



MODELING WAITING BEHAVIOR AT TRAIN STATIONS WITH CELLULAR AUTOMATON

09.09.2020 | TOBIAS SCHRÖDTER

MOTIVATION

- Simulation to assess performance of train stations during planning phase.
- Dwell times of trains are an important factor of the performance of railway facilities.
- Distribution of pedestrians impacts the boarding time.

How do pedestrians move in waiting situations?

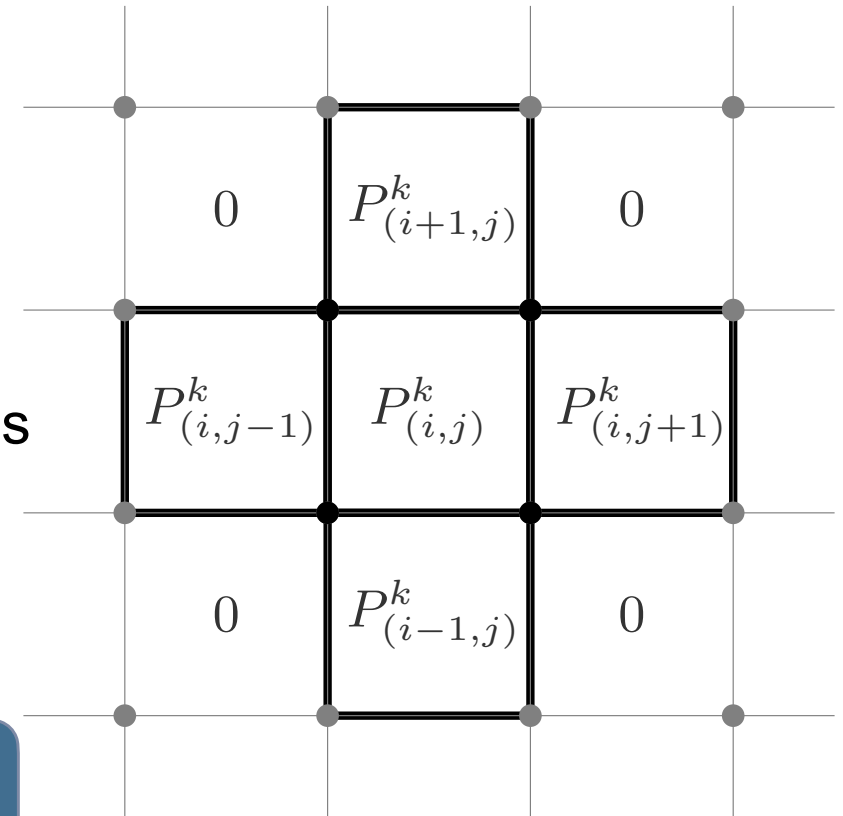


CELLULAR AUTOMATA

Basic idea:

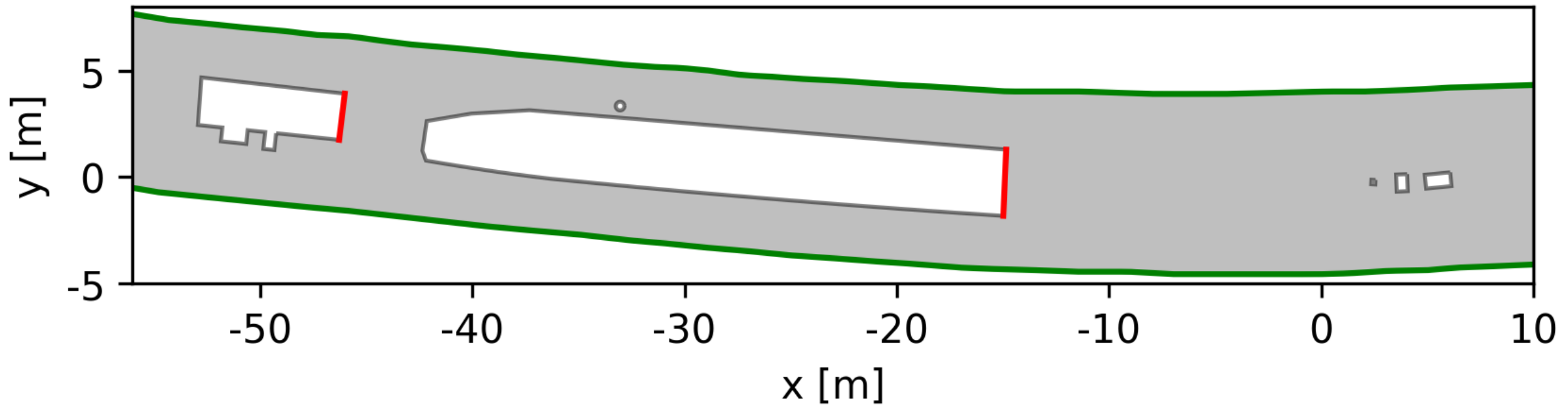
- Space is discretized into cells of 0.5m x 0.5m.
- At each time step pedestrian can move to unoccupied neighbor cells with a transition probability.
- Based on transition probabilities chose one of the cells as target.

Compute transition probability based on potential fields.



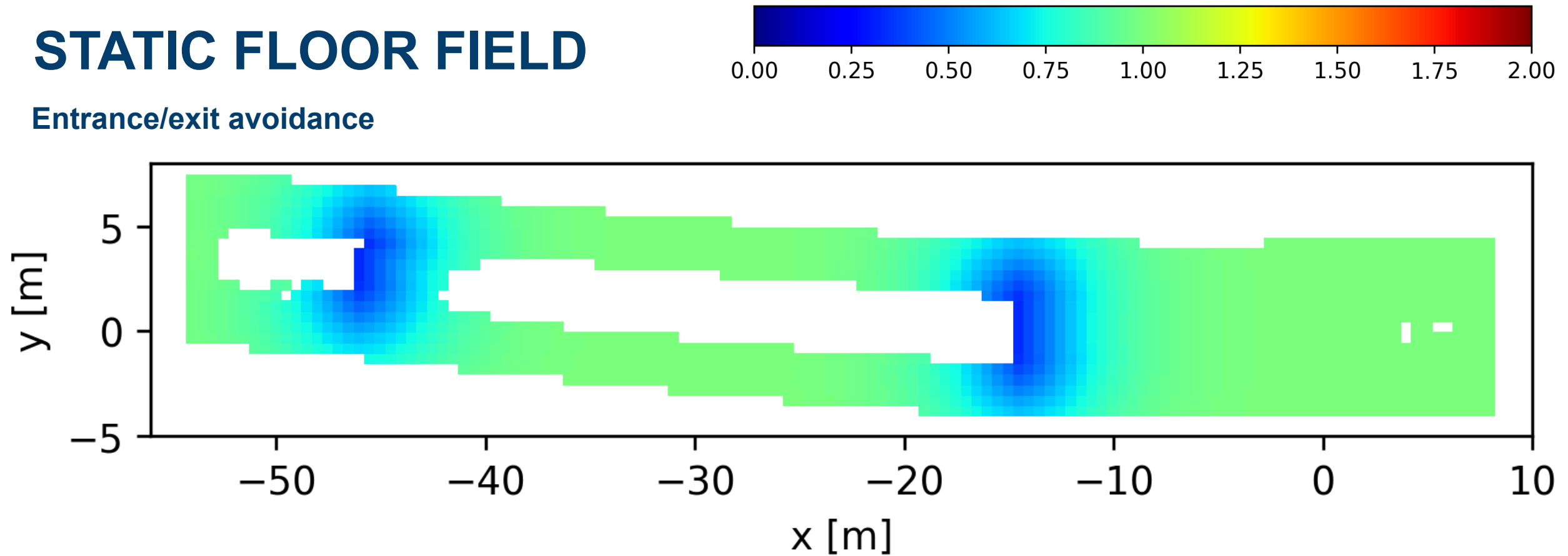
STATIC FLOOR FIELDS

Geometry: Bern, Switzerland



STATIC FLOOR FIELD

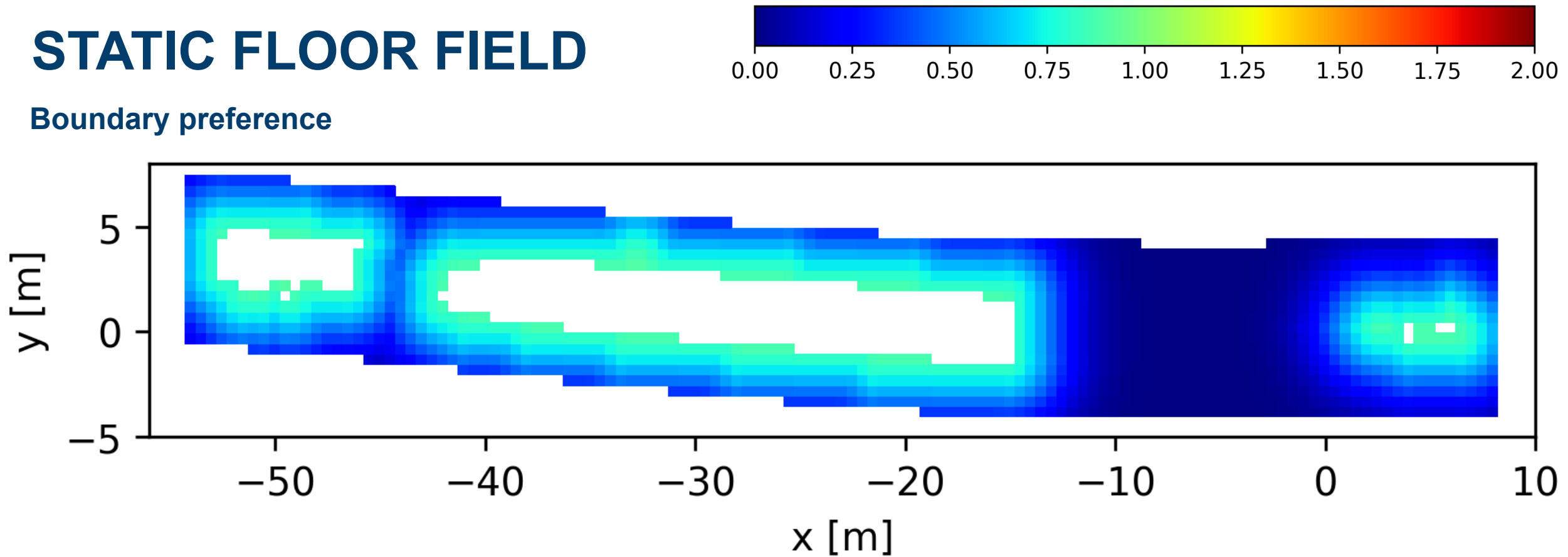
Entrance/exit avoidance



$$E_{i,j} = \left[1 + \exp^{-a_e(d_e - b_e)} \right]^{-1}$$

STATIC FLOOR FIELD

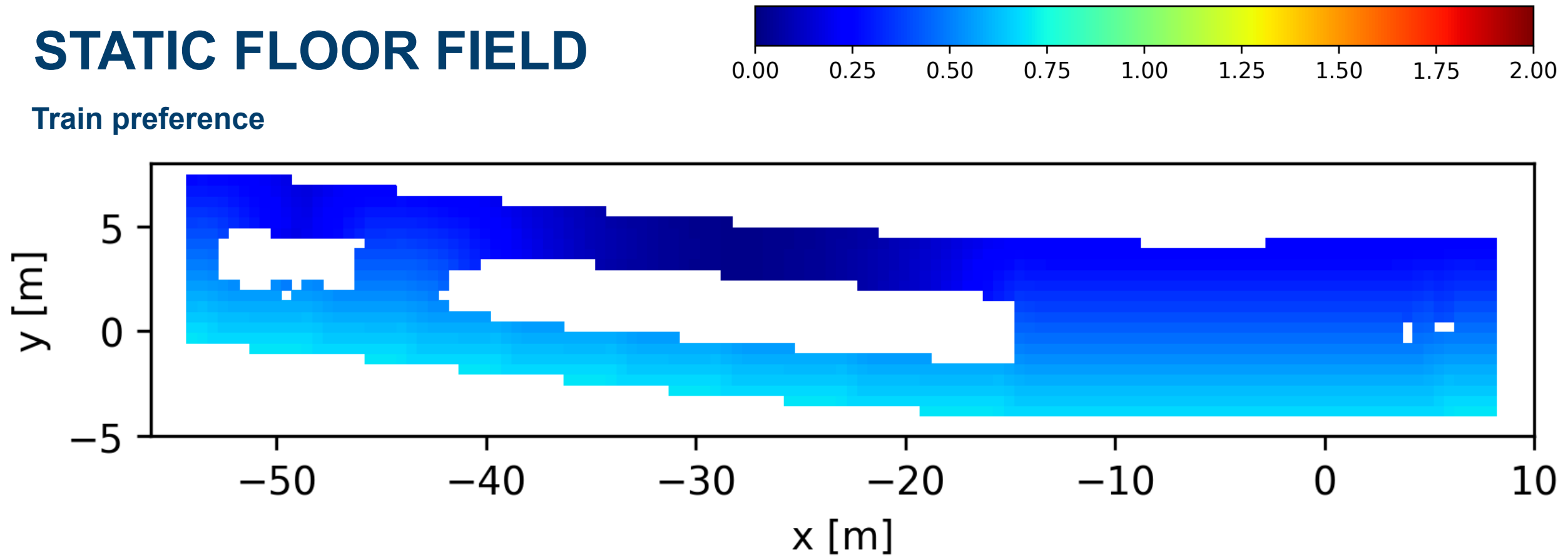
Boundary preference



$$B_{i,j} = 1 - \left[1 + \exp^{-a_b(d_b - b_b)} \right]^{-1}$$

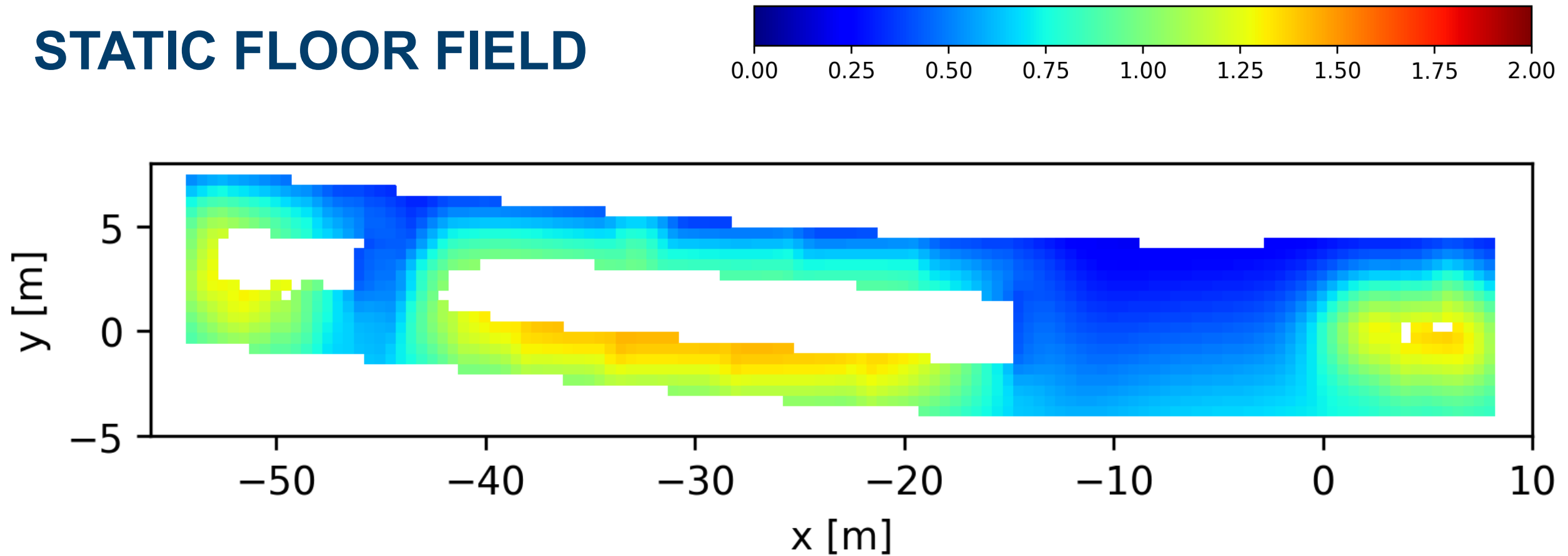
STATIC FLOOR FIELD

Train preference



$$T_{i,j} = 1 - \left[1 + \exp^{-a_t(d_t - b_t)} \right]^{-1},$$

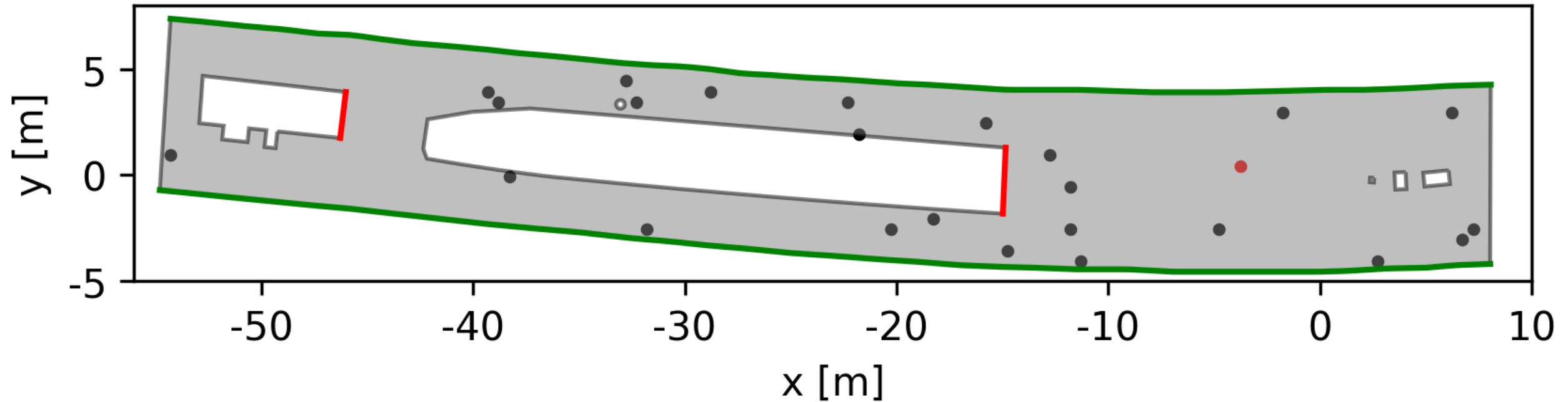
STATIC FLOOR FIELD



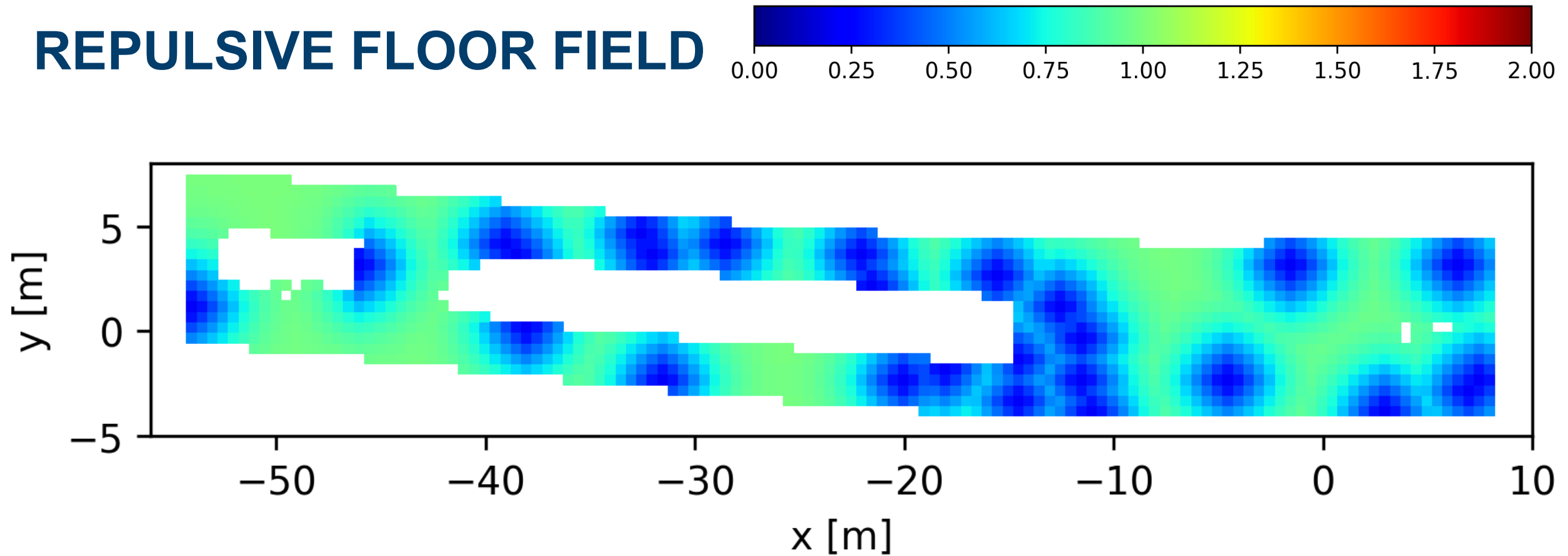
$$S_{i,j} = E_{i,j} \cdot \left[w_b \cdot B_{i,j} + w_t \cdot T_{i,j} \right]$$

DYNAMIC FLOOR FIELDS

Geometry: Bern, Switzerland with pedestrians



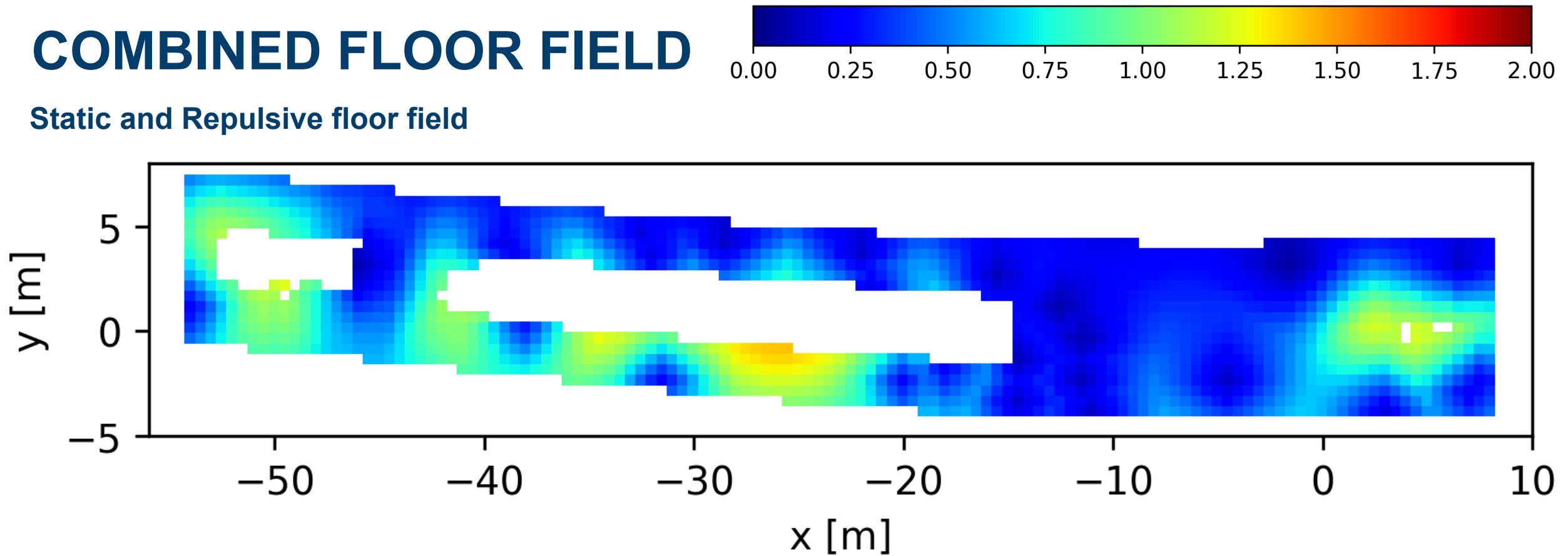
REPULSIVE FLOOR FIELD



$$R_{i,j}^k = \left[1 + \exp^{-a_r(d_{i,j}^k - b_r)} \right]^{-1}$$

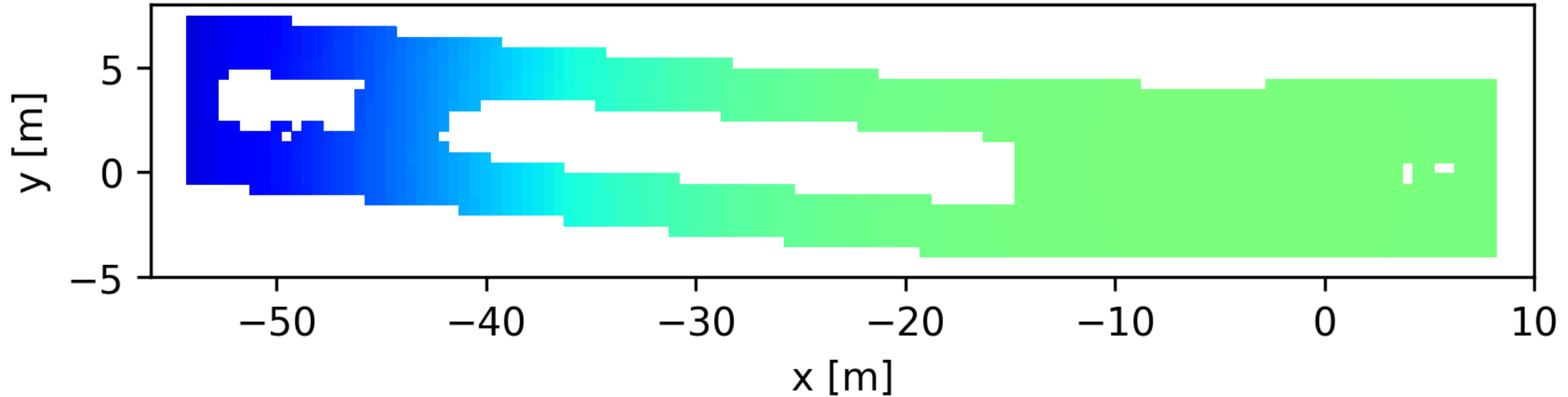
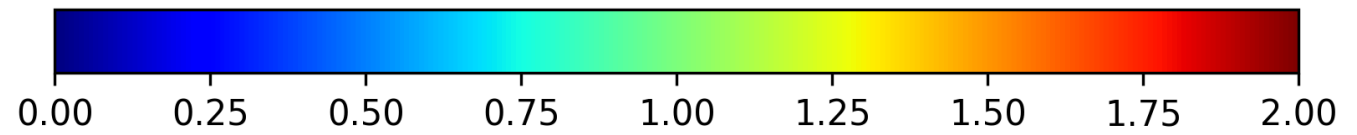
COMBINED FLOOR FIELD

Static and Repulsive floor field



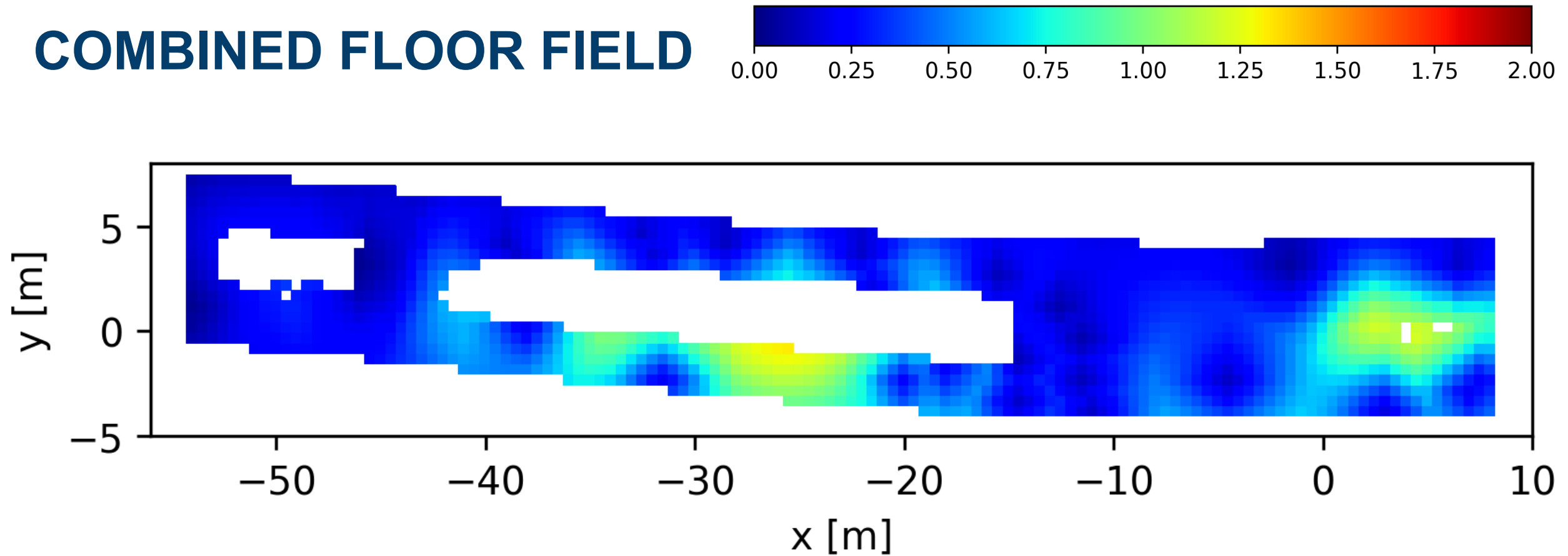
$$S_{i,j} \cdot R_{i,j}^k$$

DISTANCE FLOOR FIELD



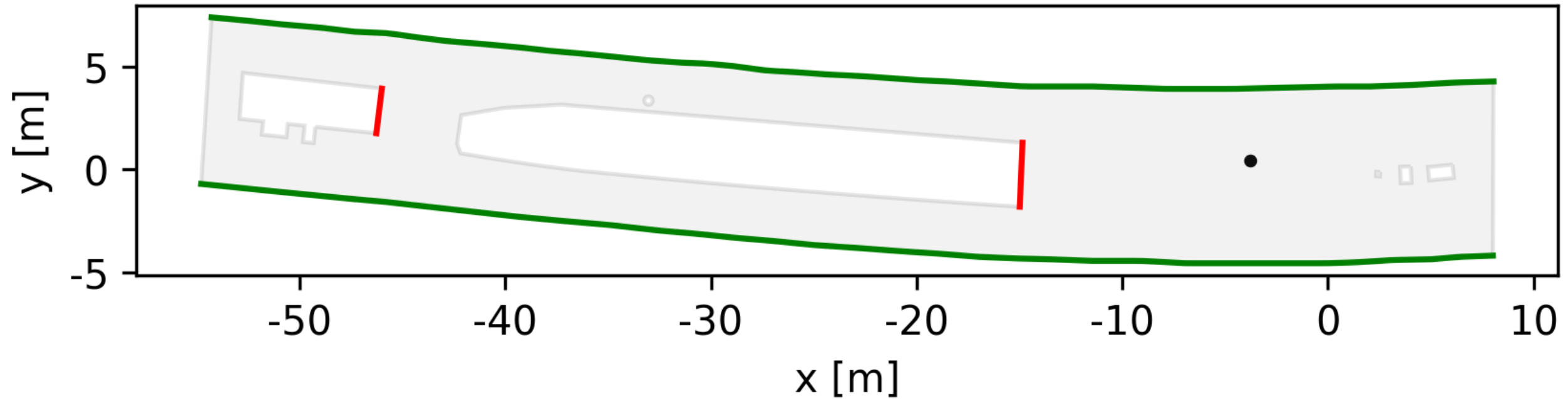
$$W_{i,j}^k = 1 - \left[1 + \exp^{-a_w(d_{i,j}^k - b_w)} \right]^{-1}$$

COMBINED FLOOR FIELD

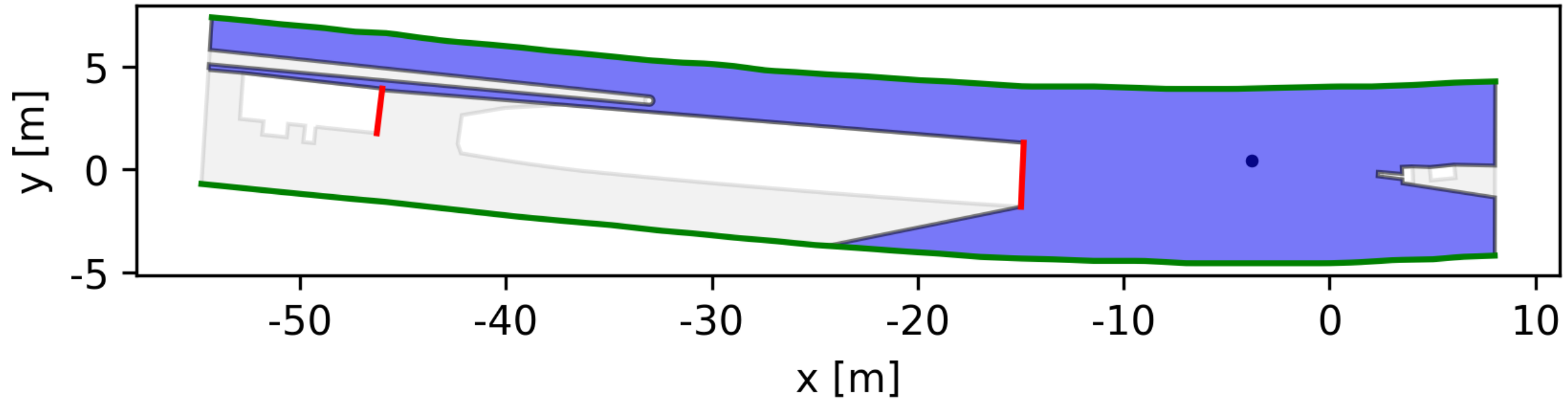


$$W_{i,j}^k \left[S_{i,j} \cdot R_{i,j}^k \right]$$

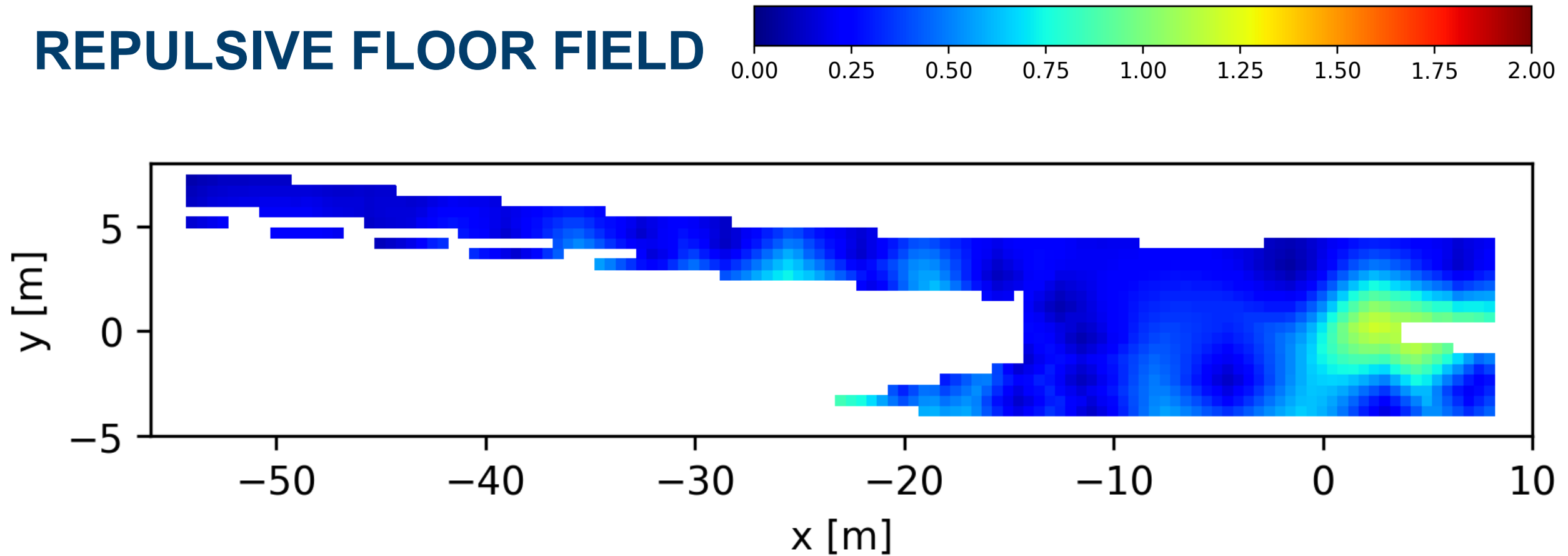
VISIBILITY CONSTRAINT



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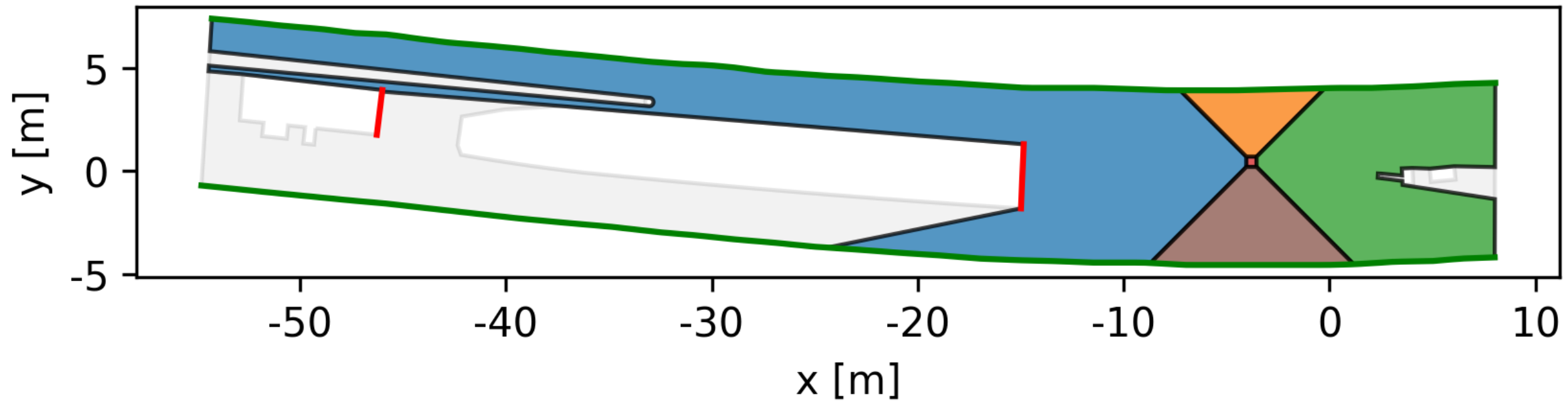
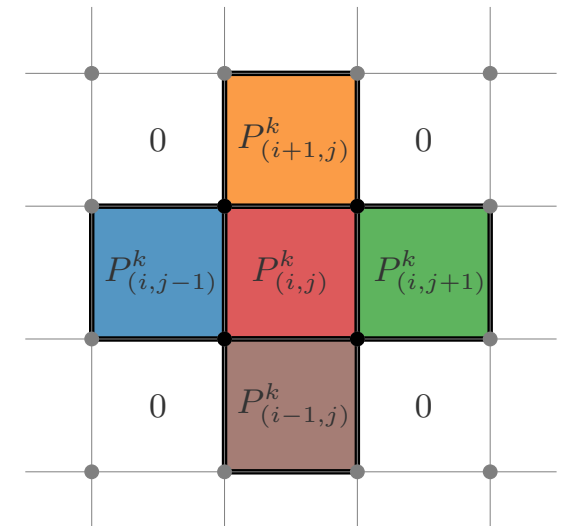


REPULSIVE FLOOR FIELD



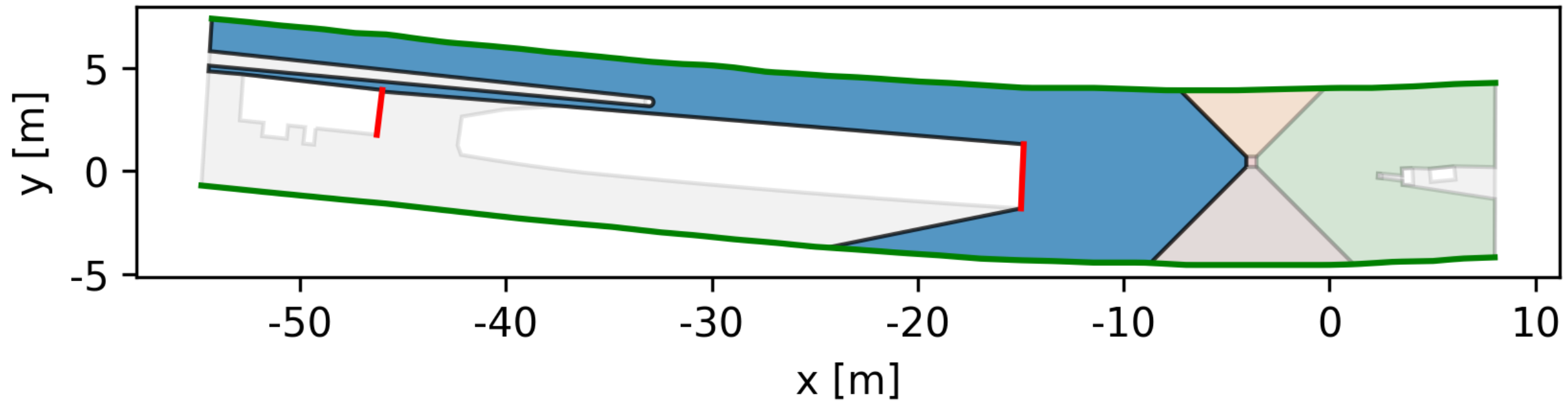
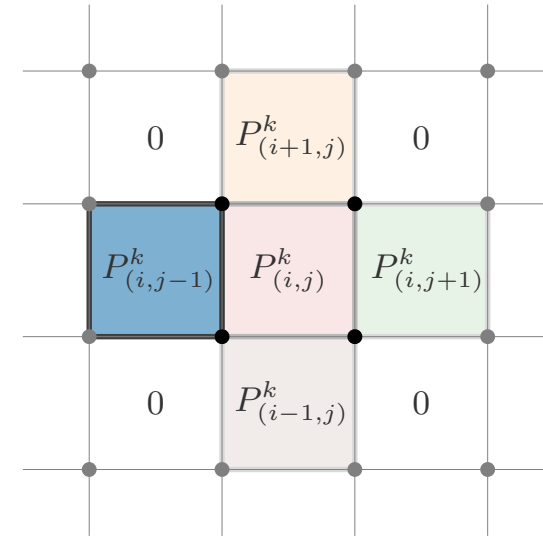
$$W_{i,j}^k \left[S_{i,j} \cdot R_{i,j}^k \right] \in V^k$$

VISIBILITY CONSTRAINT



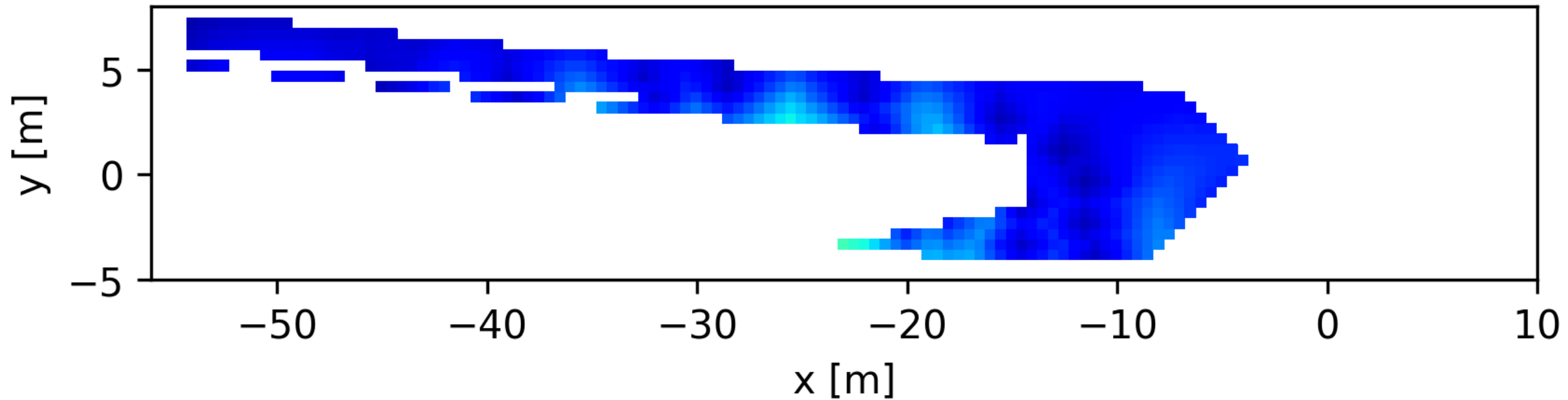
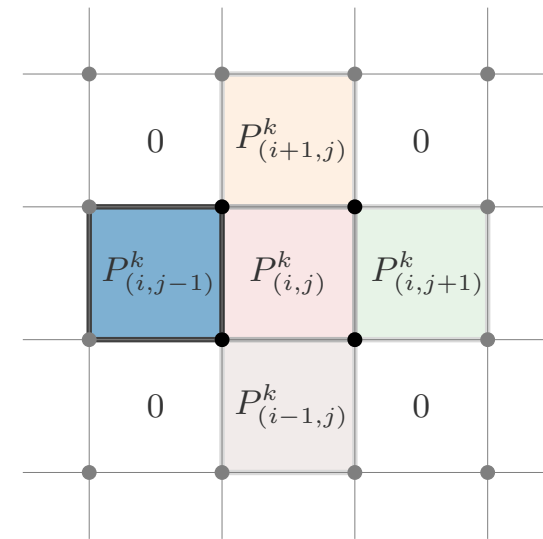
VISIBILITY CONSTRAINT

$$P_n^k = M \cdot \max_{i,j \in V^k \cap C_n} \left(W_{i,j}^k \left[S_{i,j} \cdot R_{i,j}^k \right] \right)$$



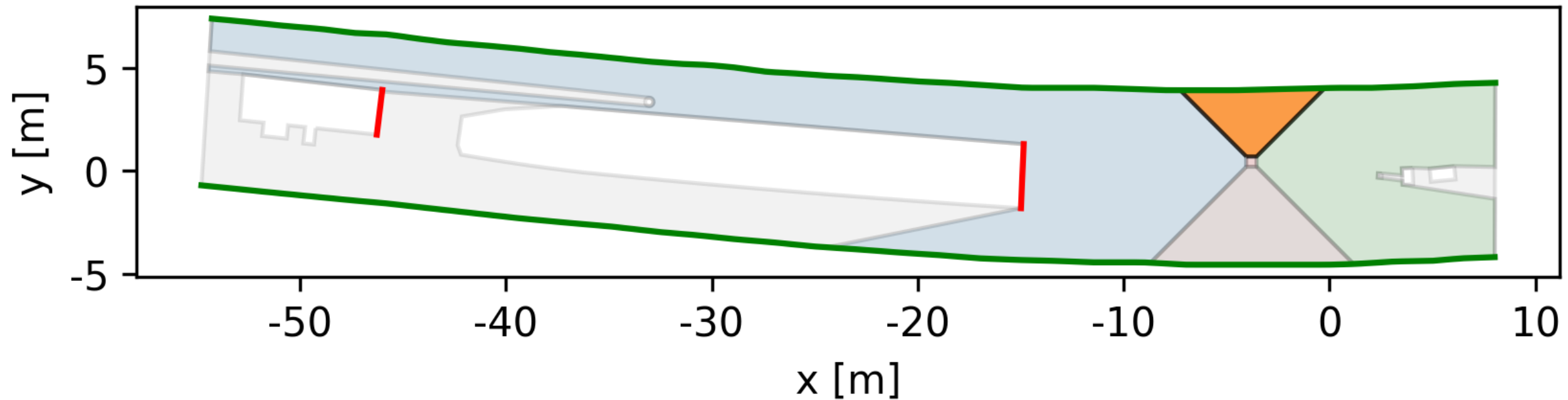
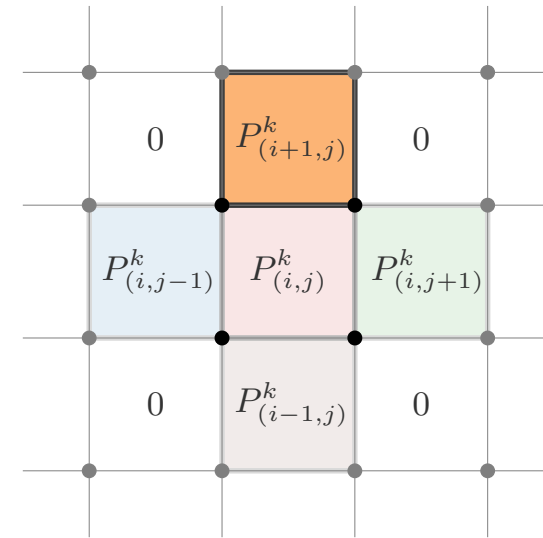
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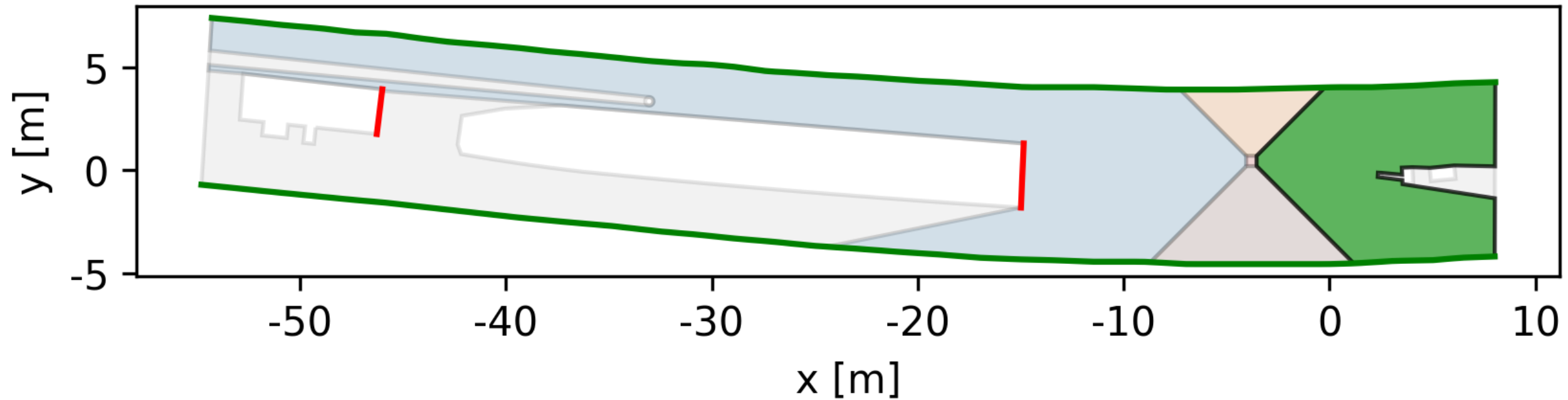
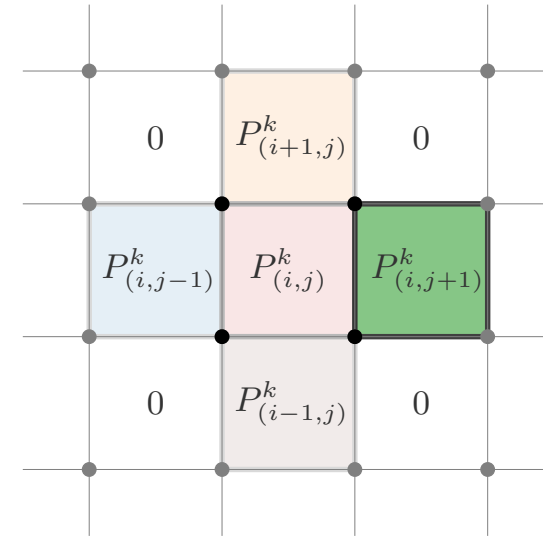
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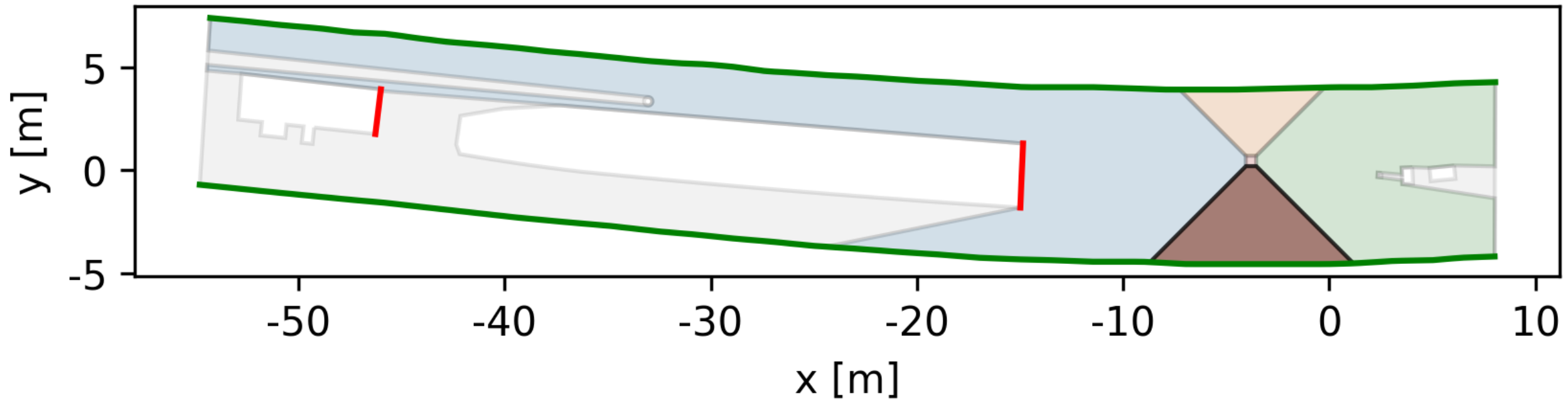
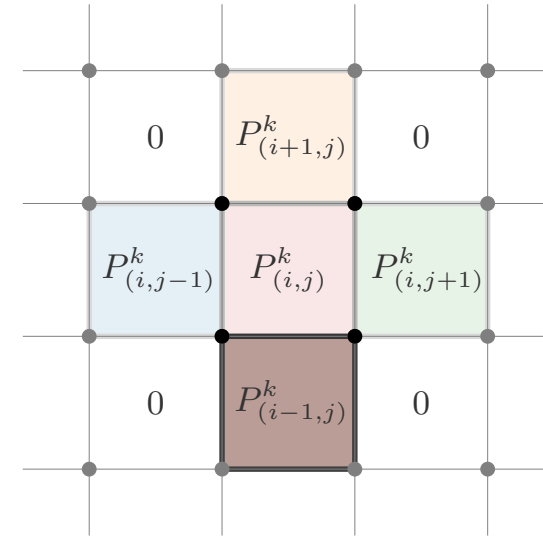
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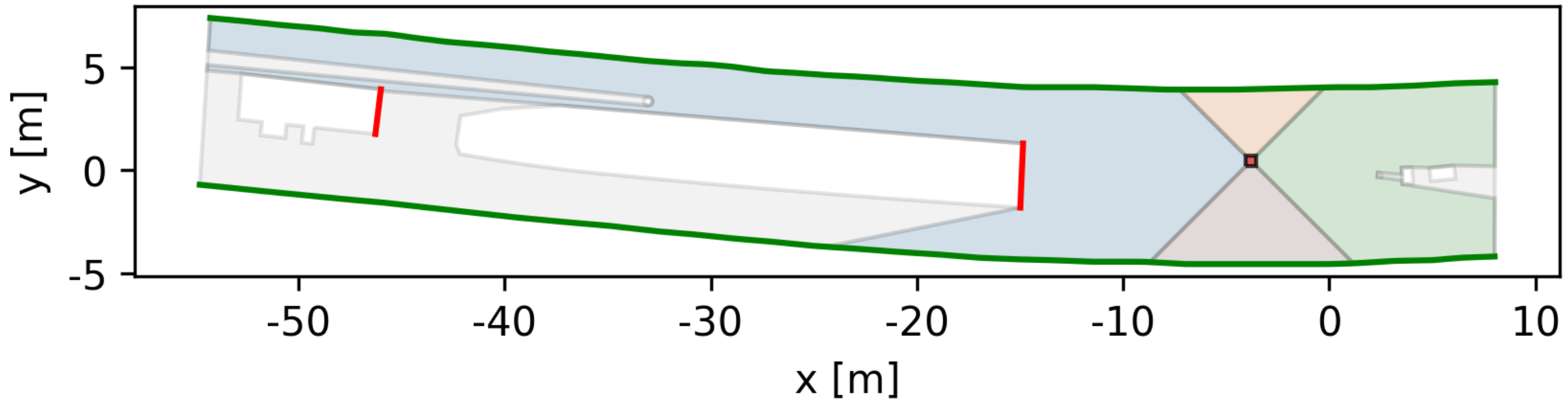
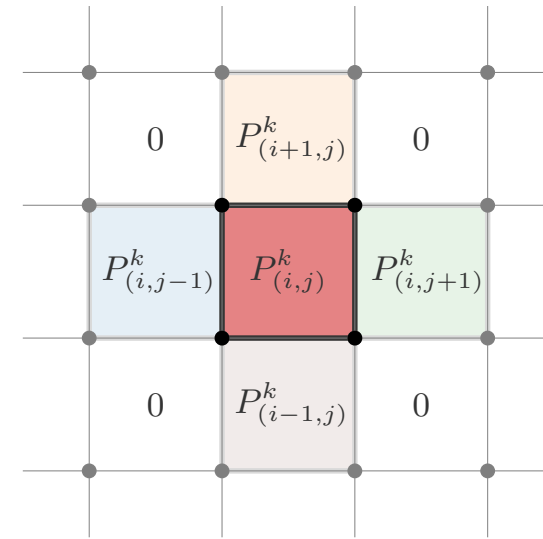
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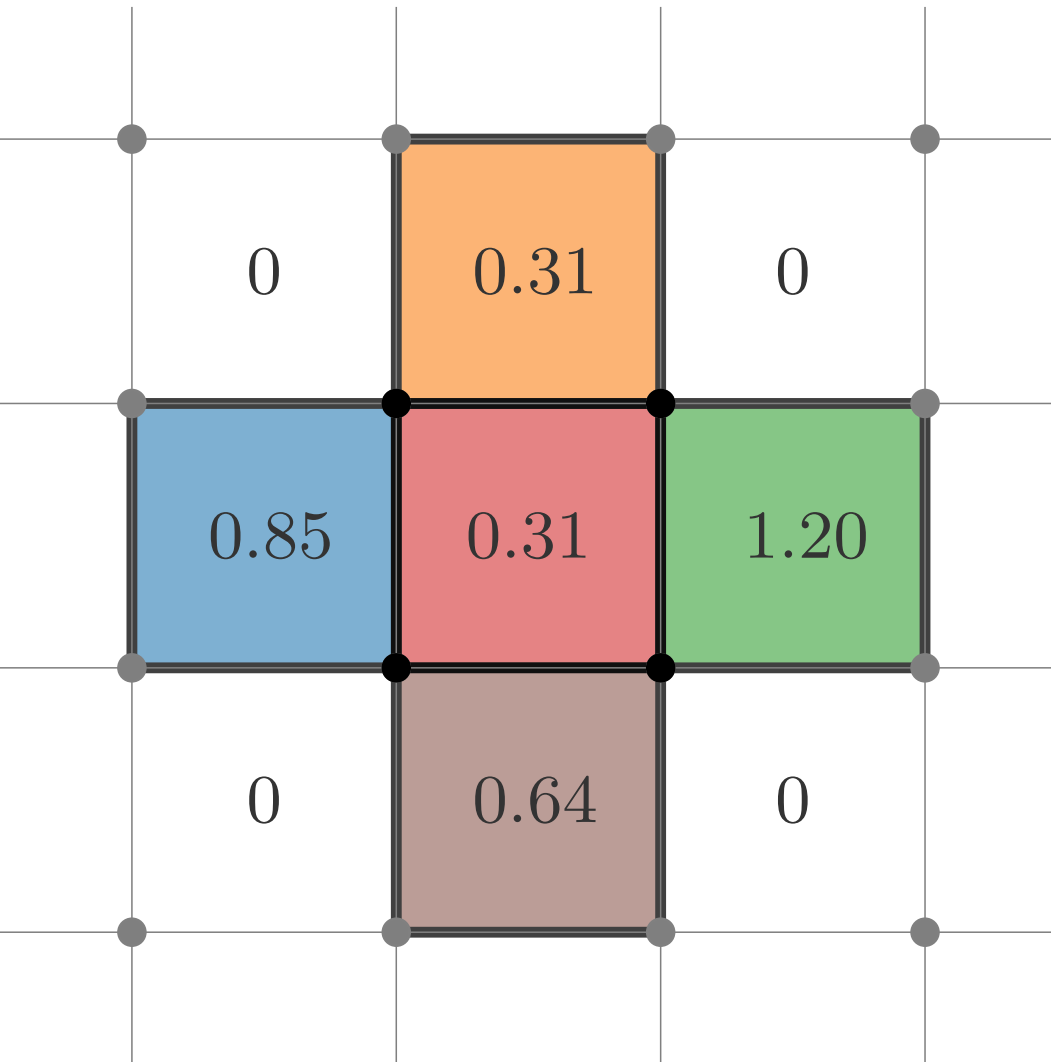


VISIBILITY CONSTRAINT

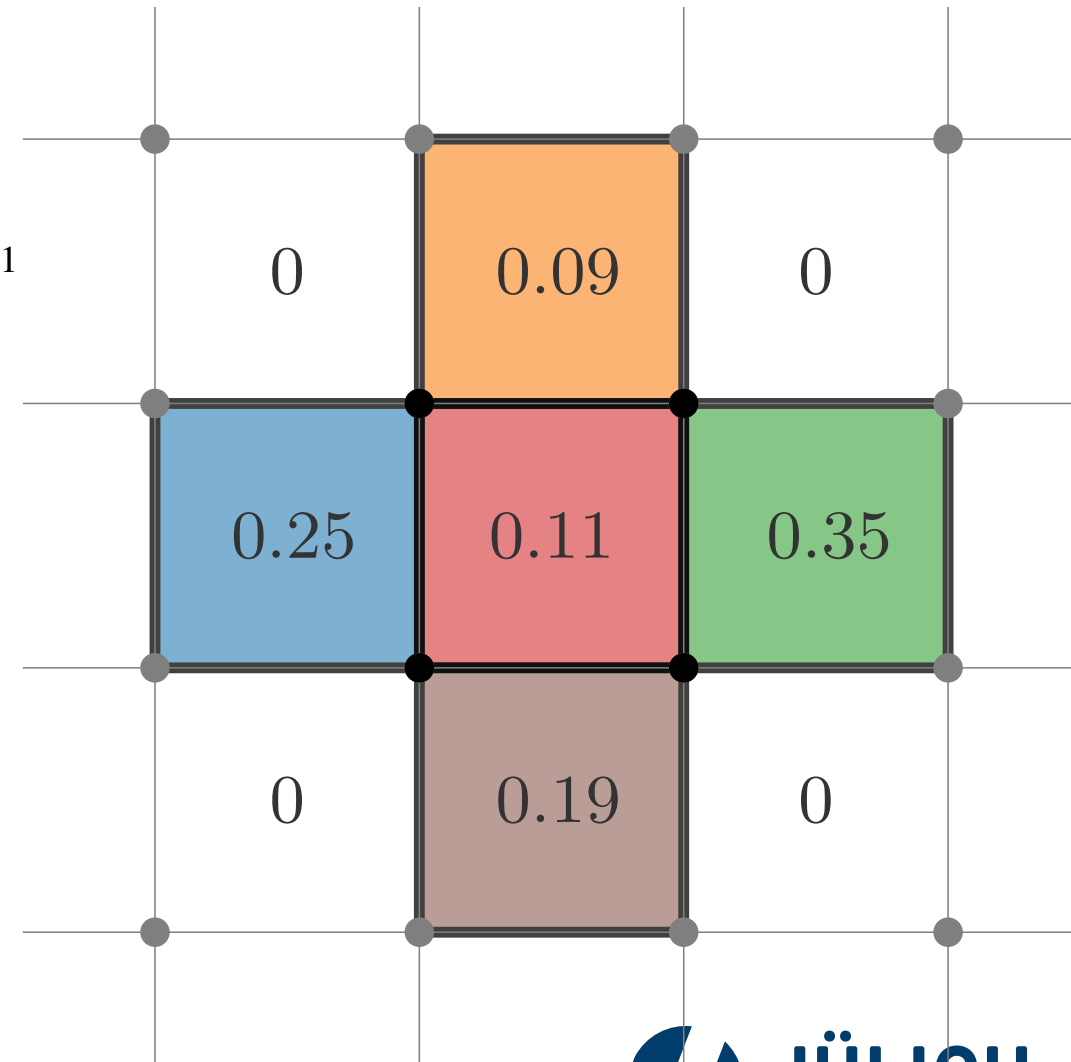
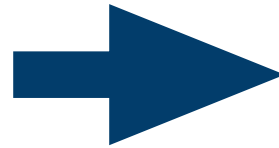
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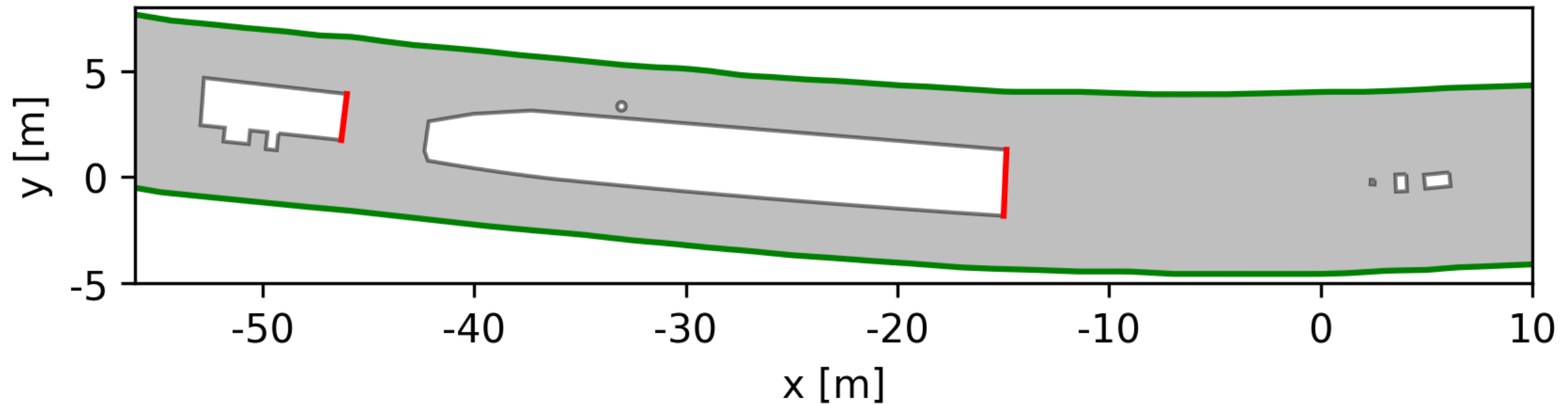
CELLULAR AUTOMATA



$$M = \left(\sum_{n \in N} P_n^k \right)^{-1}$$



RESULTS



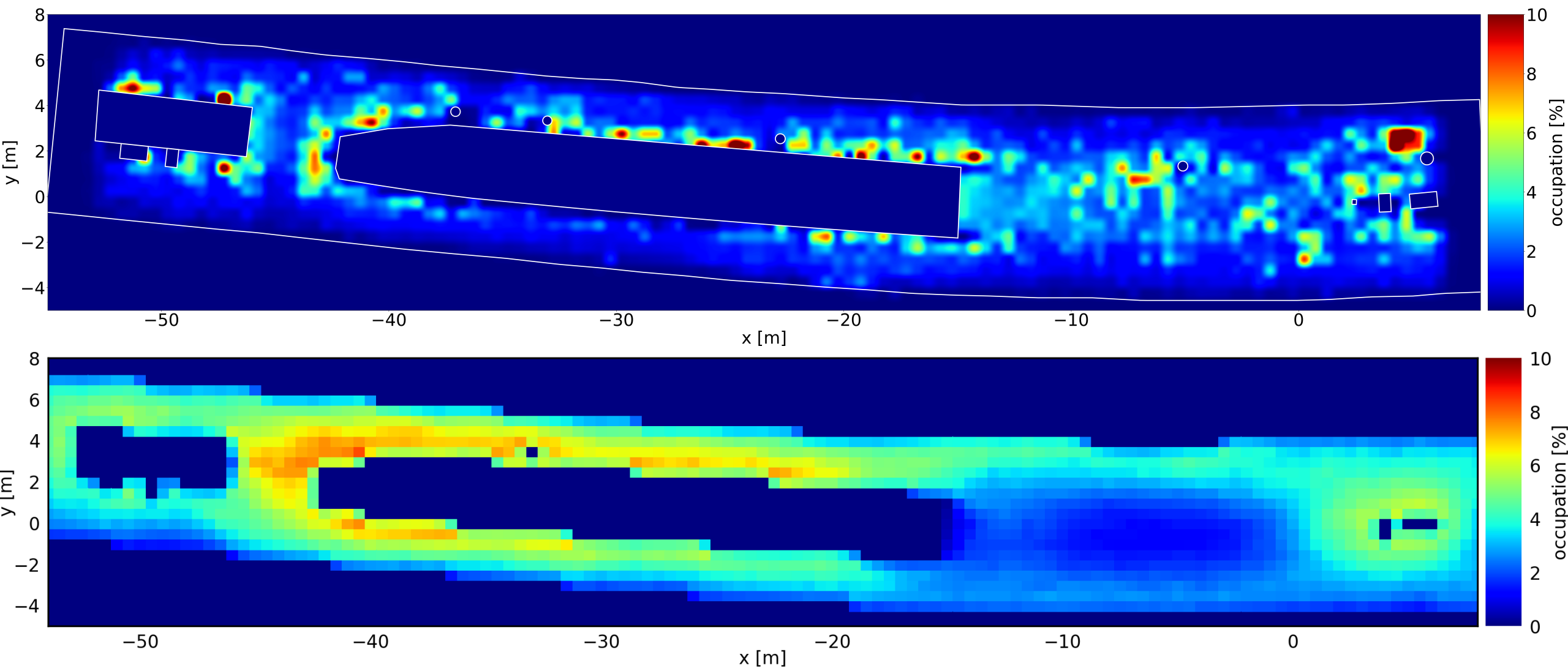
OCCUPATION OF SPACE

- Traditional measures as density are not sufficient to identify preferred waiting positions.
- Positions are occupied by one person for a longer time.
- Occupation of space [1]:

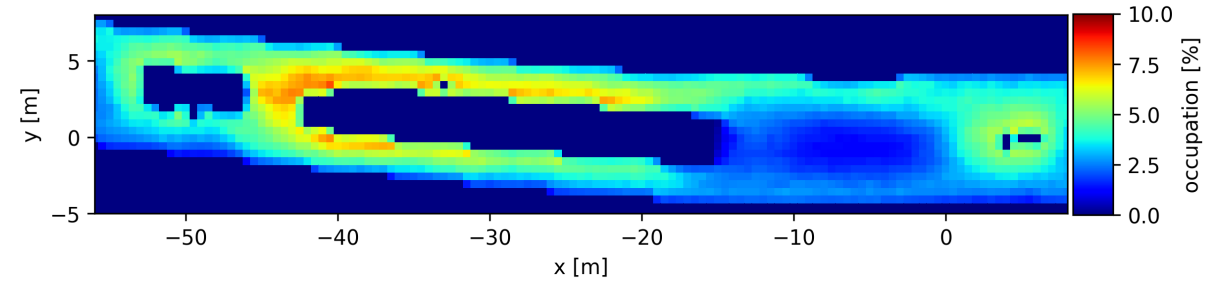
```
Divide geometry in cells;  
FOR each frame/time step:  
    Increase usage of all occupied cells by 1;  
END FOR;  
Divide usage by number of frames/time steps
```

COMPARISON

From: M. Küpper and A. Seyfried, Analysis of Space Usage on train station platforms based on trajectory data, Sustainability



CONCLUSION & OUTLOOK



- Model to describe the waiting behavior on platforms with cellular automaton.
- The Model can be calibrated by various parameters.
- Easily extendible by further influence factors.
- Extensive parameter studies to determine parameter sets for different types of travelers.
- Improve walking patterns: Weight directions by movement from previous step.
- Transfer model to continuous space, to use in other frameworks.



<https://github.com/schroedtert/dynamic-waiting>