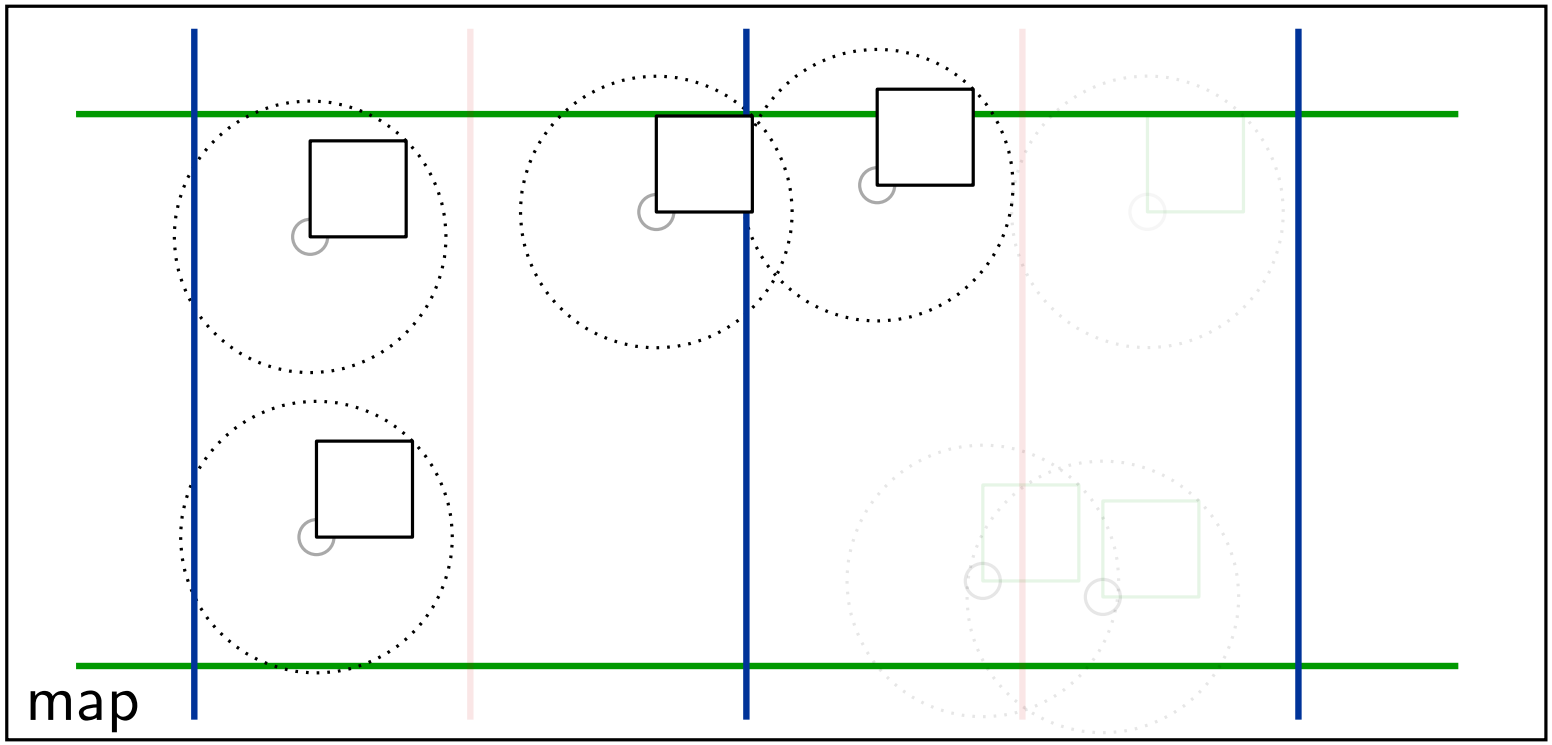

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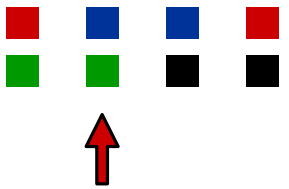

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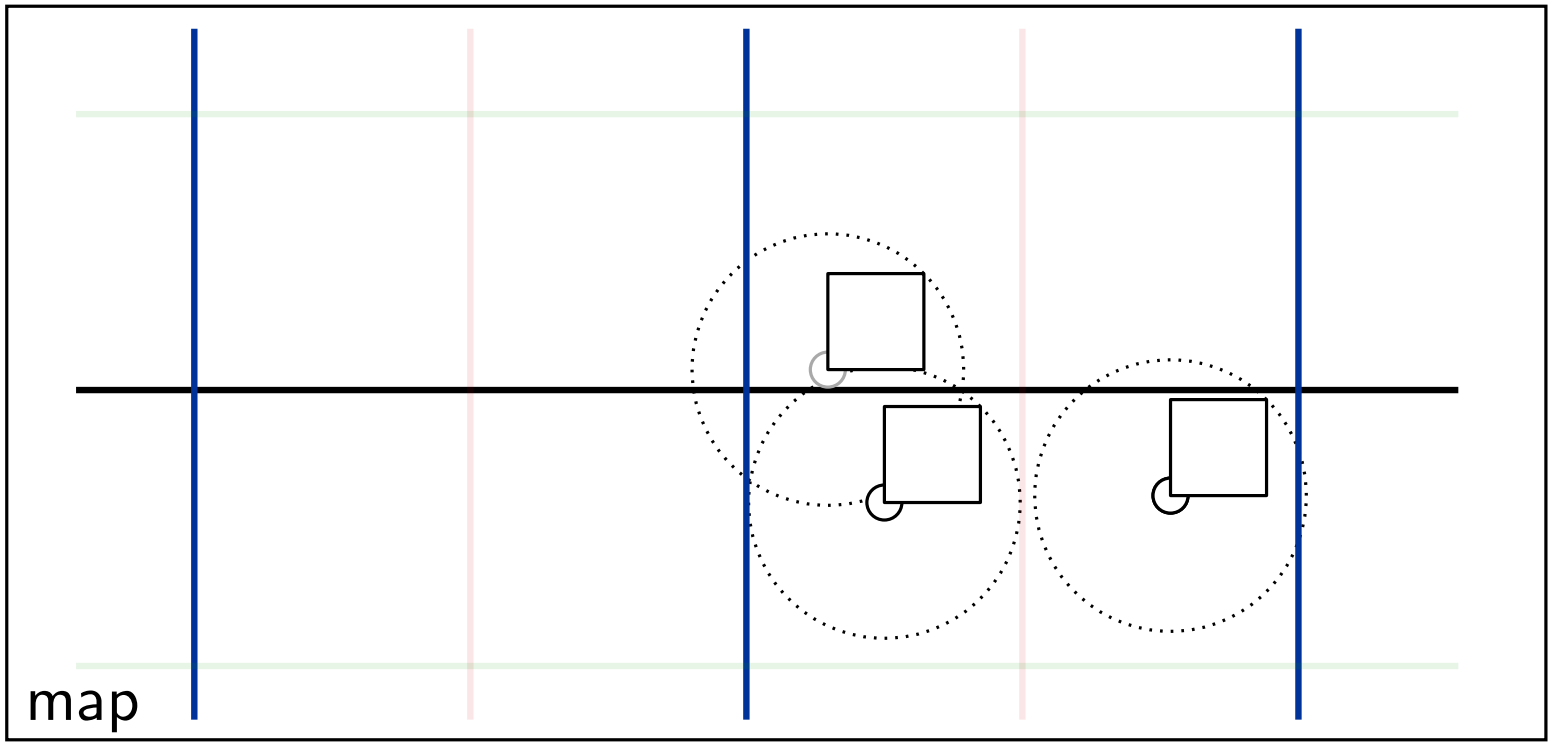

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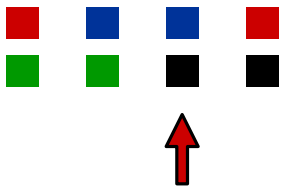
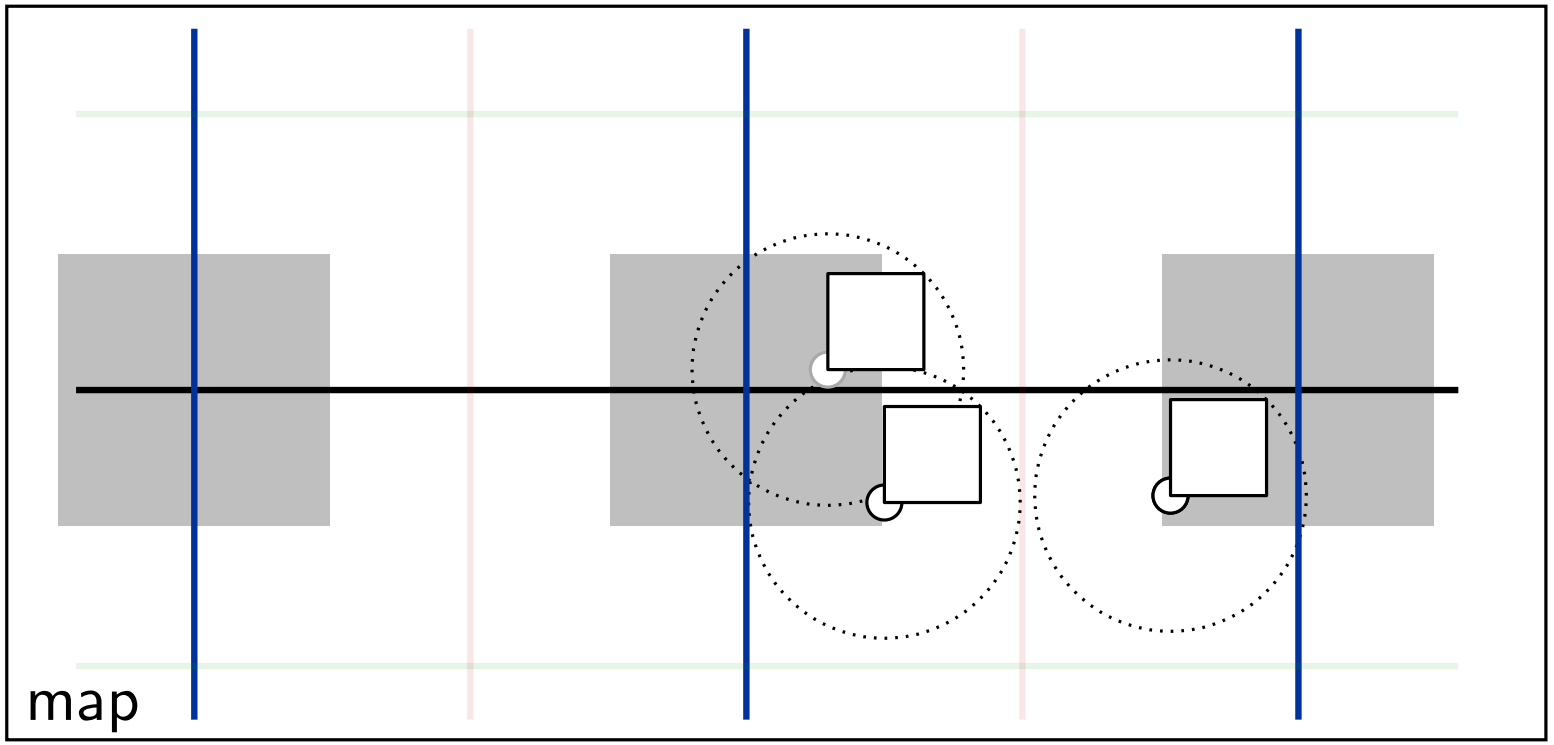


1/4-Approximation of MaxTotal



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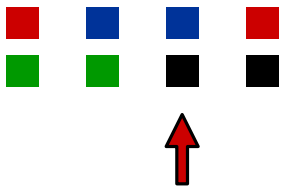

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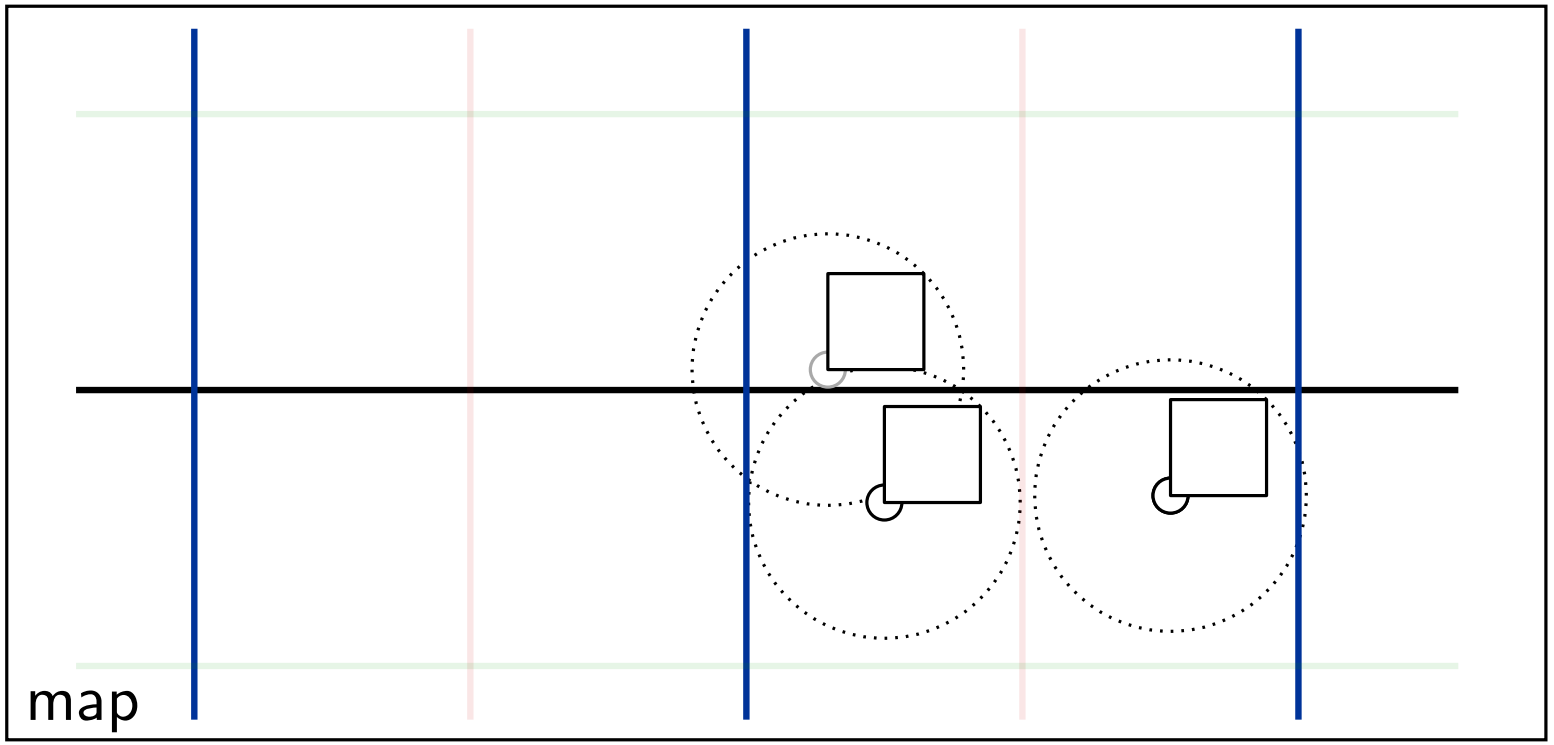

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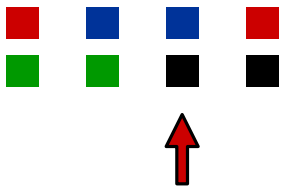

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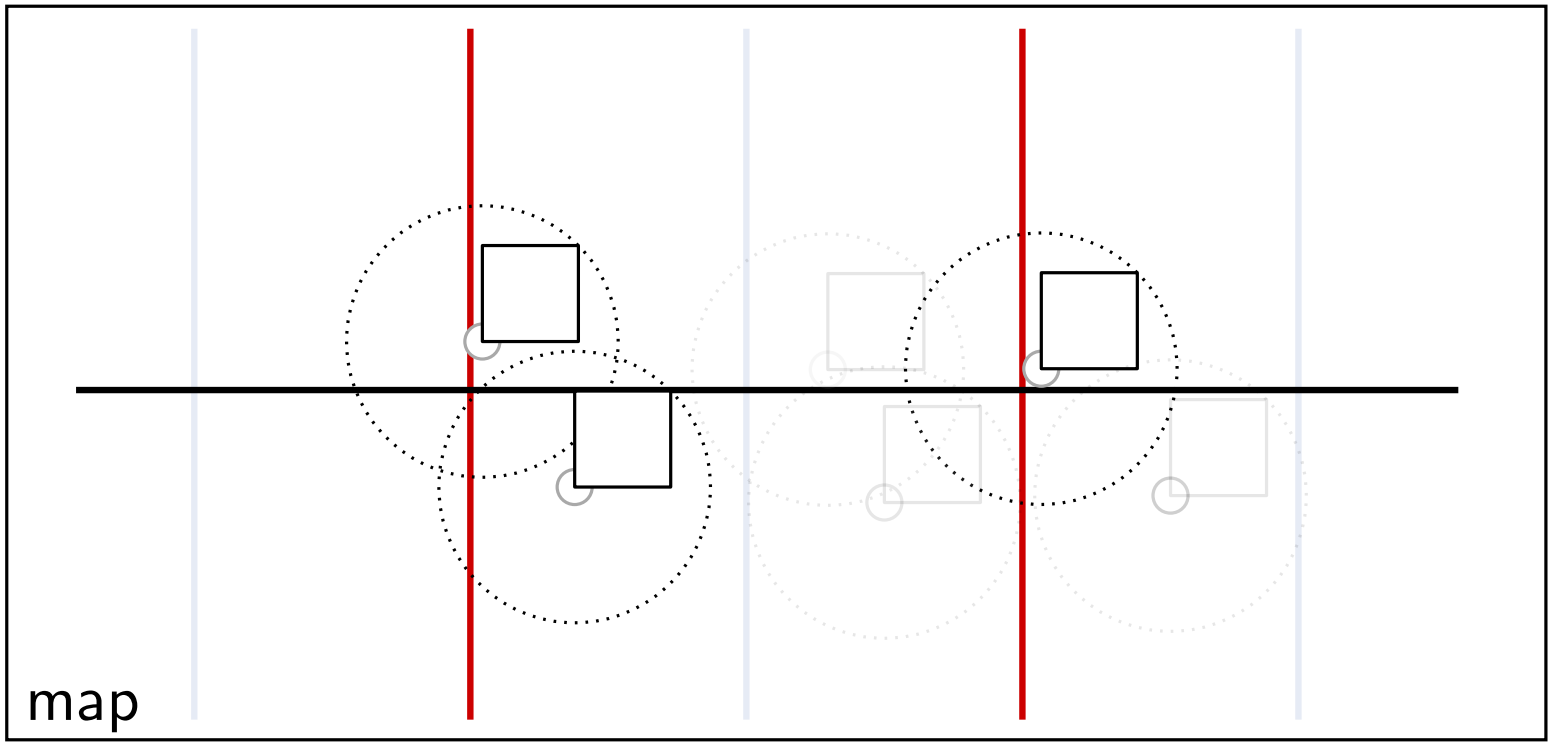

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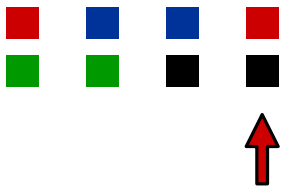

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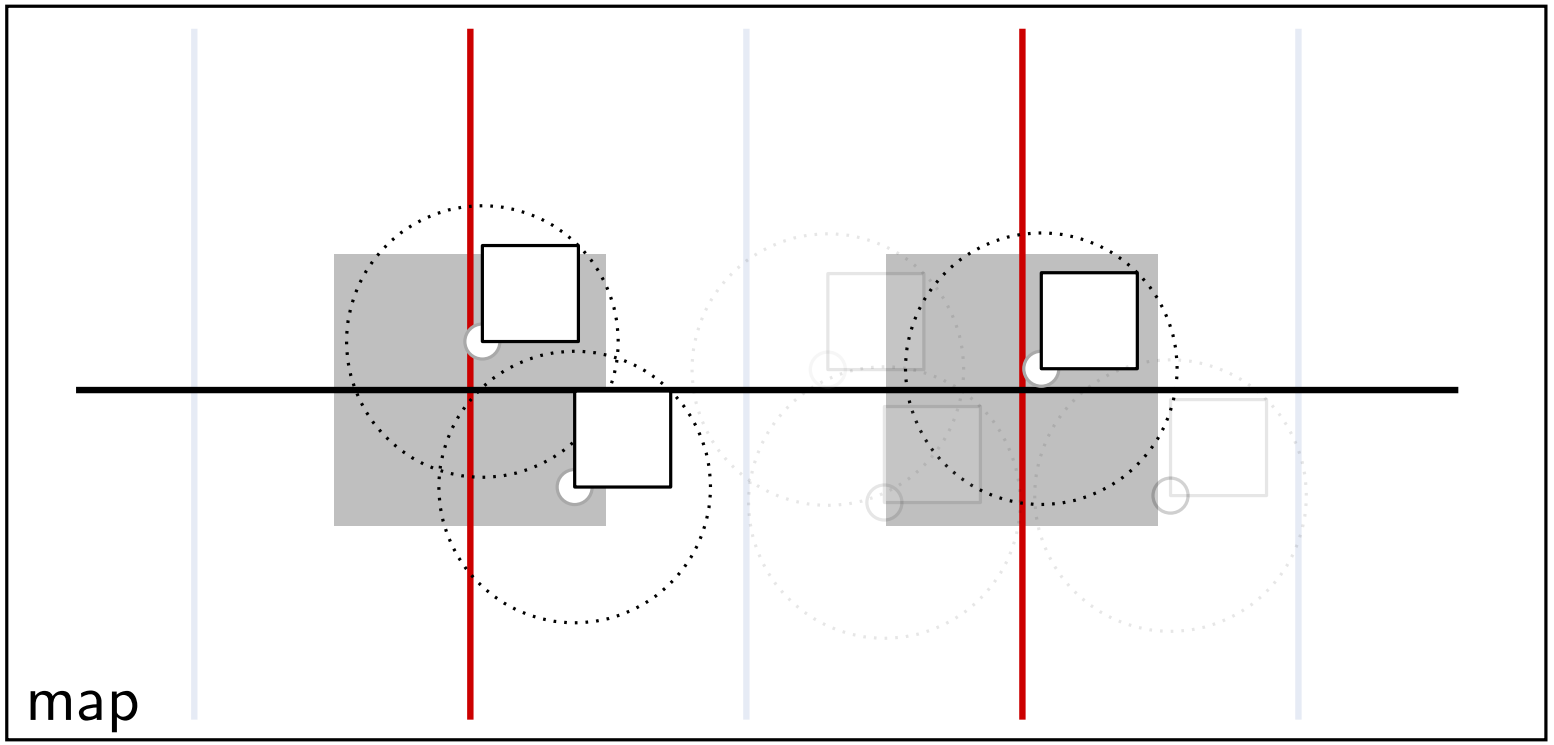

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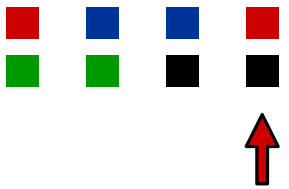
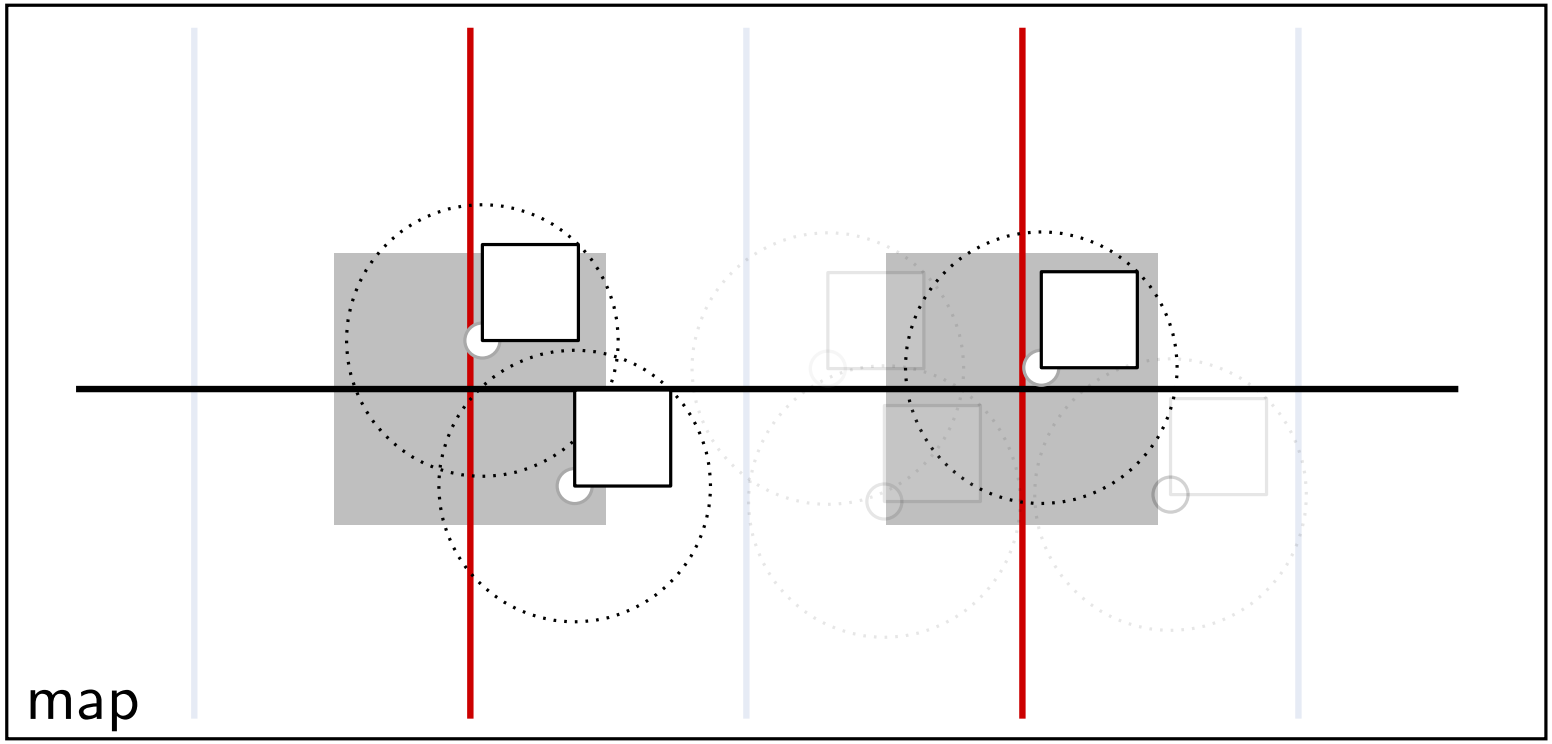


1/4-Approximation of MaxTotal



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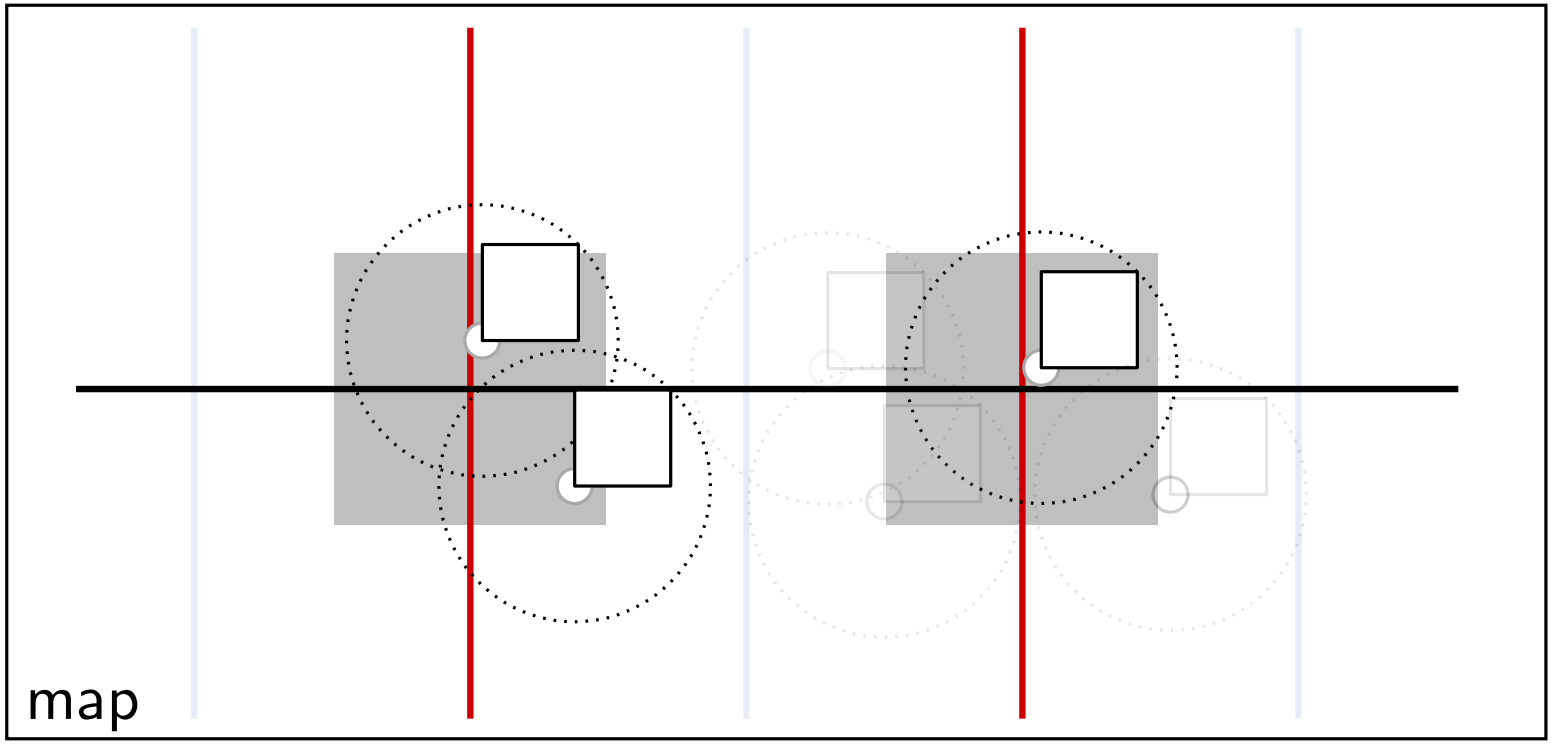
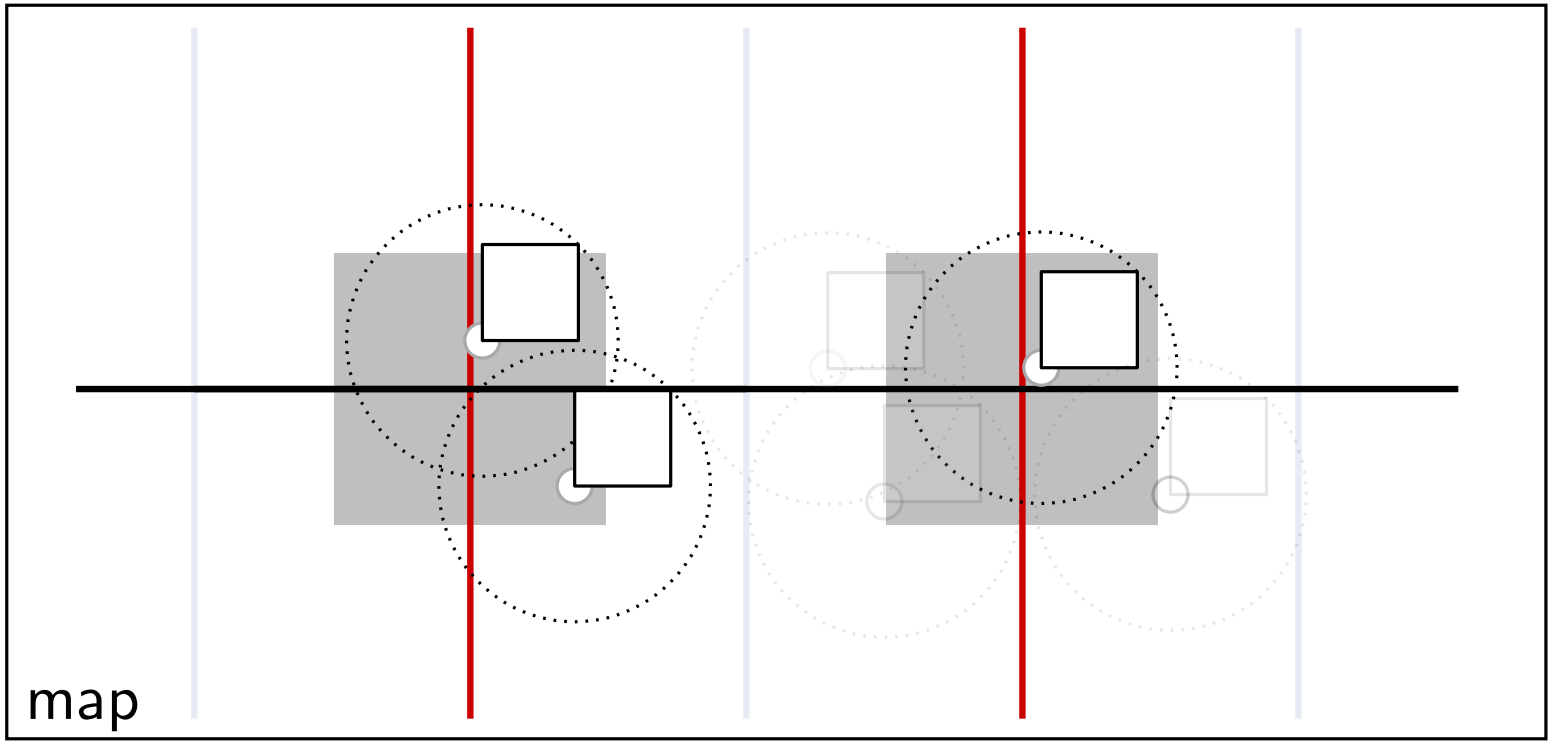
1/4-Approximation of MaxTotal



- split set of labels into **four** sets
- find optimal solution for each set separately

one of those solutions is a **1/4**–approximation

1/4-Approximation of MaxTotal



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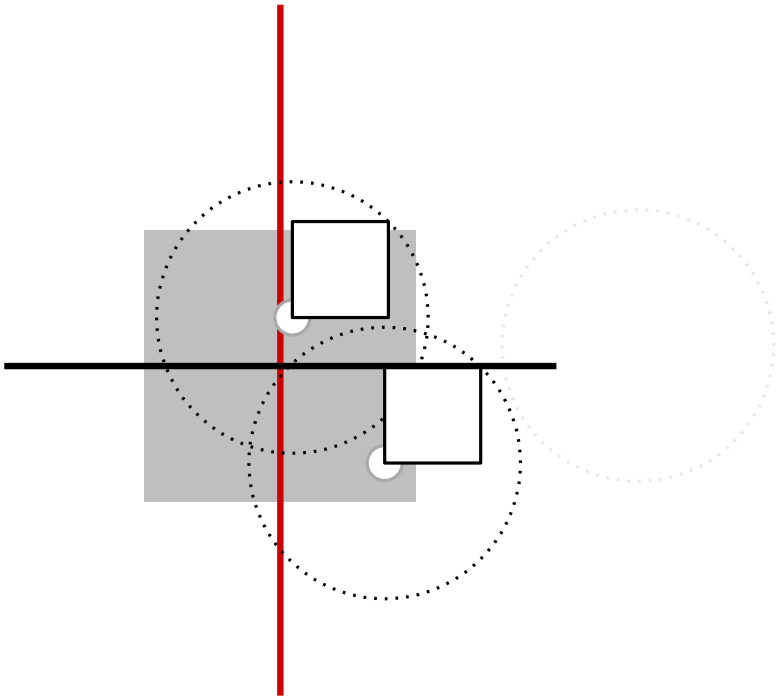

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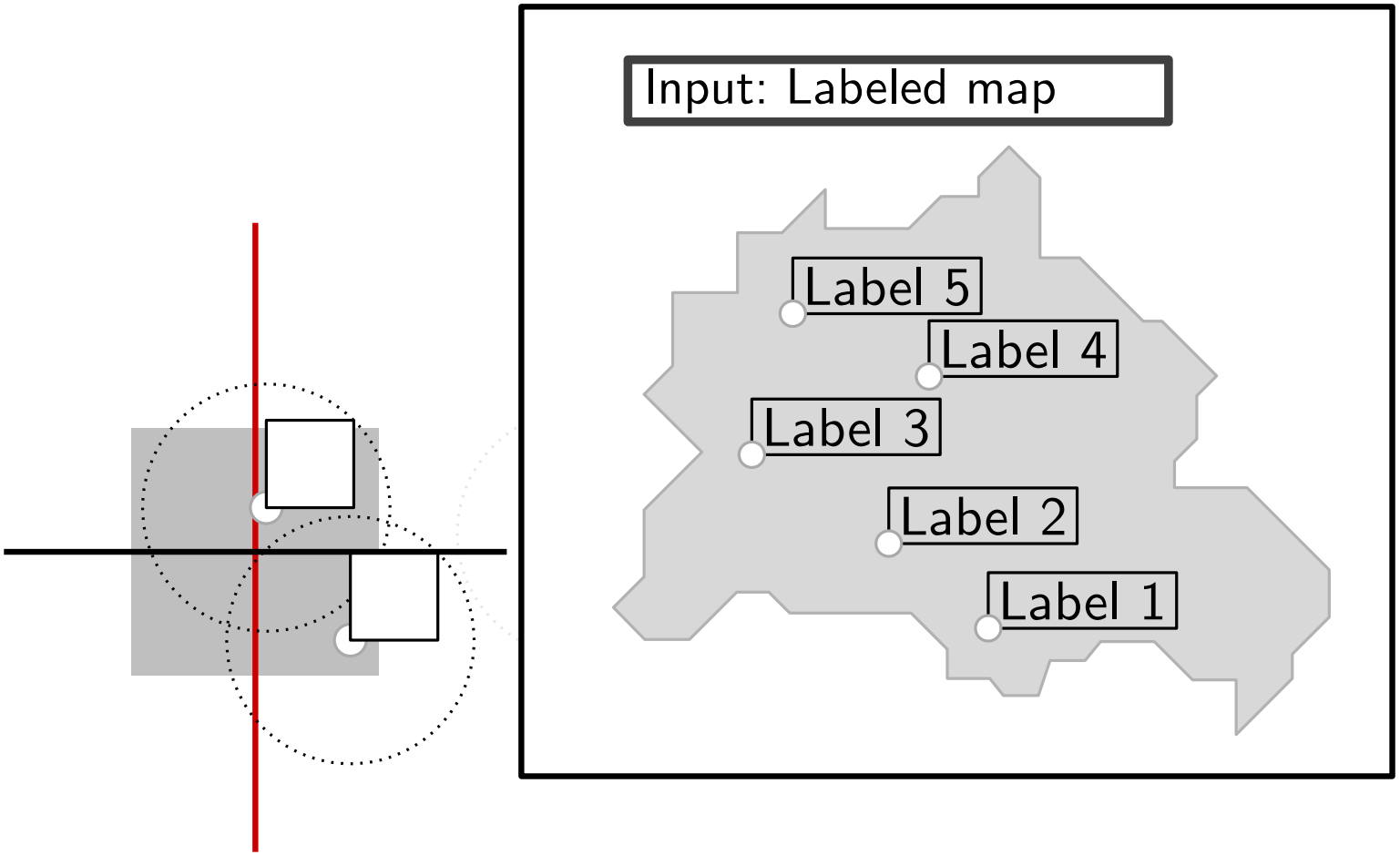
1/4-Approximation of MaxTotal



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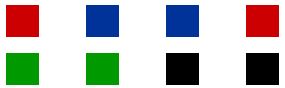

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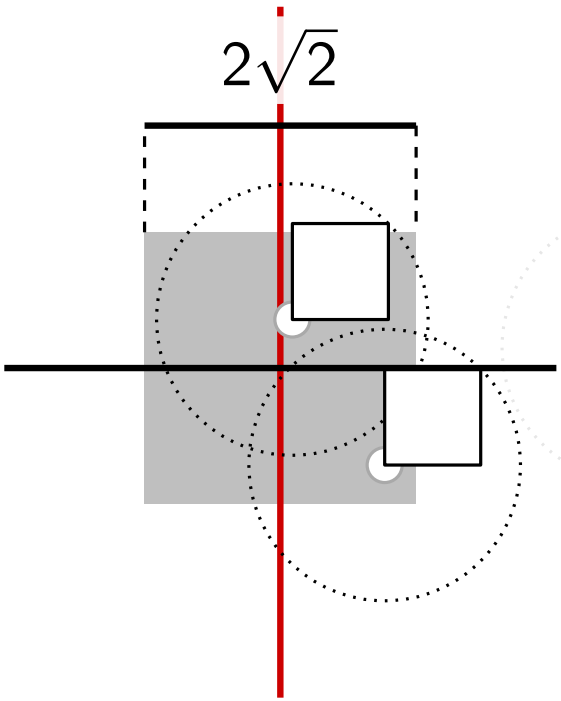
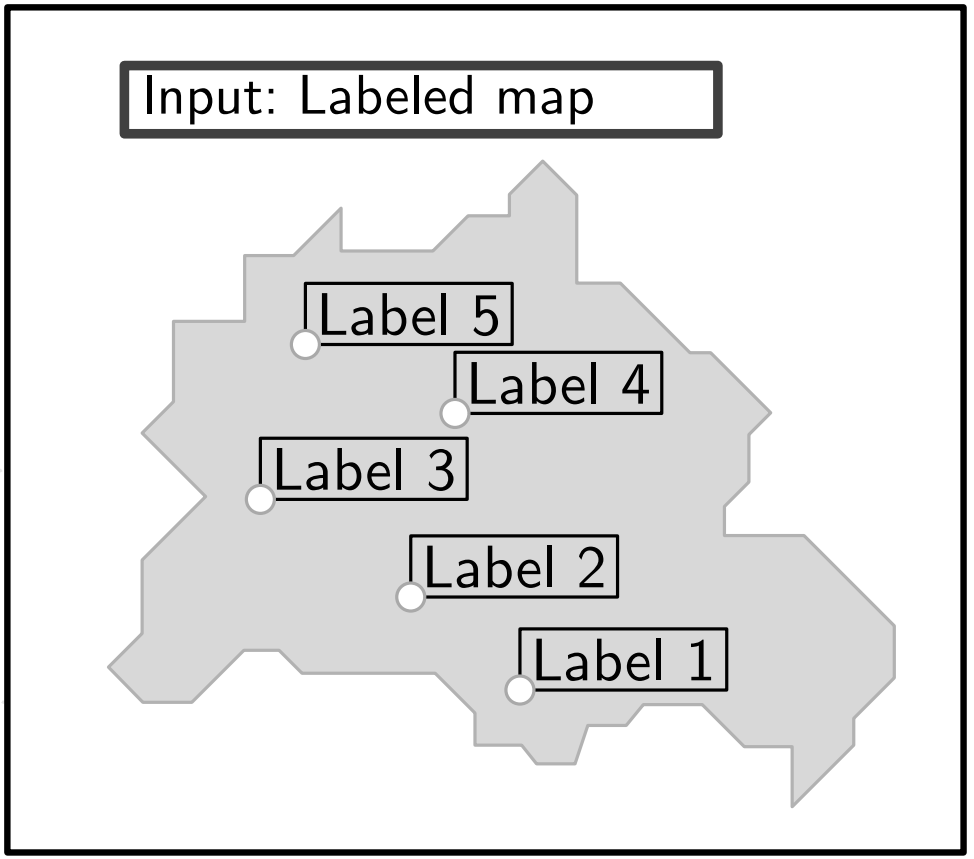
1/4-Approximation of MaxTotal





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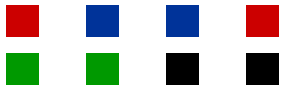

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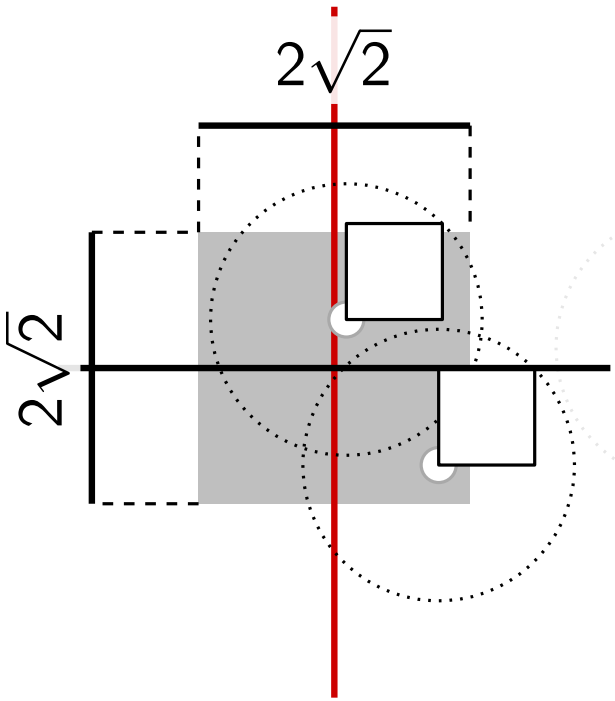

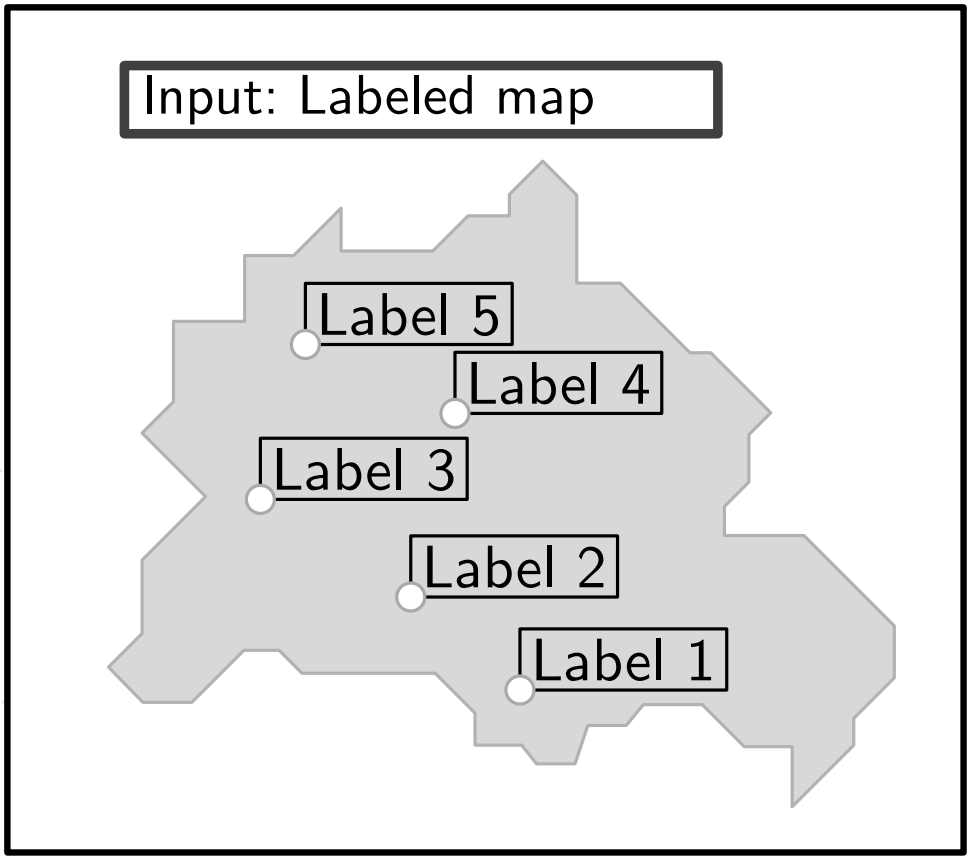

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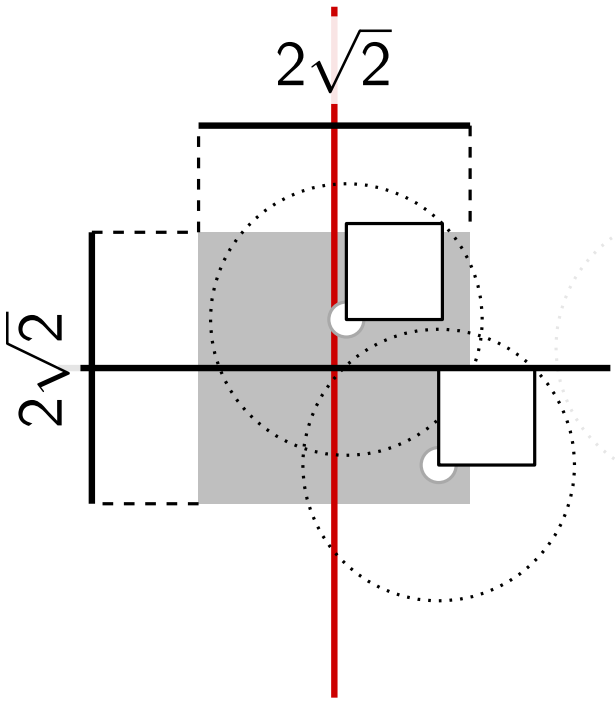

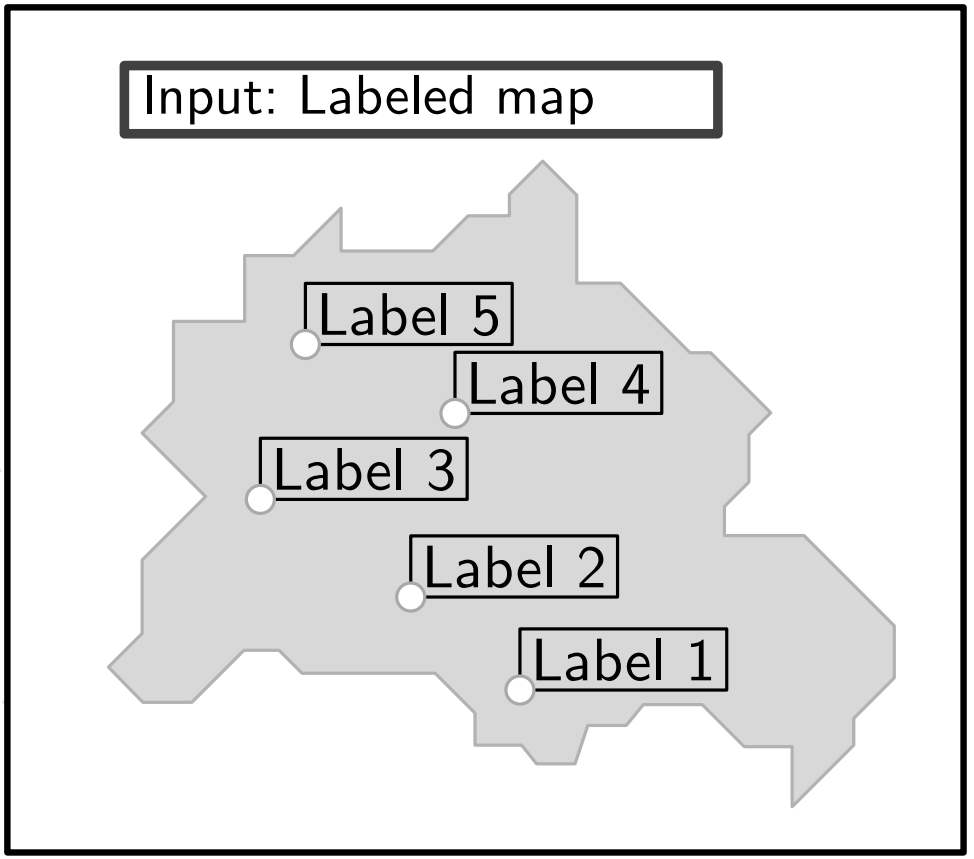

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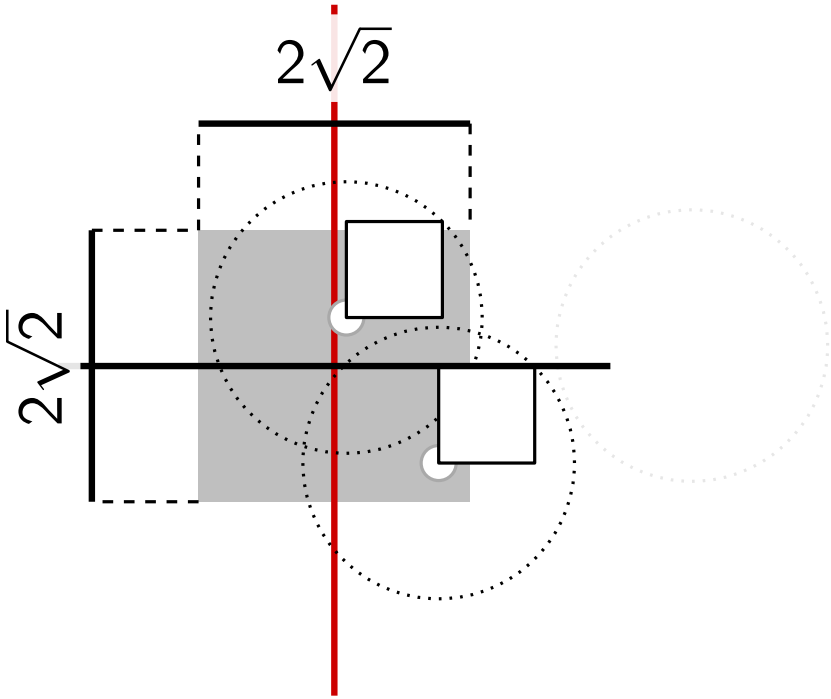

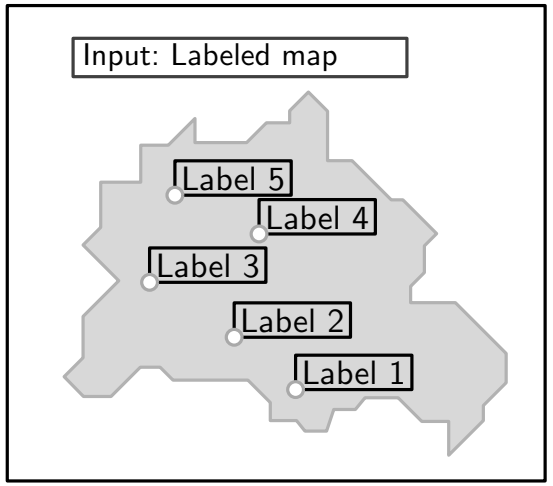

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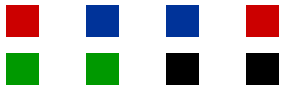

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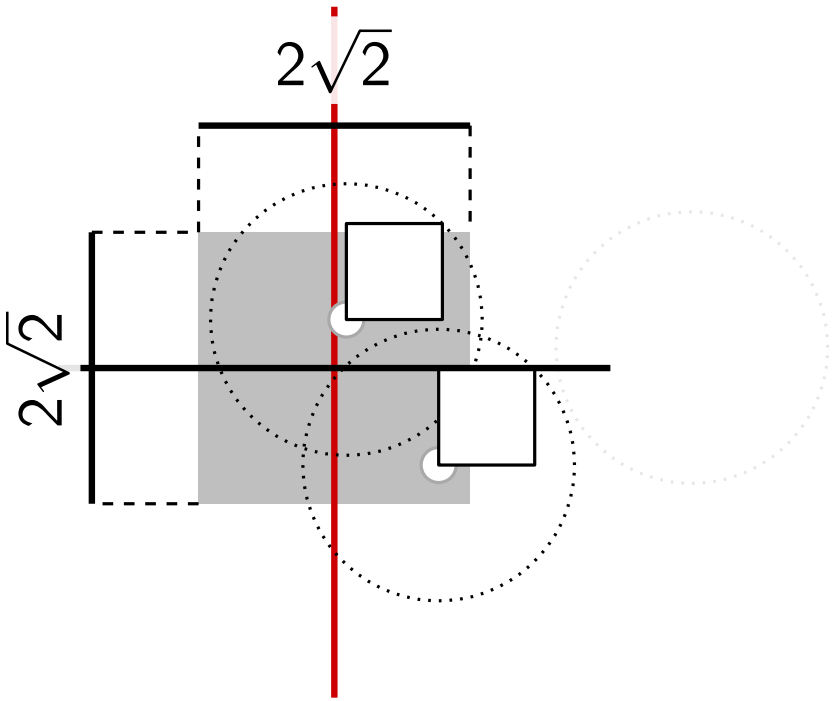
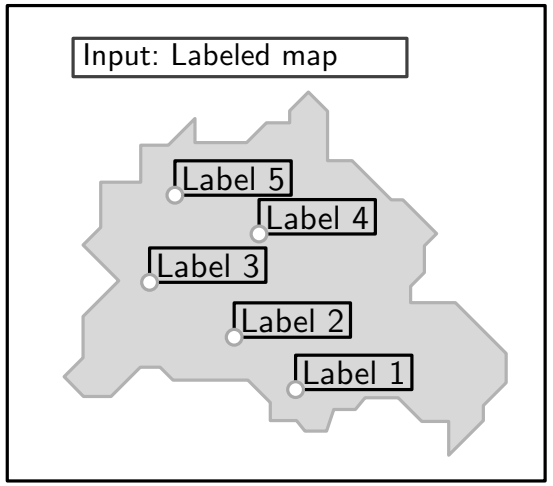
1/4-Approximation of MaxTotal

(i) constant number
of labels inside square





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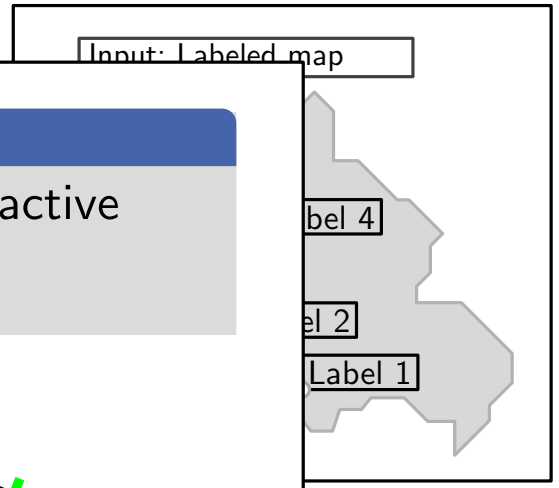


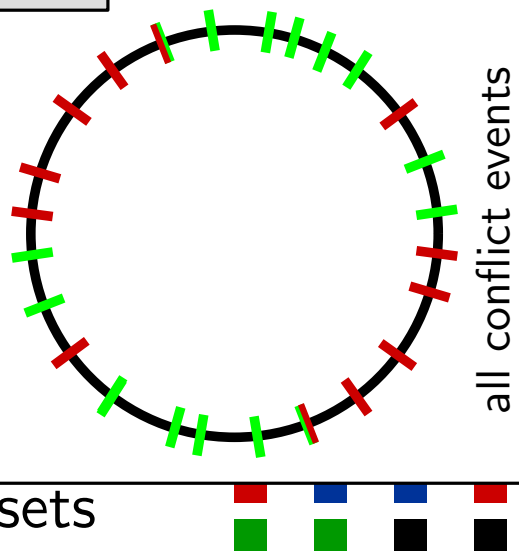
Discretization Lemma:

There is an optimal solution for MaxTotal where all active ranges start and end at conflict events.

only for MaxTotal

find optimal solution:

- compute all conflict events
- per label $\mathcal{O}(n^4)$ active range candidates
- determine all possible combinations



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1/4-Approximation of MaxTotal

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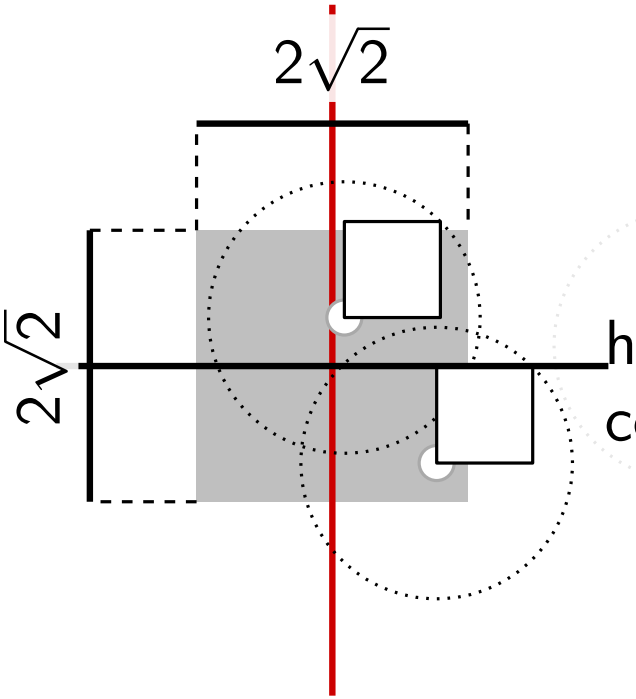
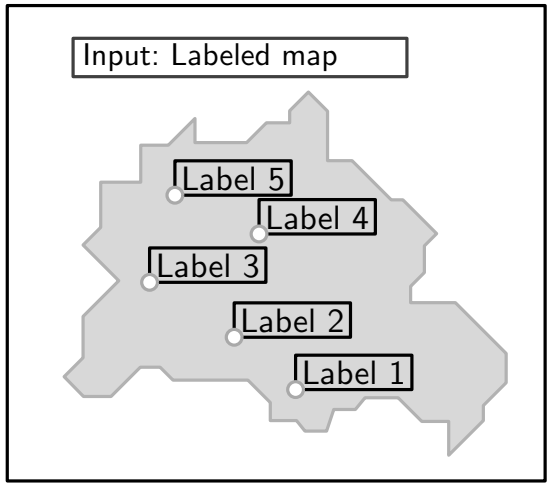
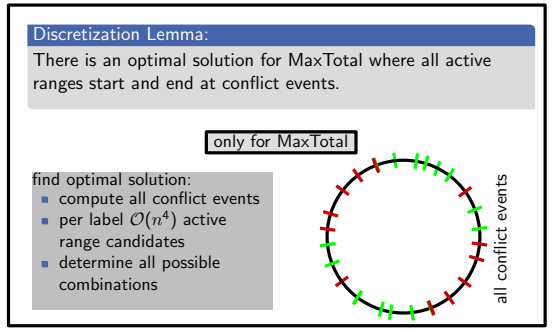


how many conflict events?





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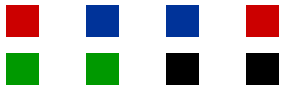

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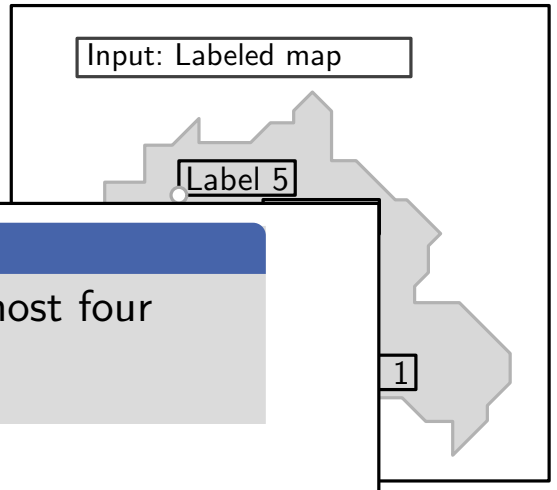
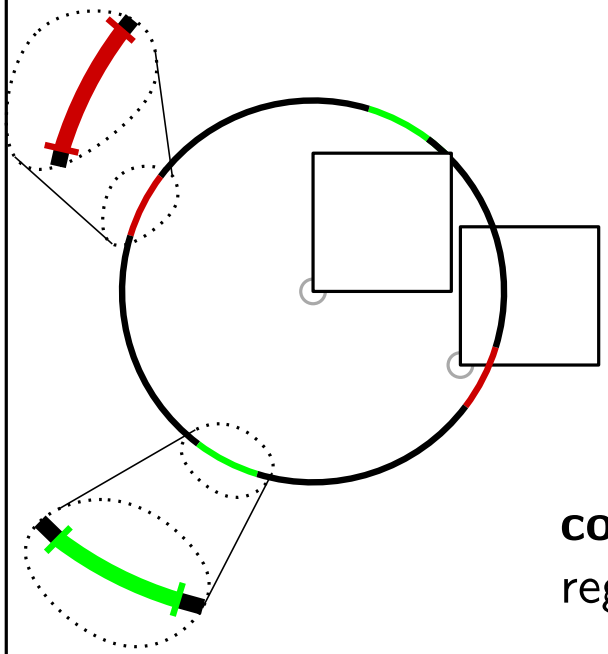


Conflict Lemma:

For two labels the set of conflicts consists of at most four contiguous conflict regions.



soft conflict: labels overlap

hard conflict: label overlaps anchor point

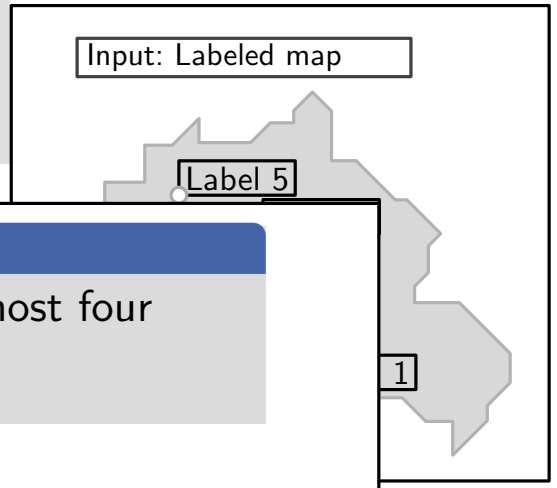
at most 8 such events per pair

conflict events: begin/end of a conflict region (borders of labels intersect)

one

1/4-Approximation of MaxTotal

(i) constant number of labels inside square



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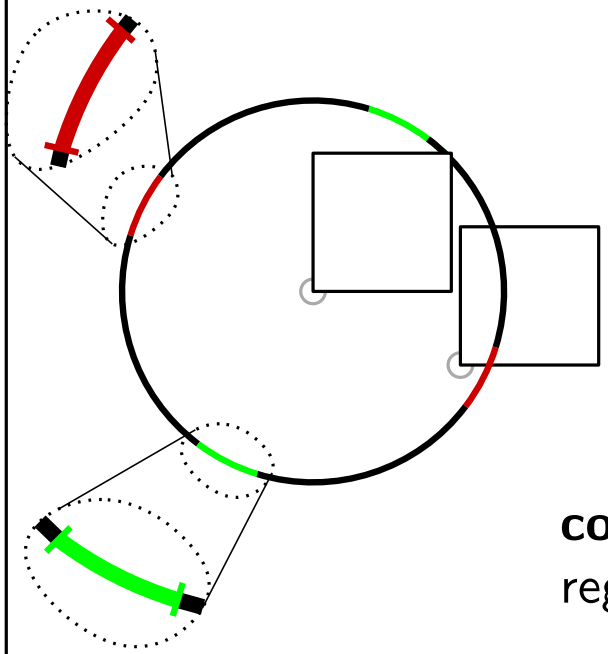

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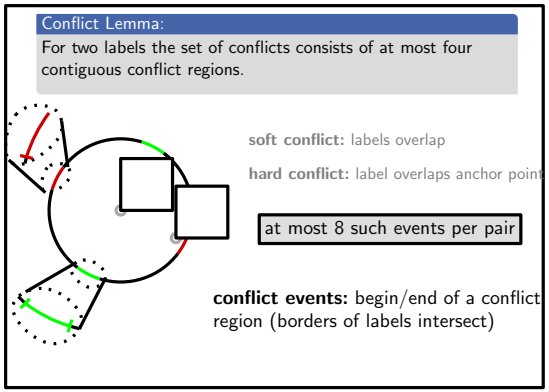
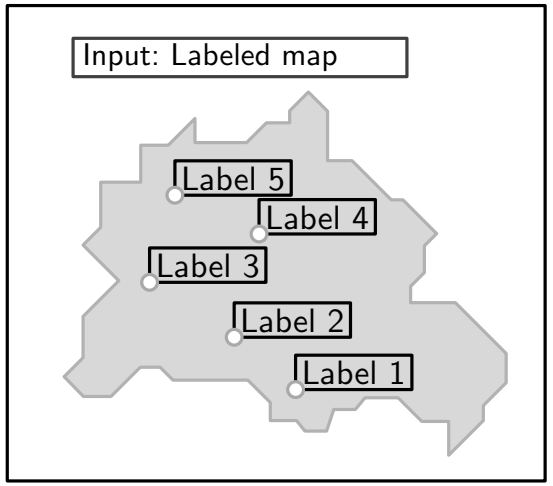
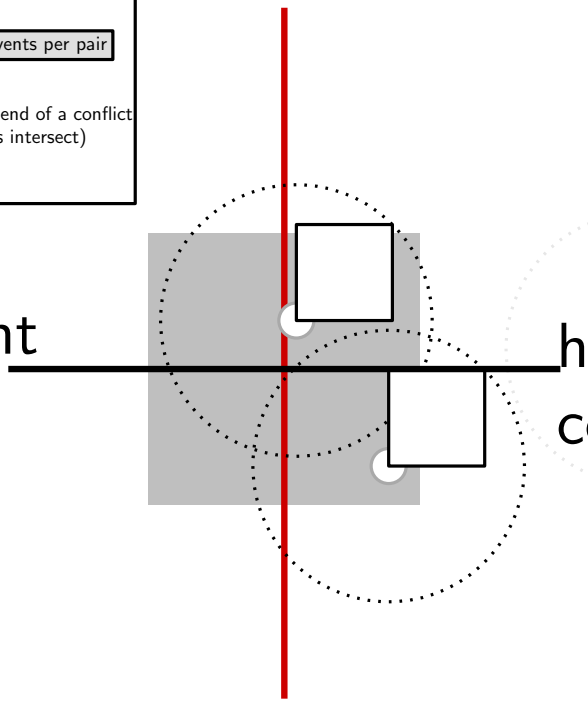


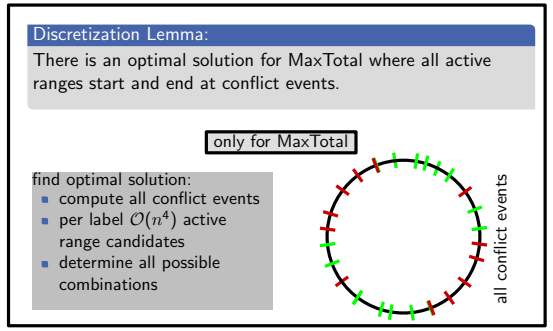
(i) constant number of labels inside square



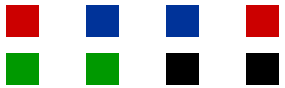
(ii) #conflict events: constant



how many conflict events?



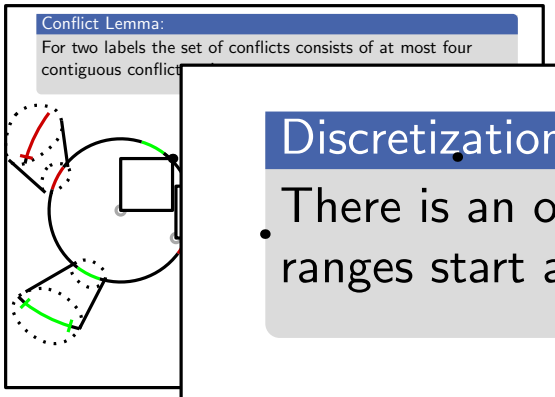
- split set of labels into **four** sets



- find optimal solution for each set separately

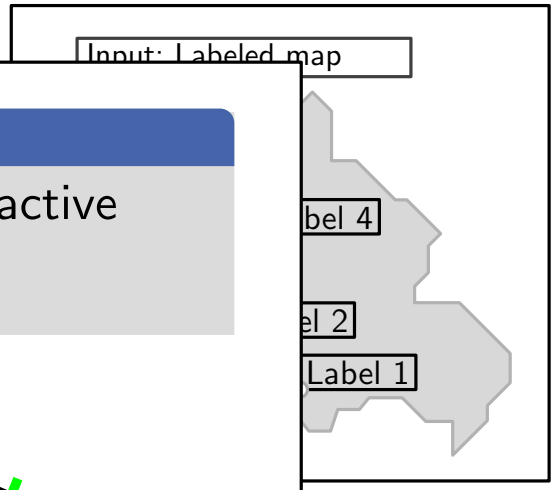
one of those solutions is a **1/4**–approximation

1/4-Approximation of MaxTotal



(i) constant number

(ii) #c
events



Discretization Lemma:

There is an optimal solution for MaxTotal where all active ranges start and end at conflict events.

only for MaxTotal

find optimal solution:
- compute all conflict events
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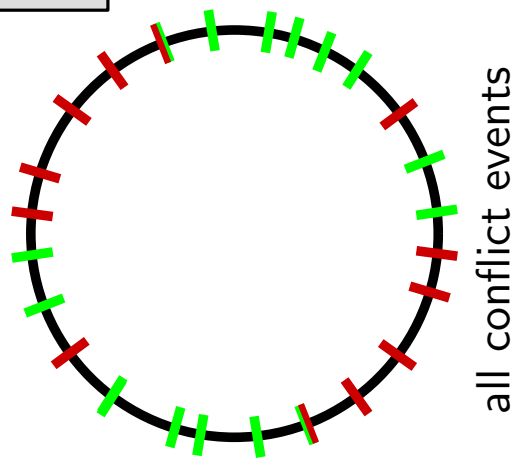

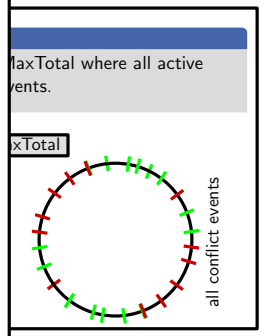

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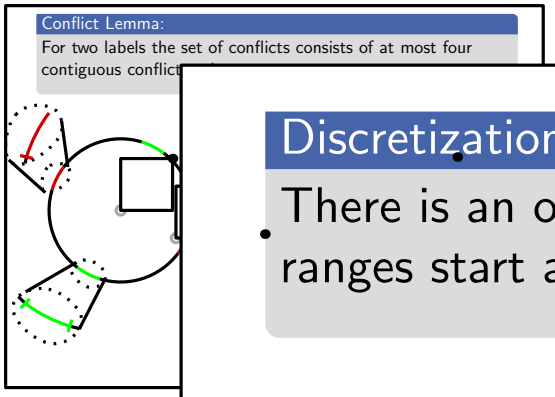

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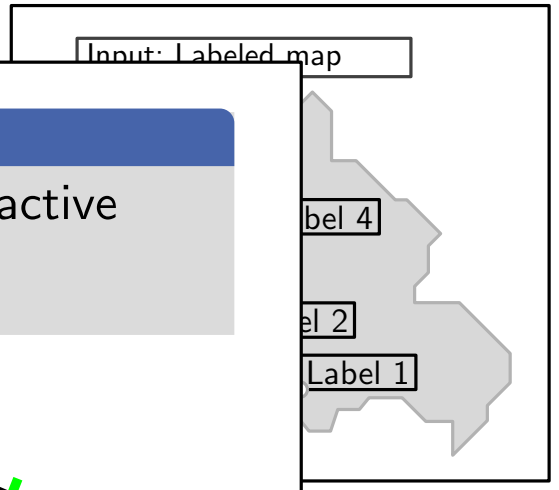

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constant

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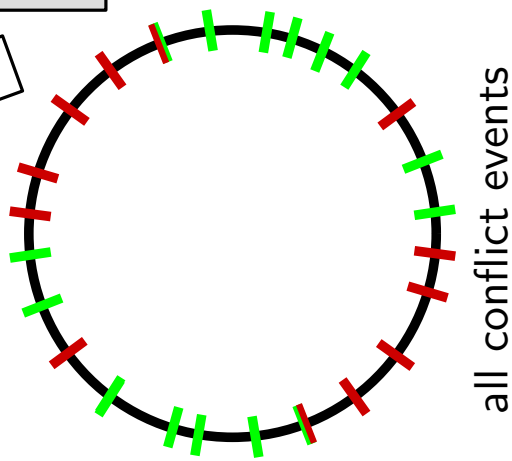

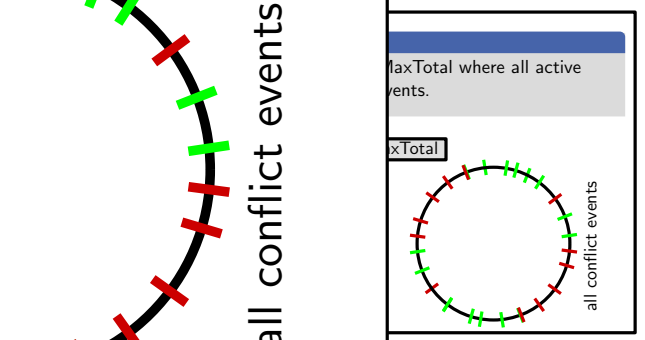

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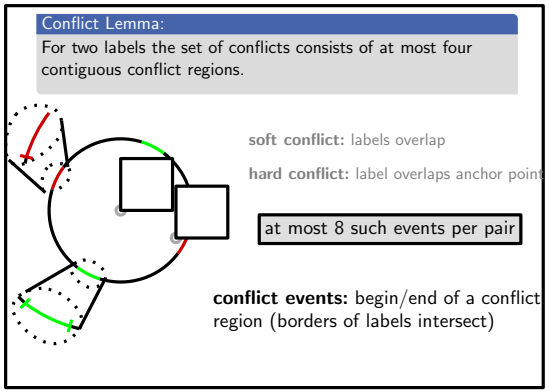

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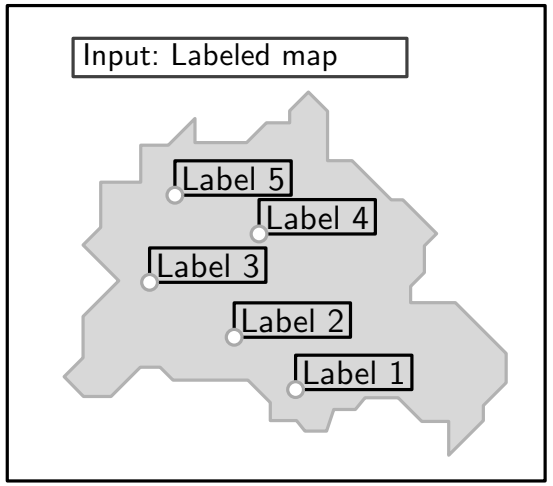

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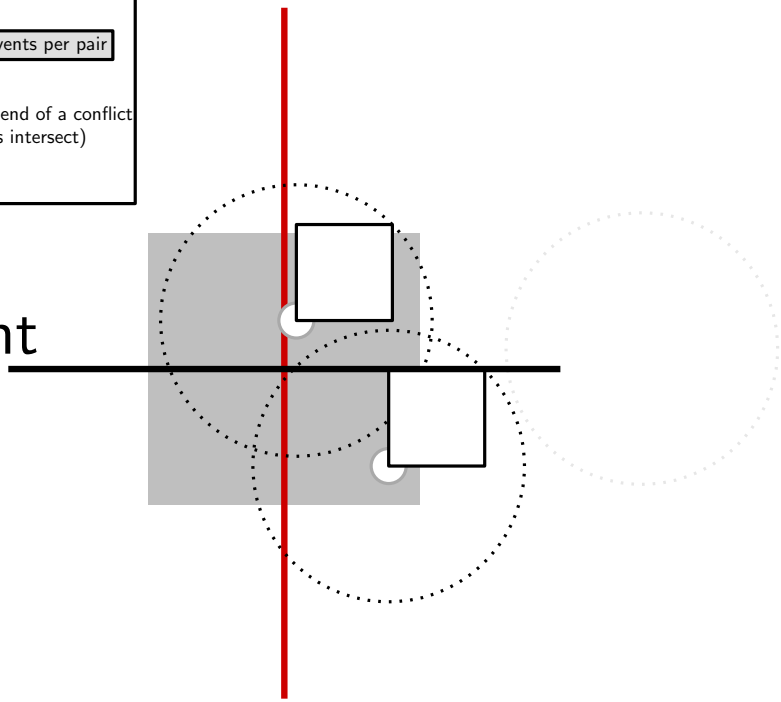

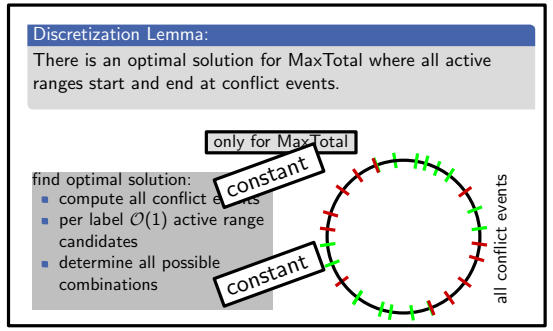

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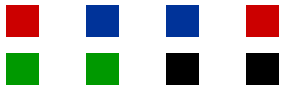

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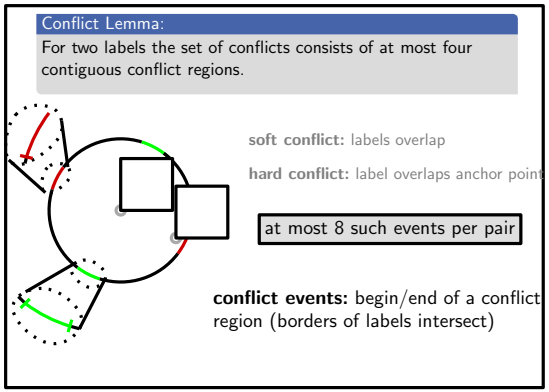

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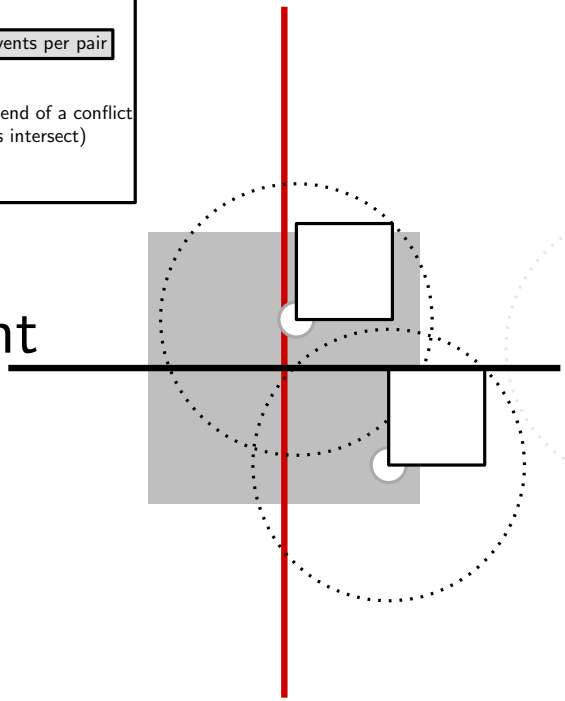
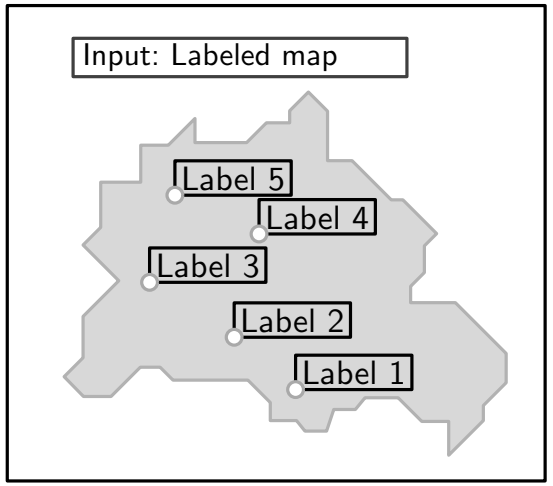
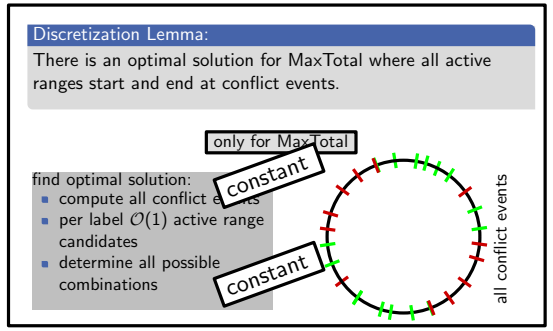


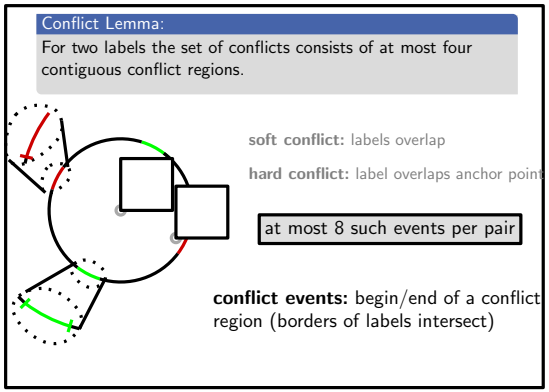




Theorem 2

There exists a 1/4–approximation algorithm for MaxTotal with time complexity $O(n \log n)$

1/4-Approximation of MaxTotal



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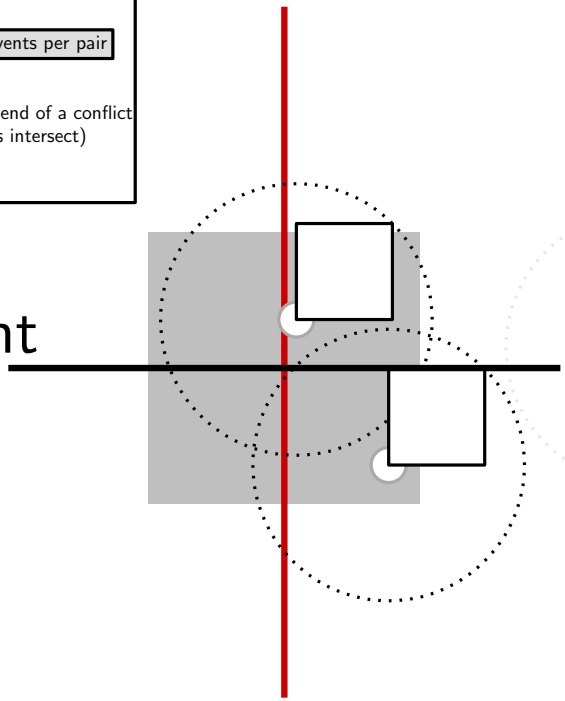

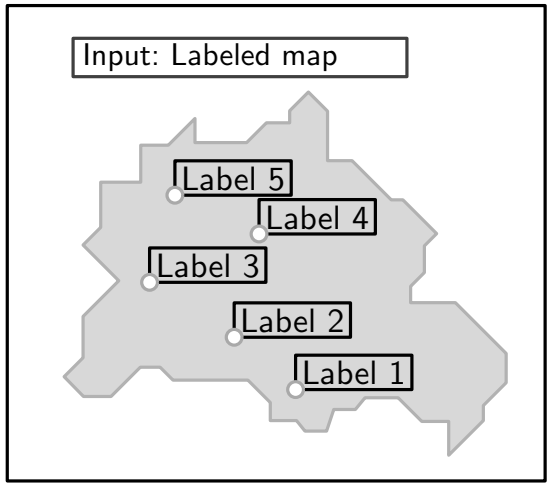

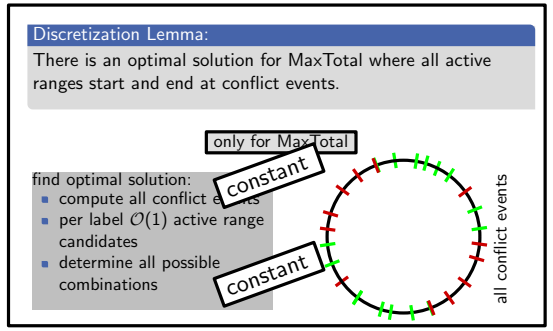

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An EPTAS for MaxTotal

for unit squares*

(E)PTAS?

polynomial-**t**ime **a**pproximation **s**cheme

- approximation algorithm that takes the **instance** and a paramter $\varepsilon > 0$ as input
- produces a solution that is $(1 - \varepsilon)$OPT within the optimal solution
- running time is polynomial in n (but typically not in ε)

$O(n^{1/\varepsilon})$, $O(n^{1/\varepsilon^{100}})$, $O(1/\varepsilon^{1/\varepsilon} \cdot n^2 \log n)$

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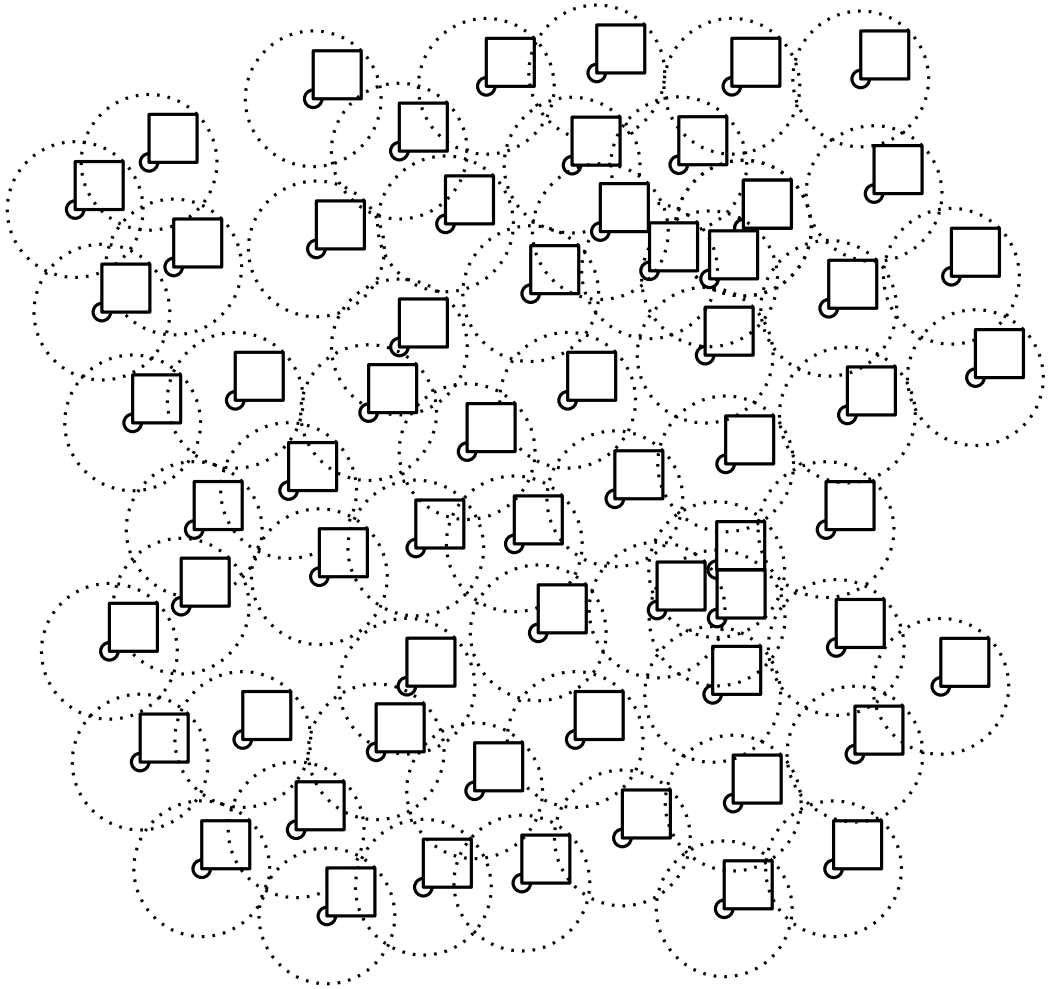
efficient **p**olynomial-**t**ime **a**pproximation **s**cheme

- every EPTAS is a PTAS with...
- running time is in n^c for some constant c

$O(1/\varepsilon^{1/\varepsilon} \cdot n^2 \log n)$

An EPTAS for MaxTotal

use the same principle as before



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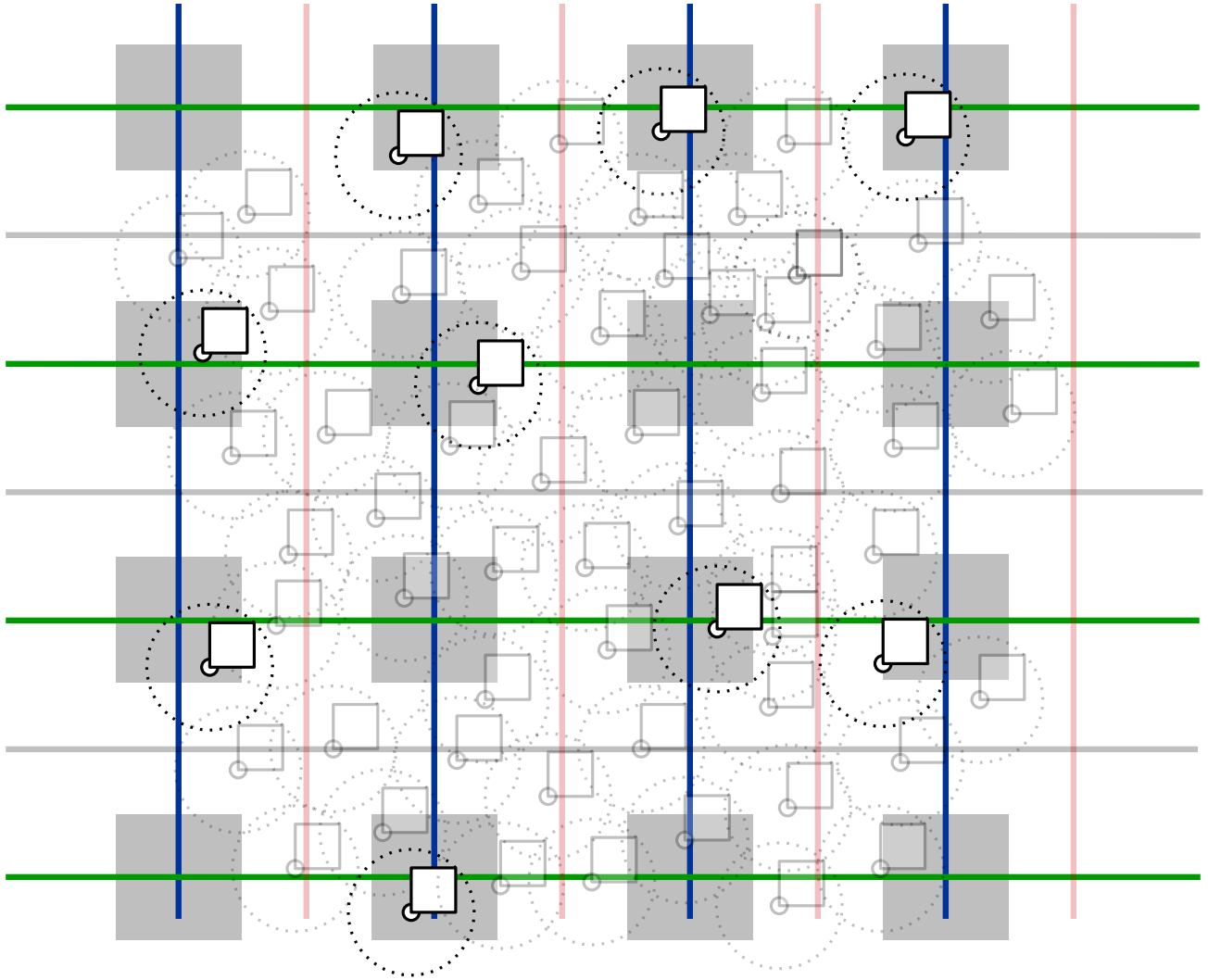

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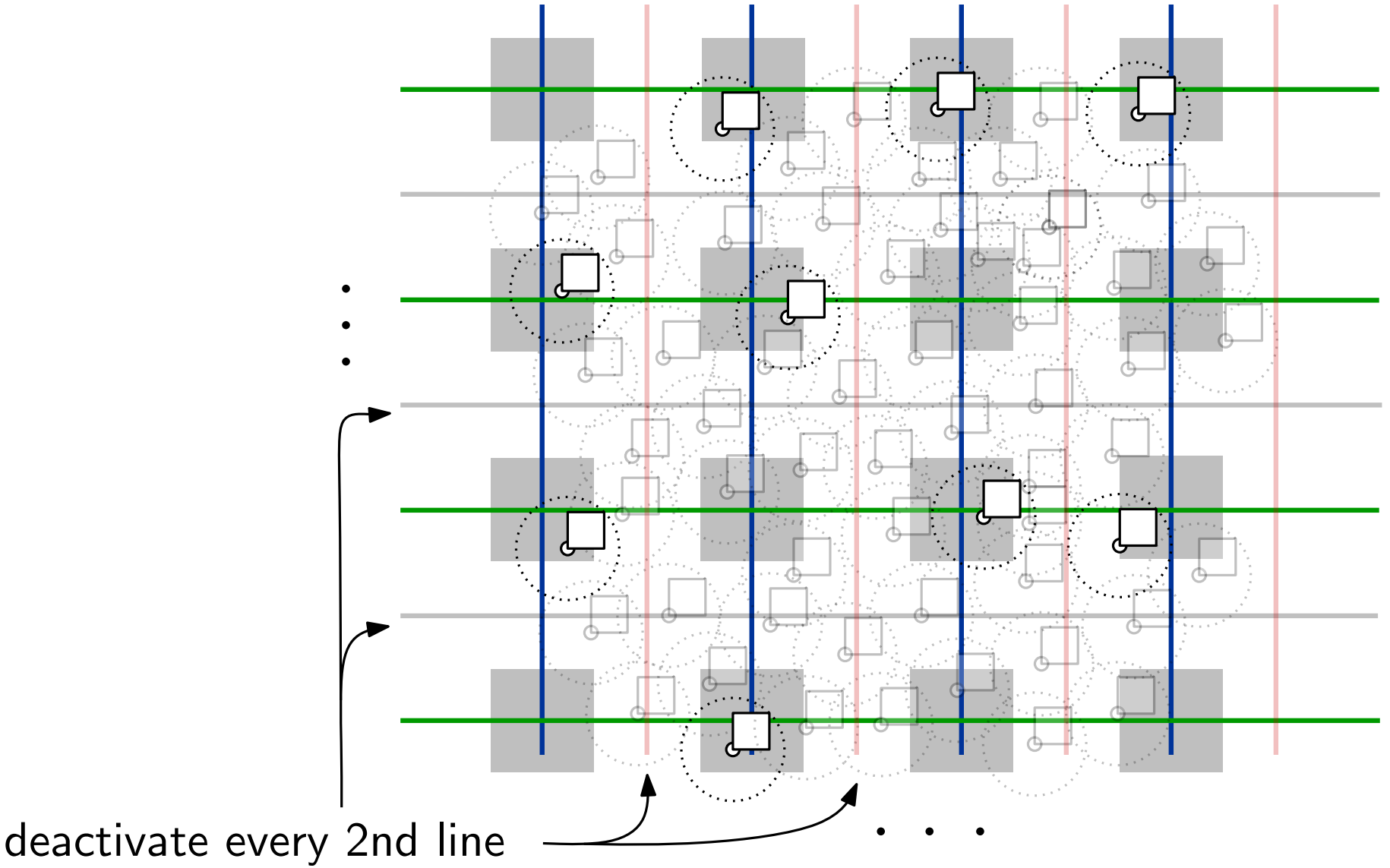

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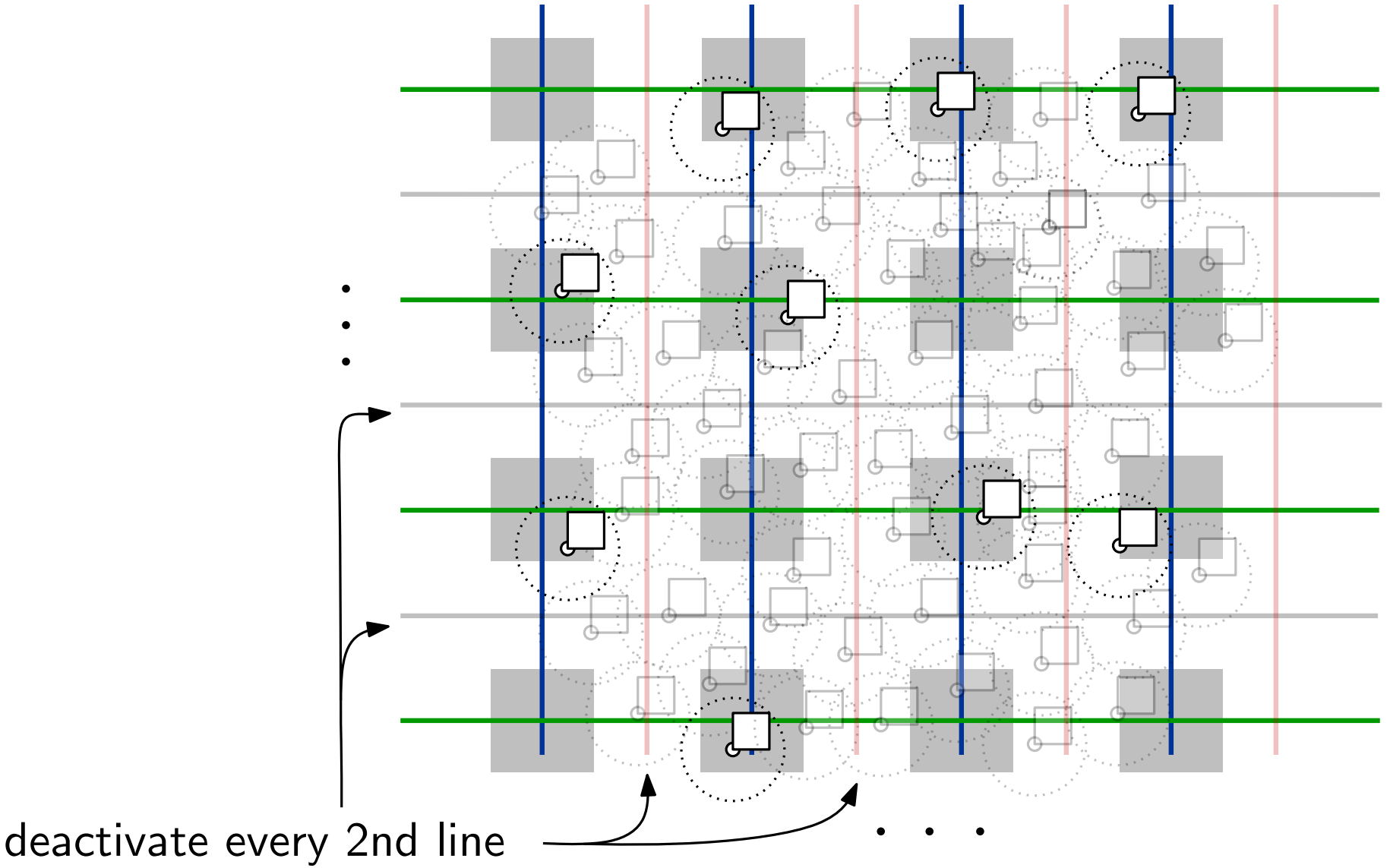

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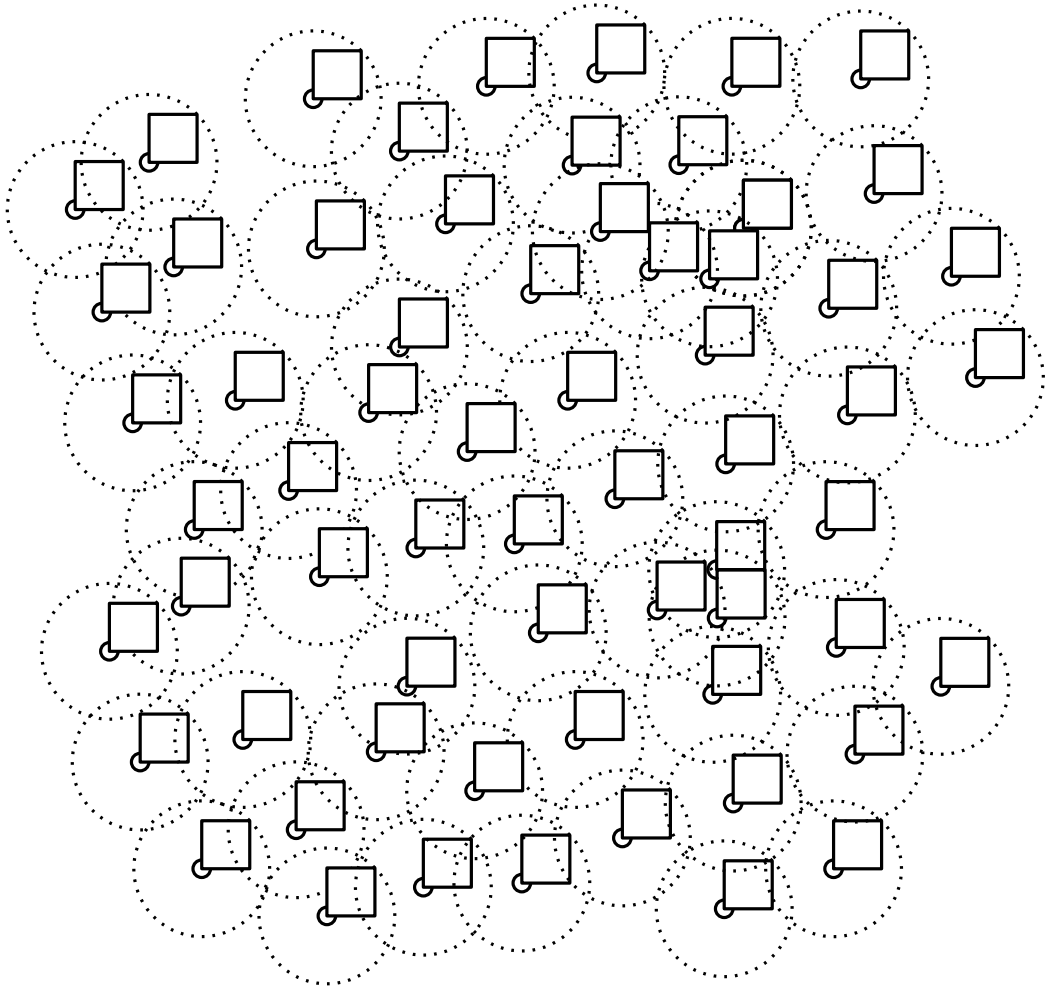

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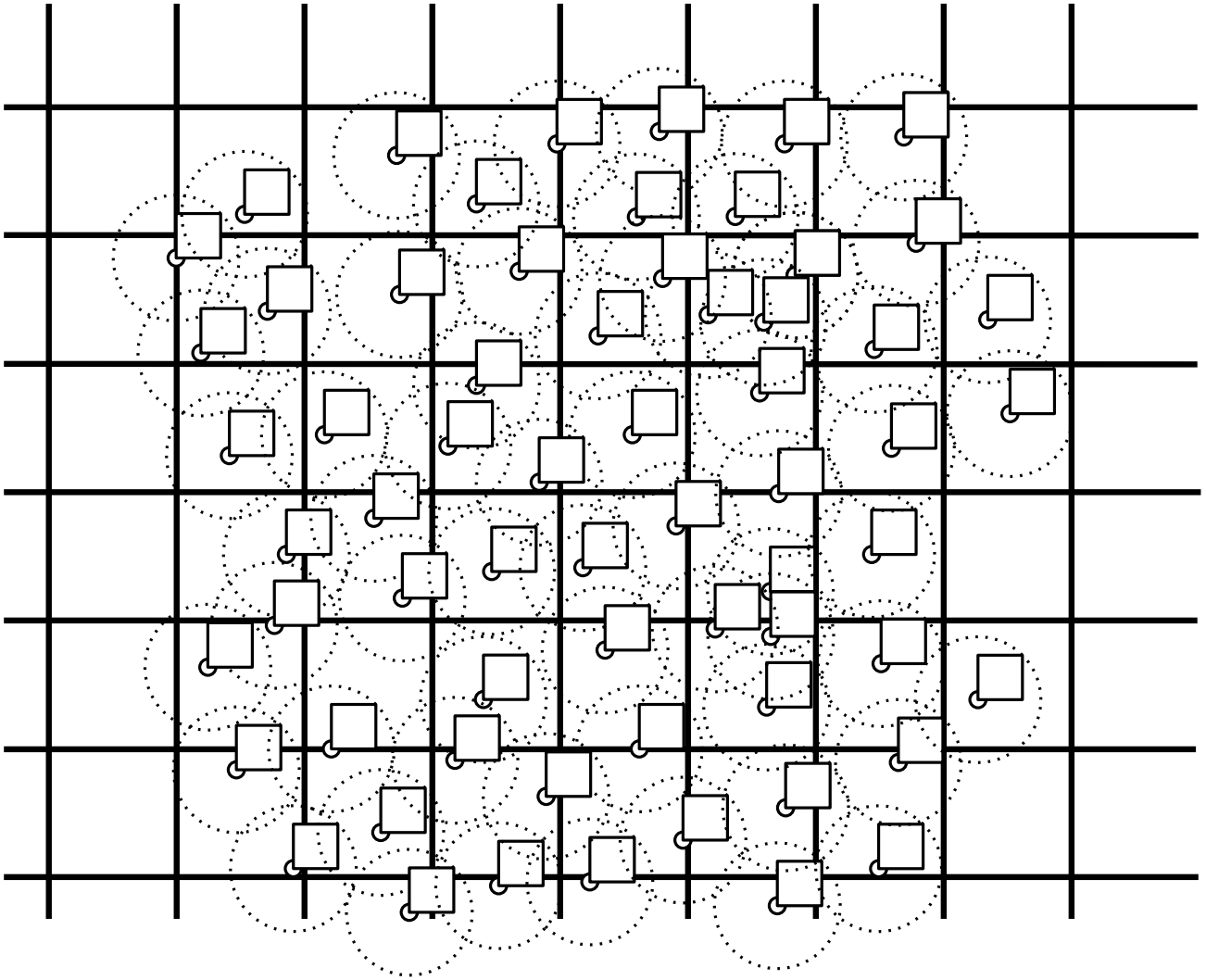

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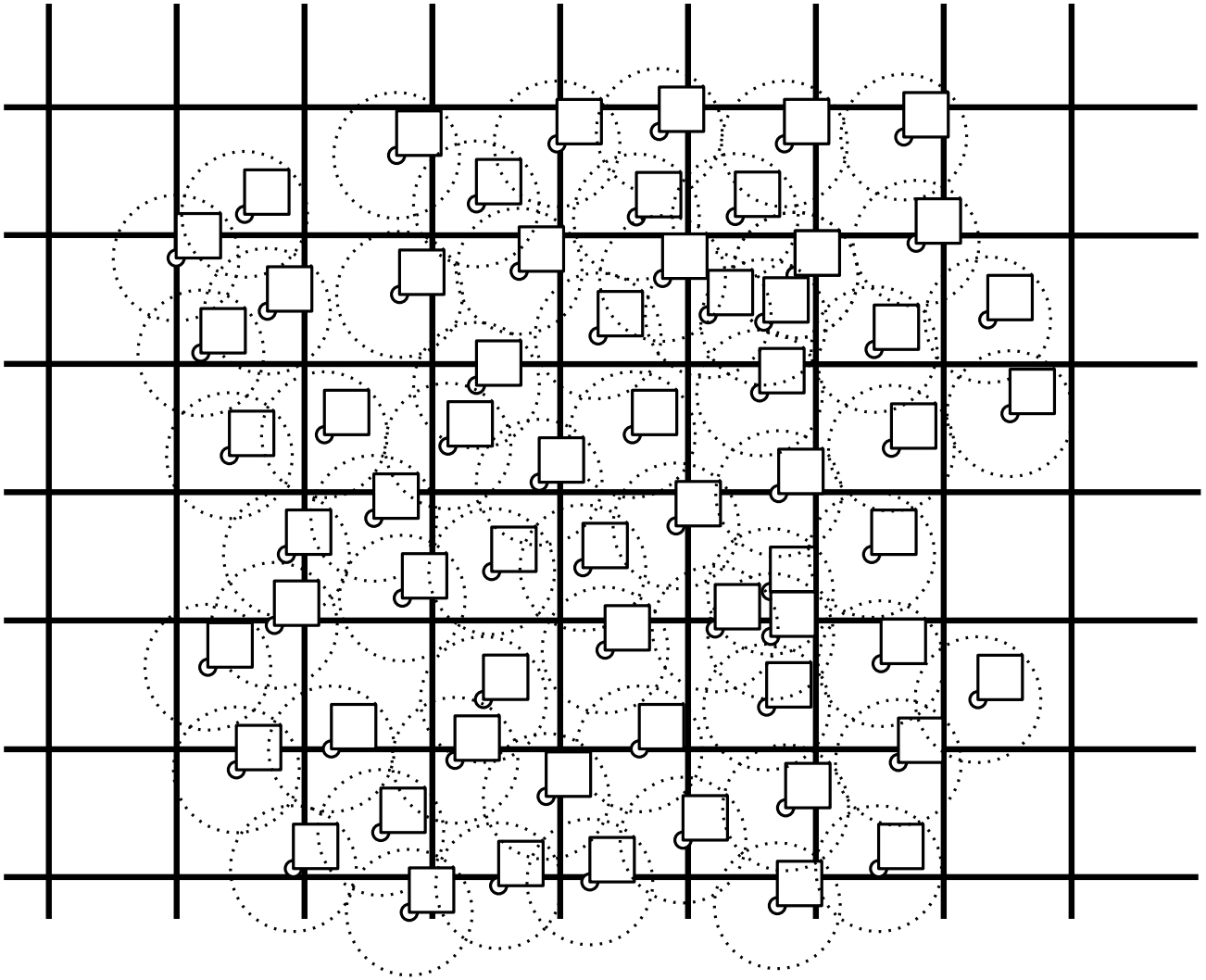

deactivate every k–th line

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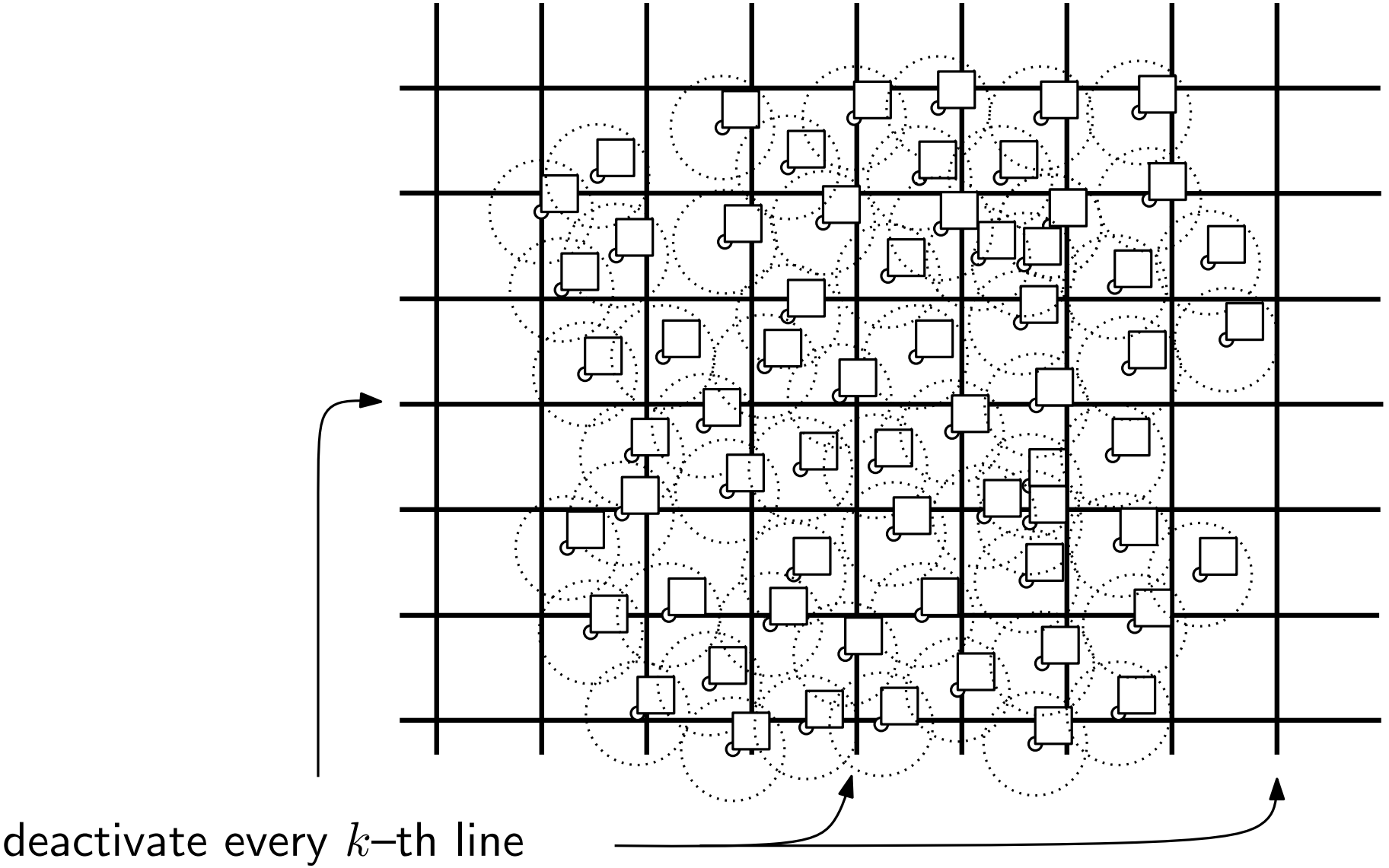

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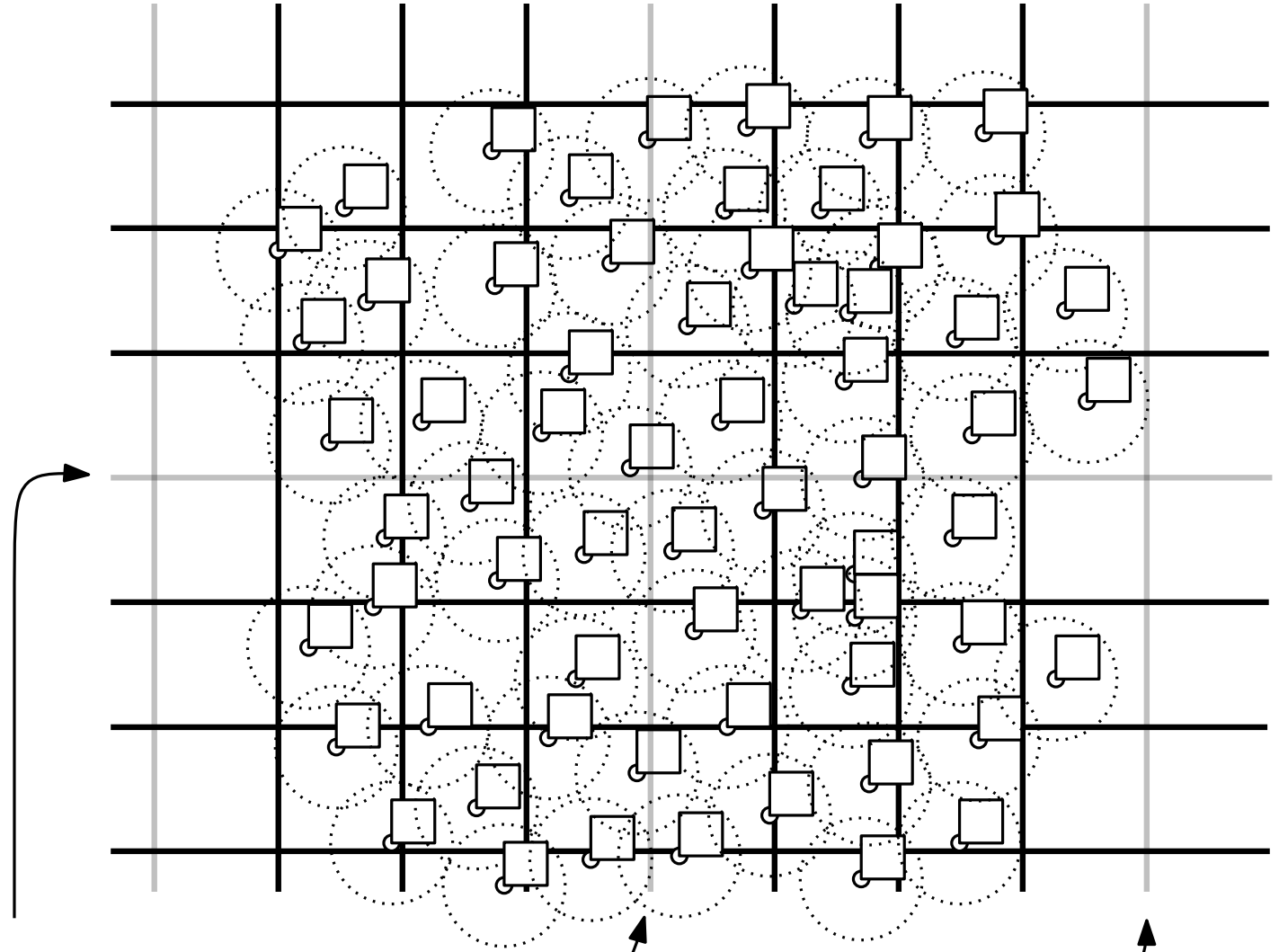

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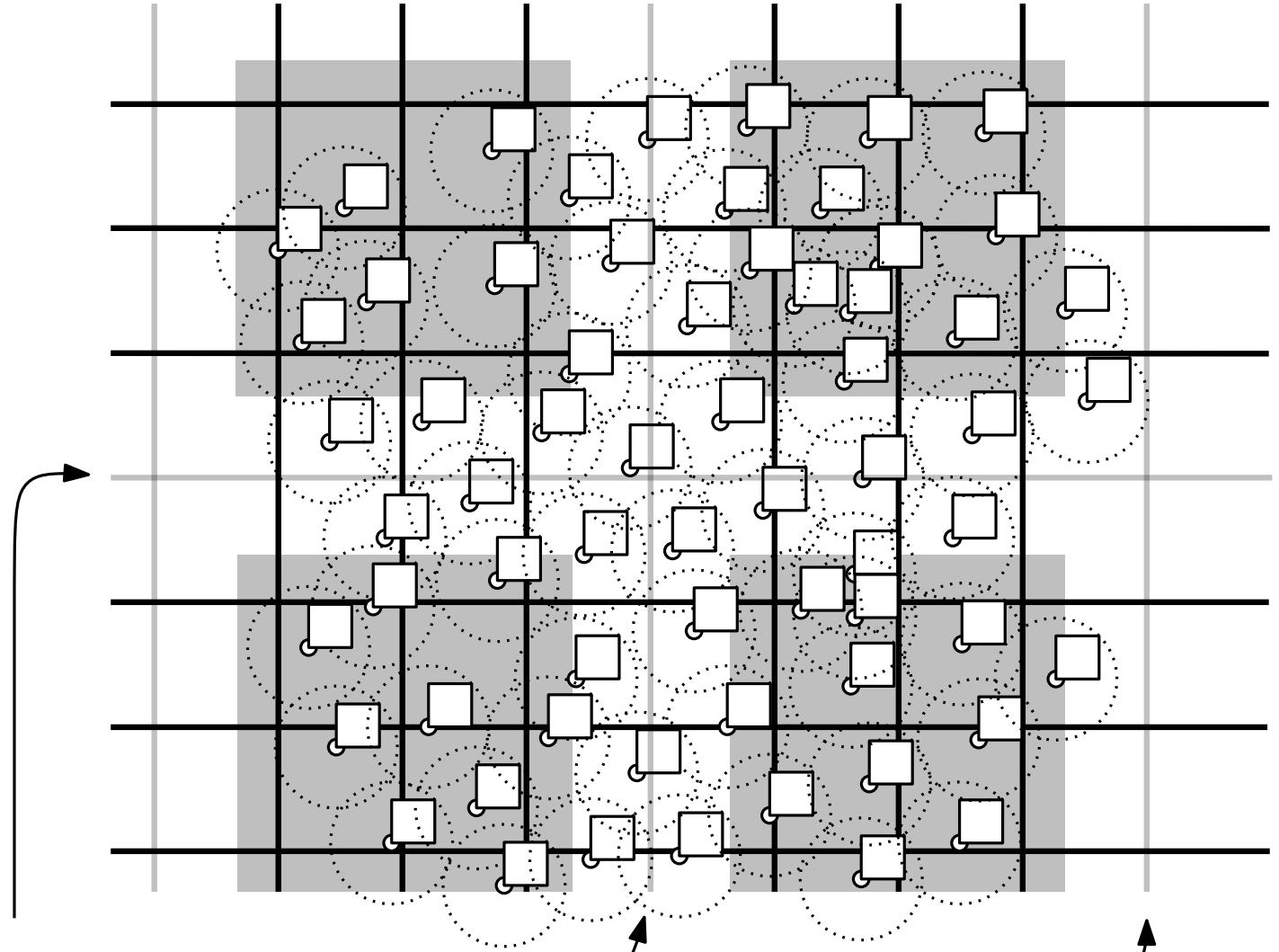

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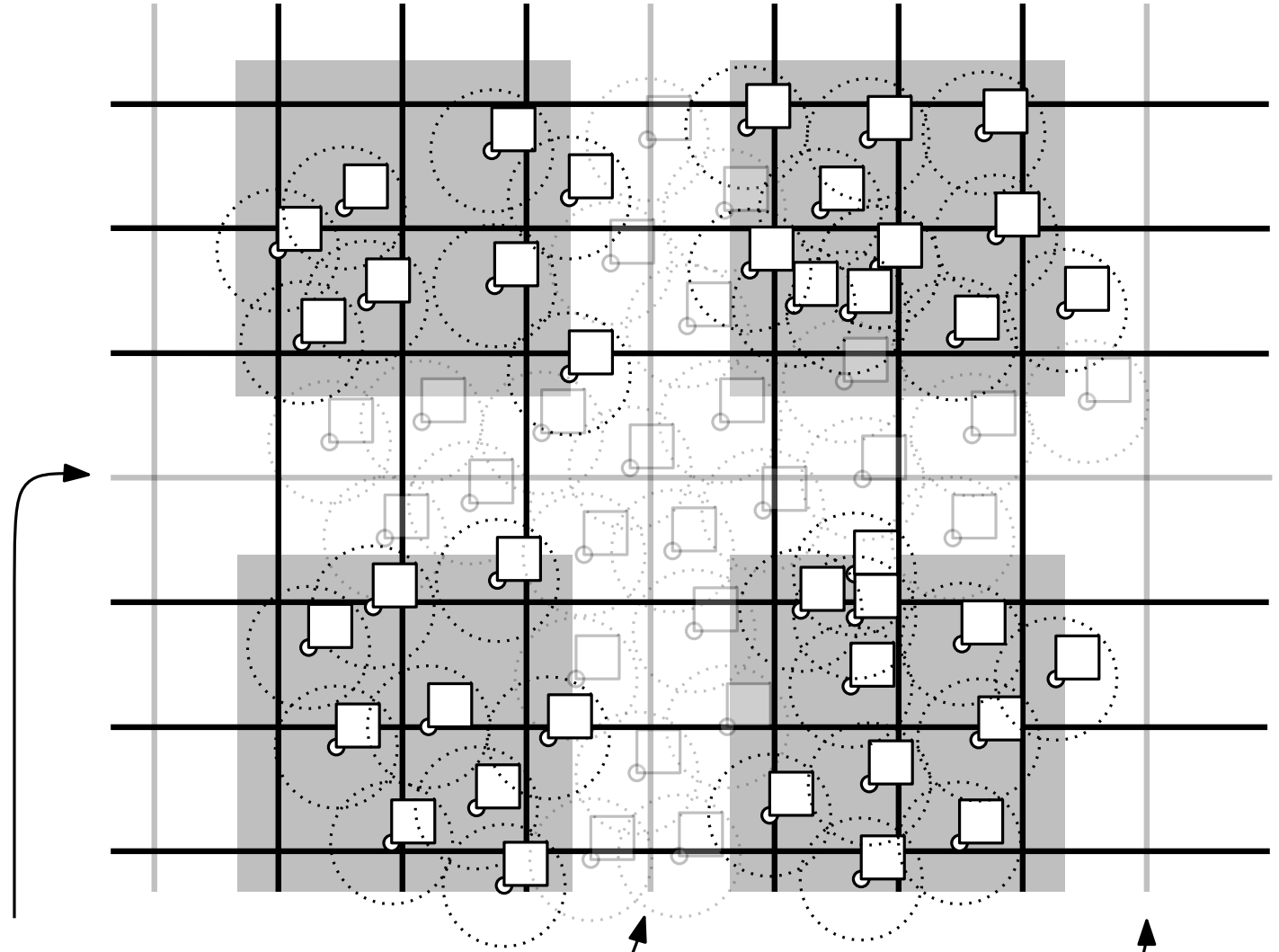

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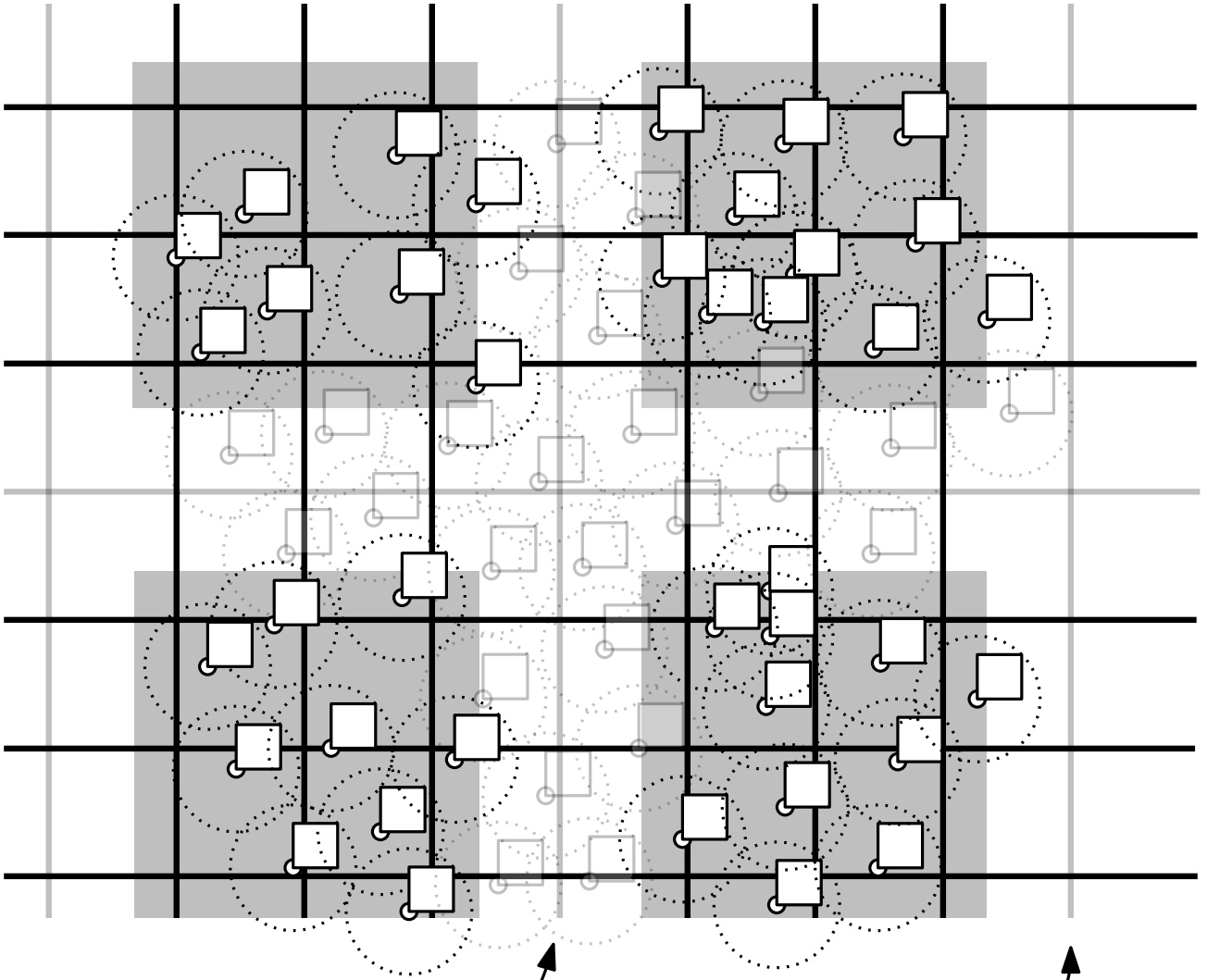
An EPTAS for MaxTotal

use the same principle as before

- there are k^2 possible combinations
- yielding k^2 sets $S_1, \ldots, S_{k^2}$
- for $k = \lceil 2/\varepsilon \rceil$ one combination yields a $(1-\varepsilon)$–approximation



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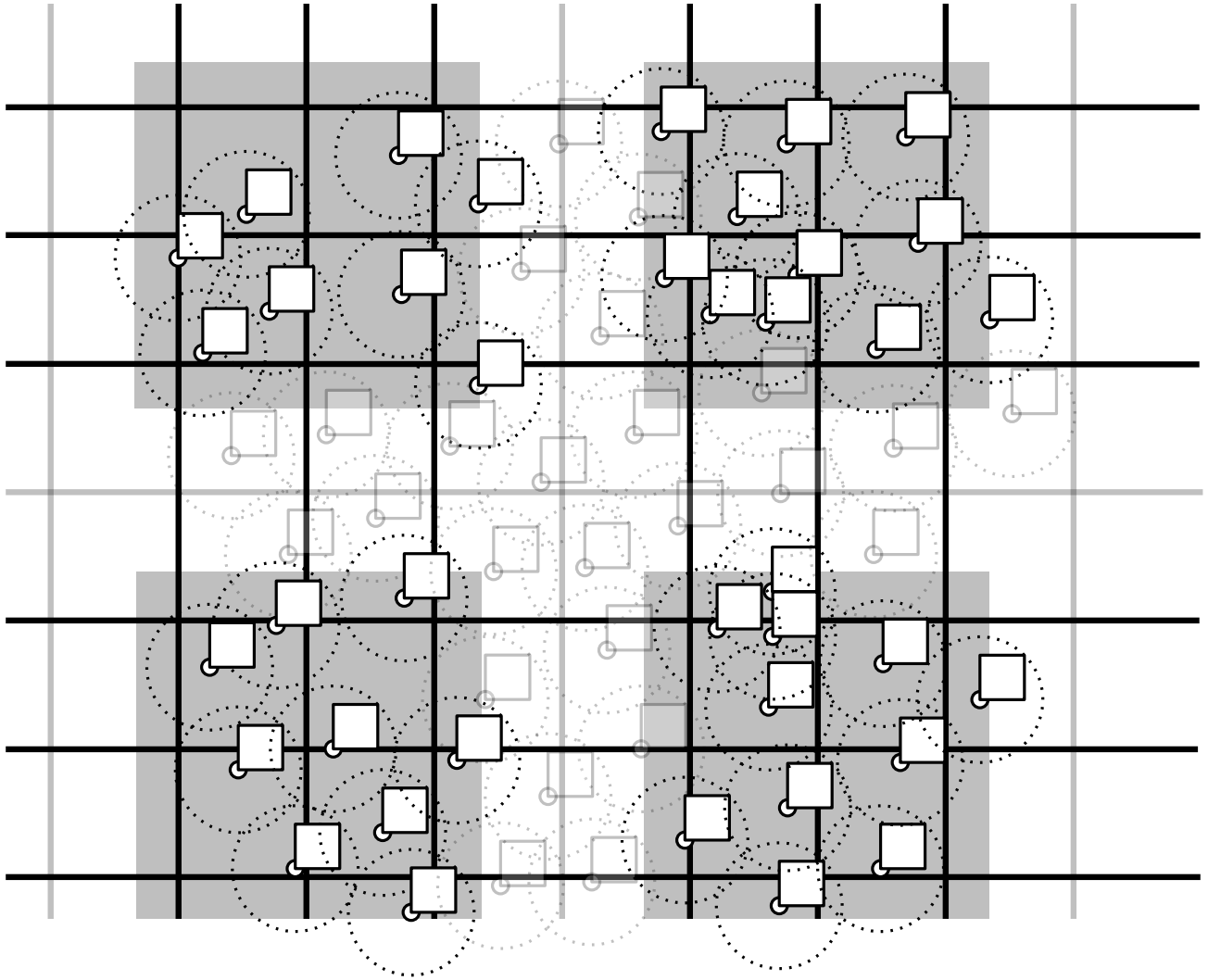

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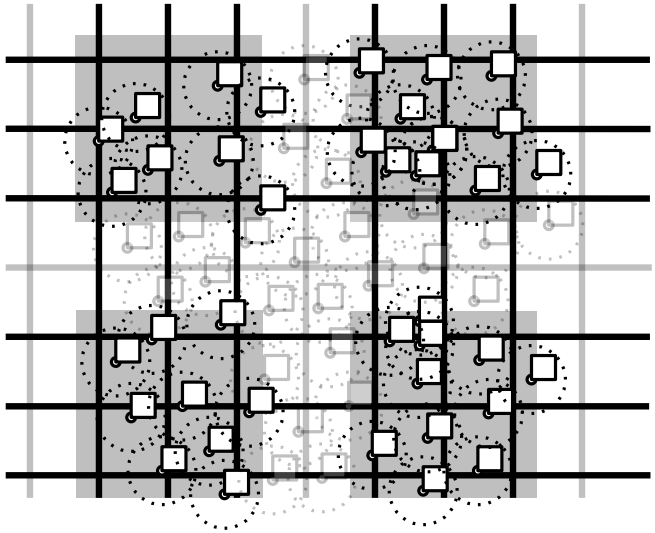


Lemma

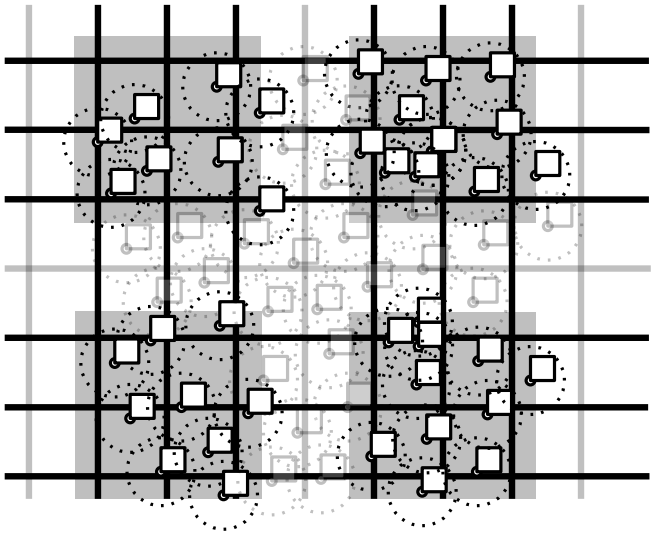
There exists a set S_i, $1 \leq i \leq k^2$ for which $\mathrm{OPT}(S_i) \leq (1 - 1/k)^2 \cdot \mathrm{OPT}$

$k = \lceil 2/\varepsilon \rceil$

OPT: value of optimal solution

OPT(S): optimal solution for set S

L: set of all labels of the instance



V_r: Labels hit by a **vertical** line with line number mod $k = r$

H_r: Labels hit by a **horizontal** line with line number mod $k = r$

Lemma

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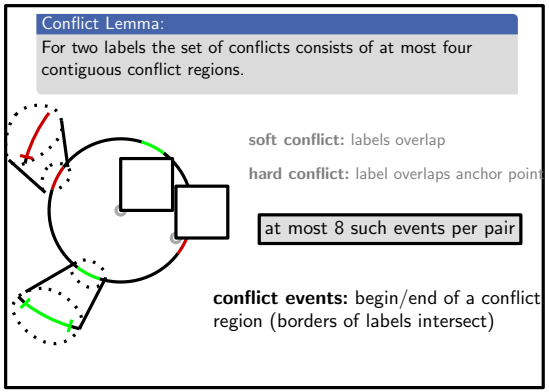
An EPTAS for MaxTotal



(i) number of labels inside square: $\mathcal{O}(1/\varepsilon^2)$

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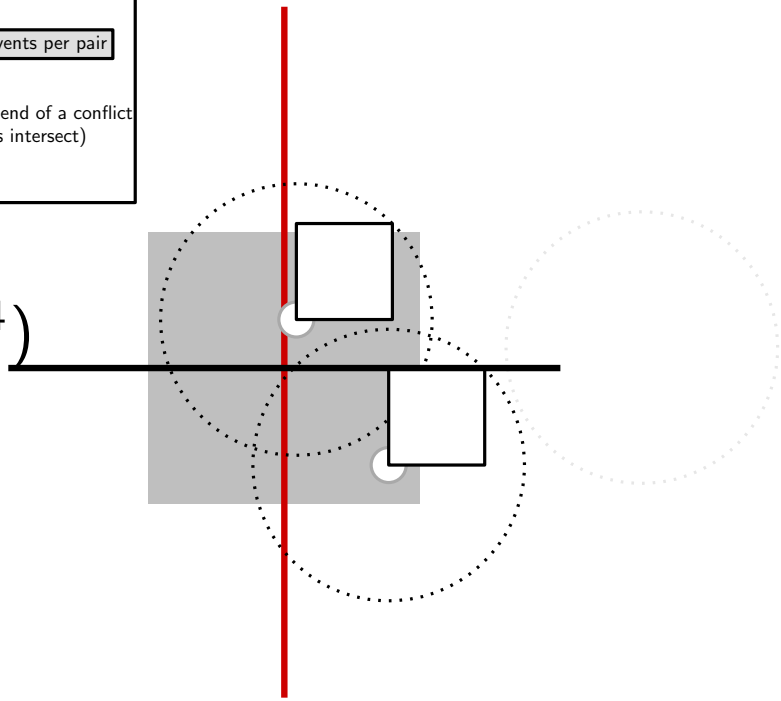
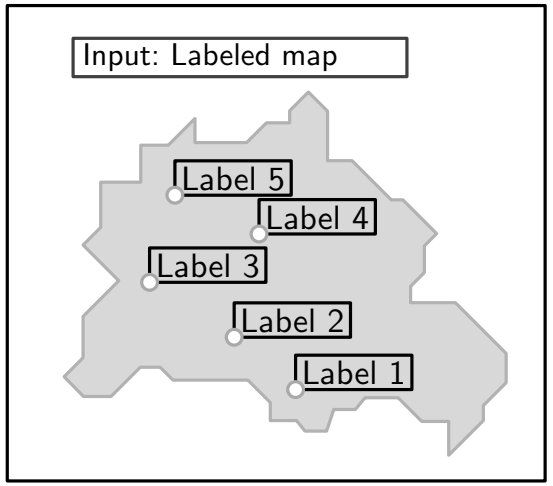
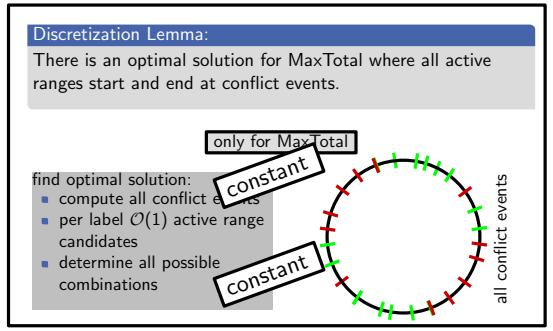




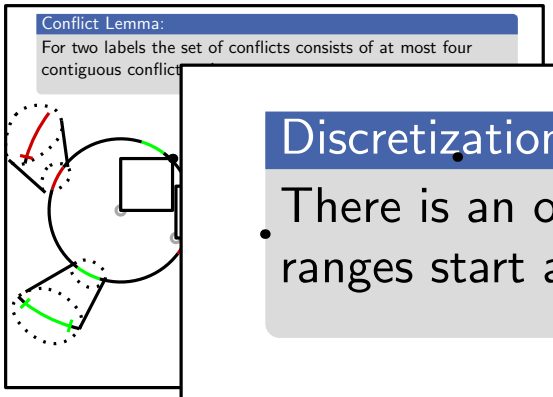


Theorem 3

There exists a $(1-\varepsilon)$–approximation for MaxTotal.

Time complexity $O((n \cdot 2^{O(1/\varepsilon^2 \log 1/\varepsilon^8)} + n \log n)/\varepsilon^2)$.

An EPTAS for MaxTotal



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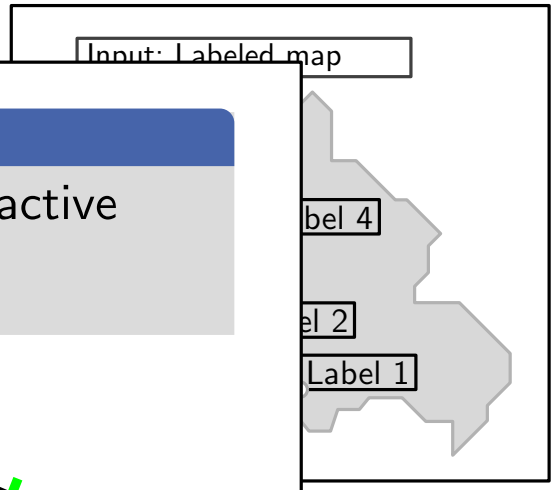

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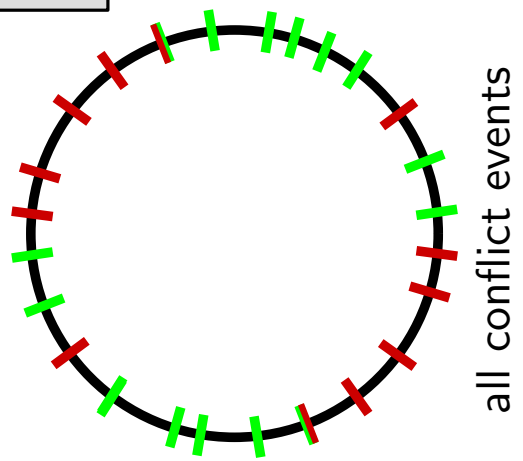

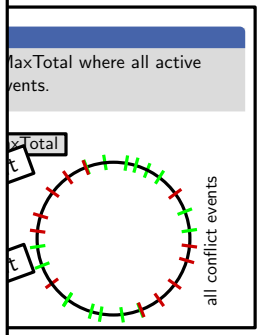

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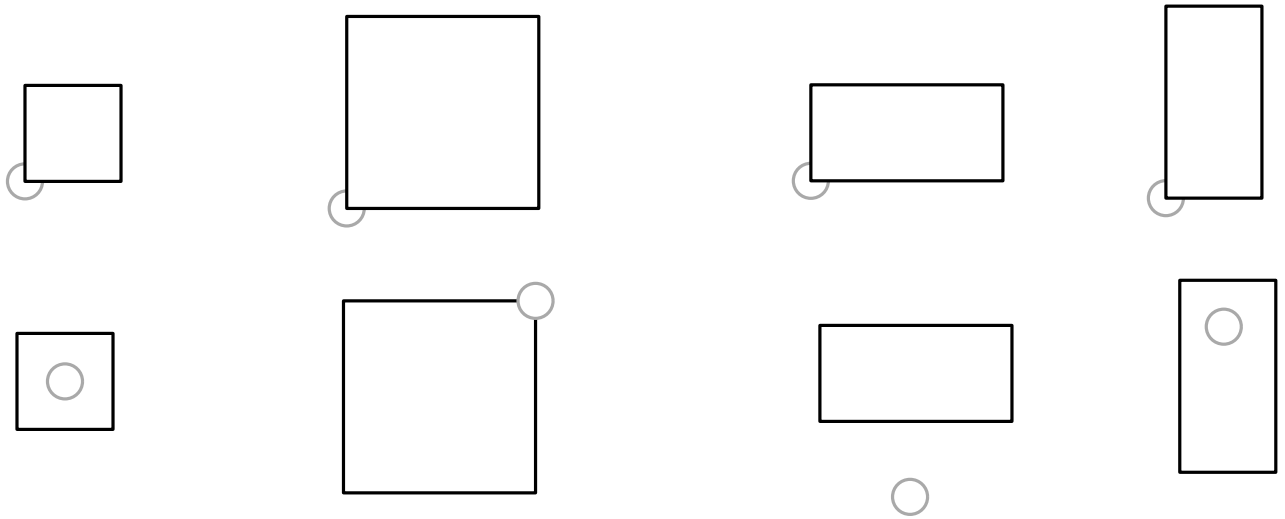
An EPTAS for MaxTotal

Our EPTAS can be extended to arbitrary* **label dimensions** and arbitrary relative **anchor positions**

- Key components Discretization and Conflict Lemma remain valid

shapes:

anchor point:



Theorem 3

There exists a $(1-\varepsilon)$–approximation for MaxTotal.
Time complexity $O((n \cdot 2^{O(1/\varepsilon^2 \log 1/\varepsilon^8)} + n \log n)/\varepsilon^2)$.

Summary I

Results:

- MaxTotal is NP-complete, MaxMin is NP-hard
- There is an EPTAS for MaxTotal
- EPTAS uses **line stabbing** (geometric problems)
- MaxMin is hard to approximate (within 3/4 opt)

Open Problems:

- Approximation algorithm for MaxMin?
- Simpler/Better algorithms for MaxTotal?

Did we actually solve the problem?