MODELING WAITING BEHAVIOR AT TRAIN STATIONS WITH CELLULAR AUTOMATON

09.09.2020 I TOBIAS SCHRÖDTER

JÜLICH
Forschungszentrum

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.
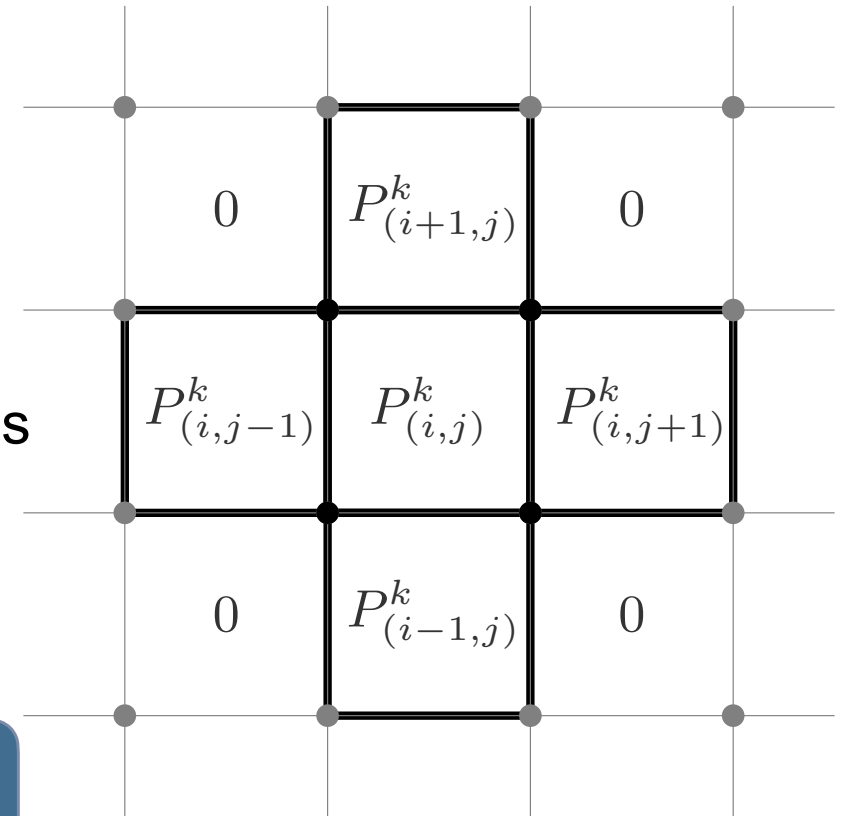
How do pedestrians move in waiting situations?

JÜLICH
Forschungszentrum

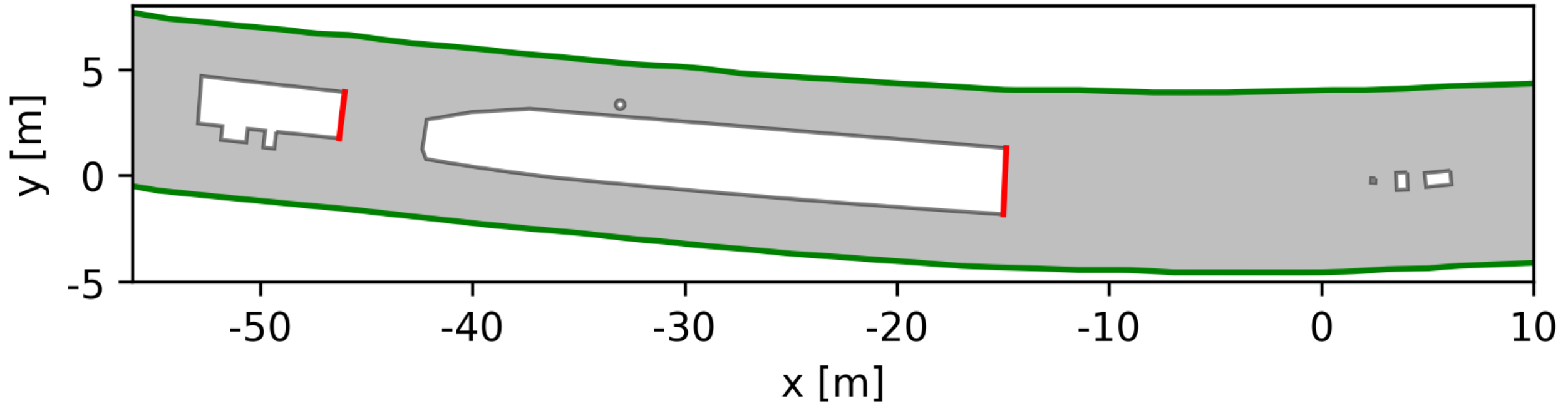# CELLULAR AUTOMATA

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.

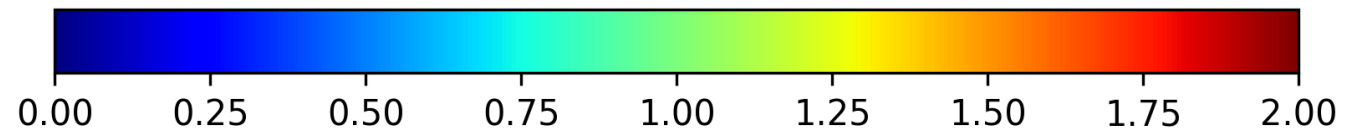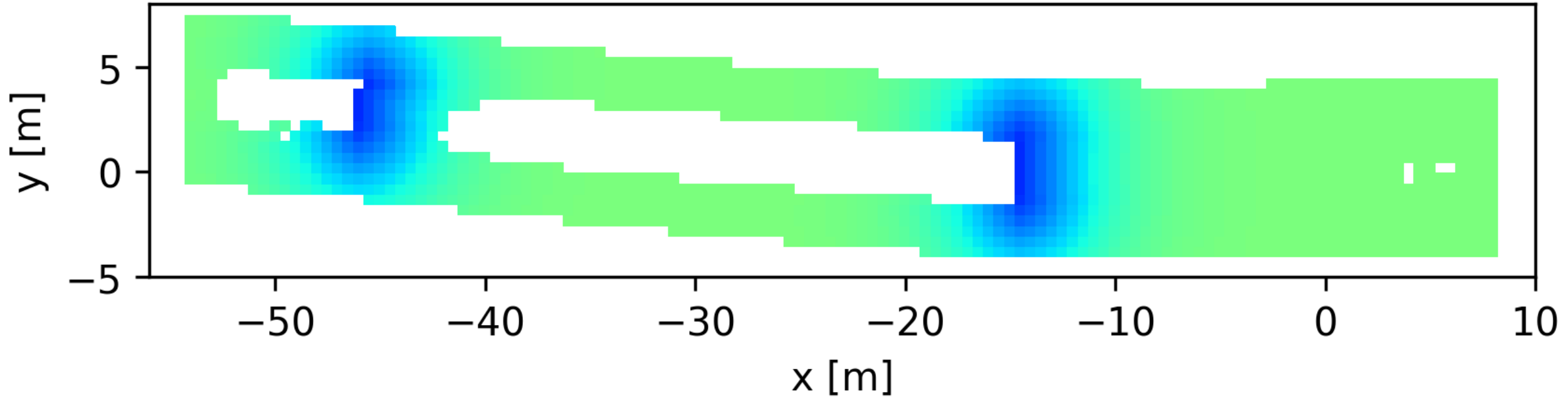> Compute transition probability based on potential fields.

The grid cells show transition probabilities:

$$
\begin{array}{ccc}
0 & P^k_{(i+1,j)} & 0 \\
P^k_{(i,j-1)} & P^k_{(i,j)} & P^k_{(i,j+1)} \\
0 & P^k_{(i-1,j)} & 0
\end{array}
$$

JÜLICH
Forschungszentrum

STATIC FLOOR FIELDS

Geometry: Bern, Switzerland

JÜLICH
Forschungszentrum

STATIC FLOOR FIELD

Entrance/exit avoidance

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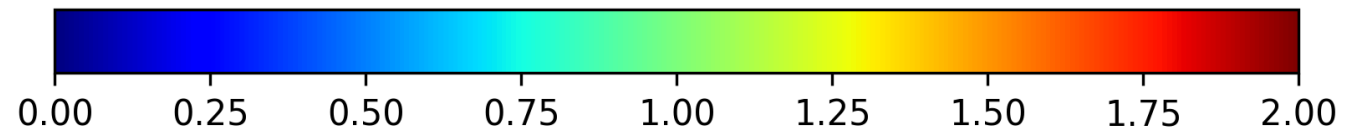
JÜLICH
Forschungszentrum
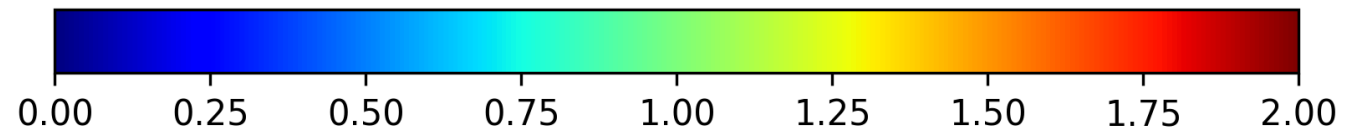
STATIC FLOOR FIELD

Boundary preference

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

JÜLICH
Forschungszentrum
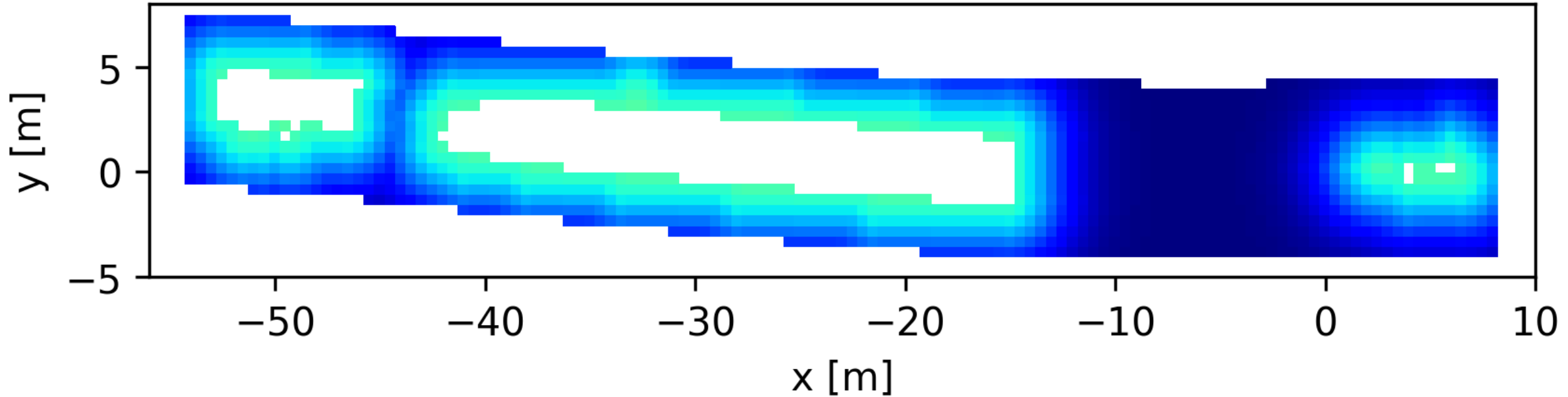
STATIC FLOOR FIELD

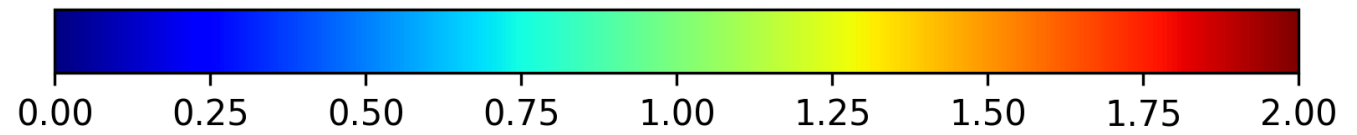**Train preference**

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

JÜLICH
Forschungszentrum
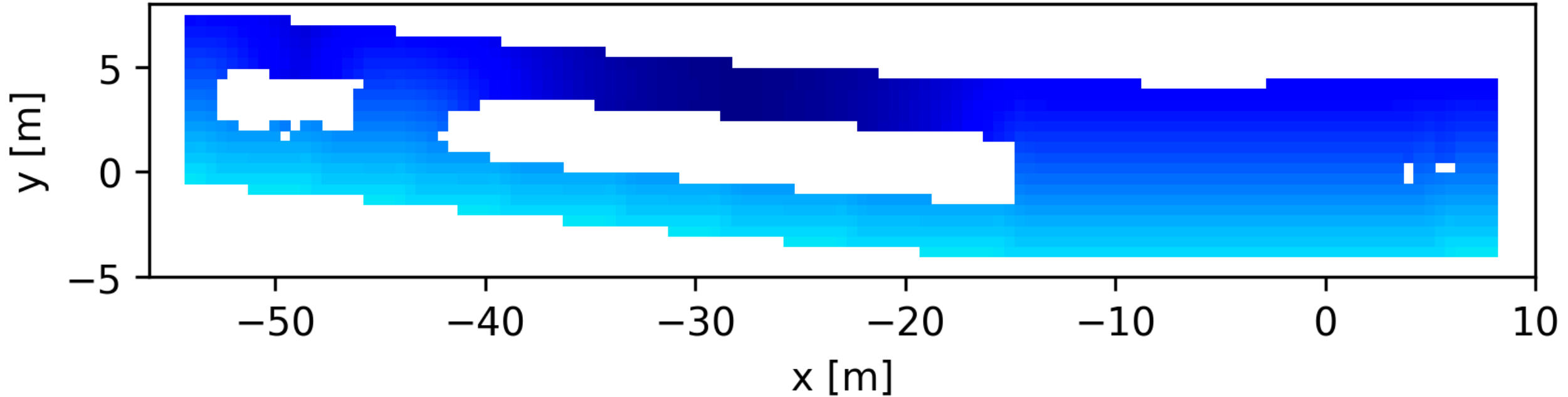
STATIC FLOOR FIELD

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

JÜLICH
Forschungszentrum
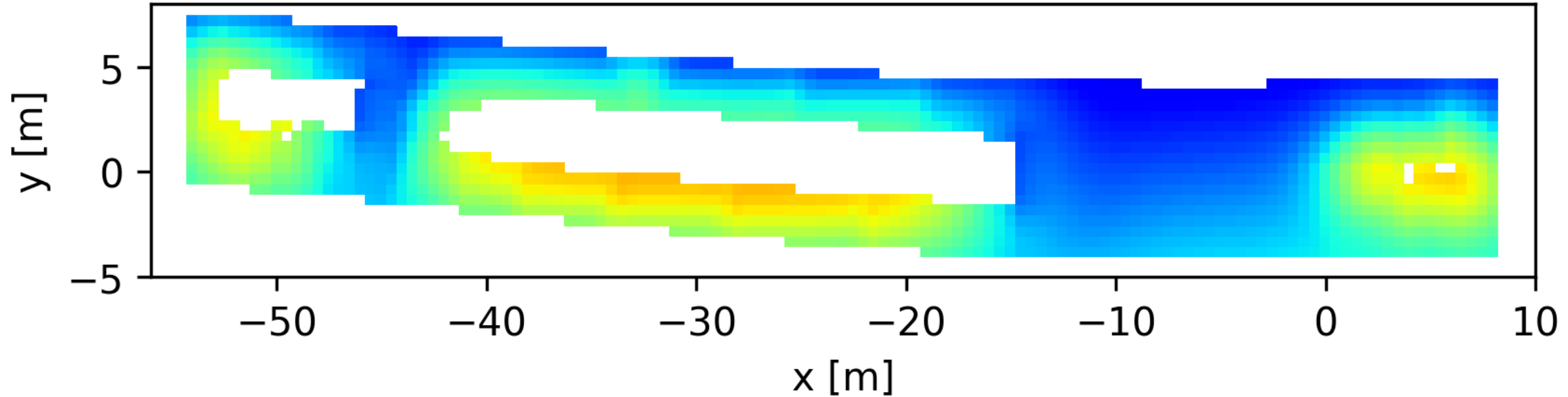
DYNAMIC FLOOR FIELDS

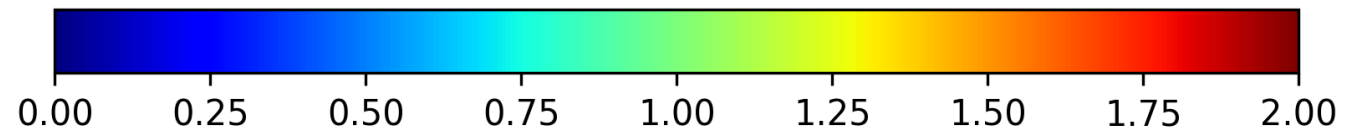## Geometry: Bern, Switzerland with pedestrians

JÜLICH
Forschungszentrum
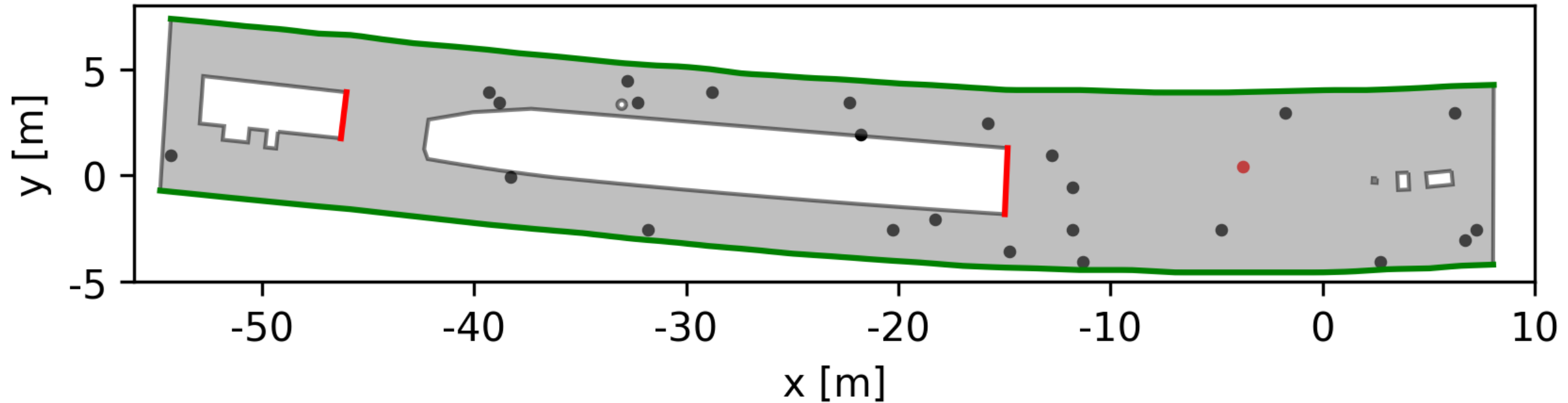
REPULSIVE FLOOR FIELD

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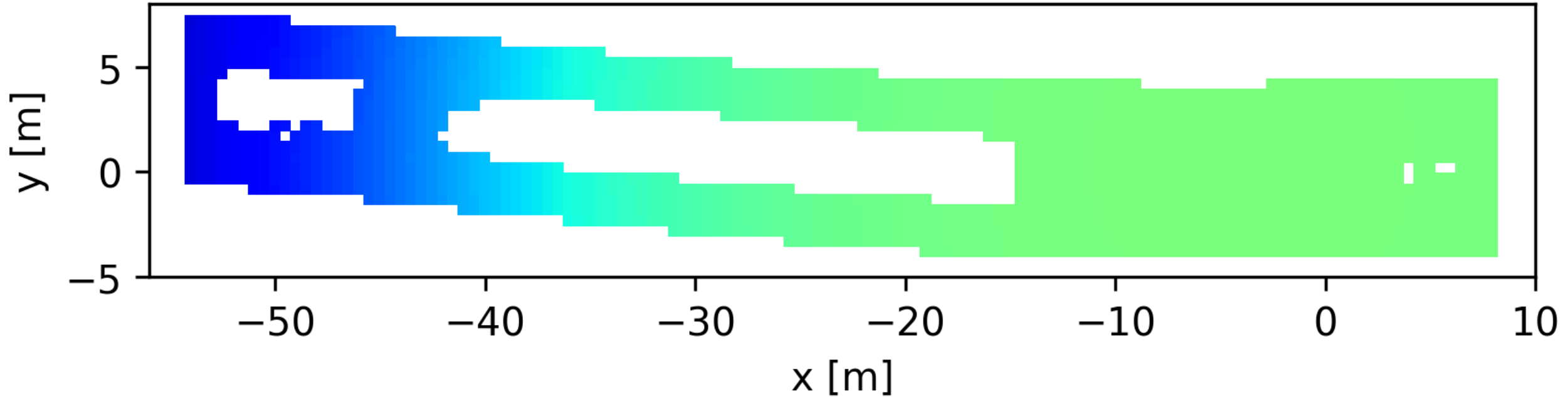
JÜLICH
Forschungszentrum
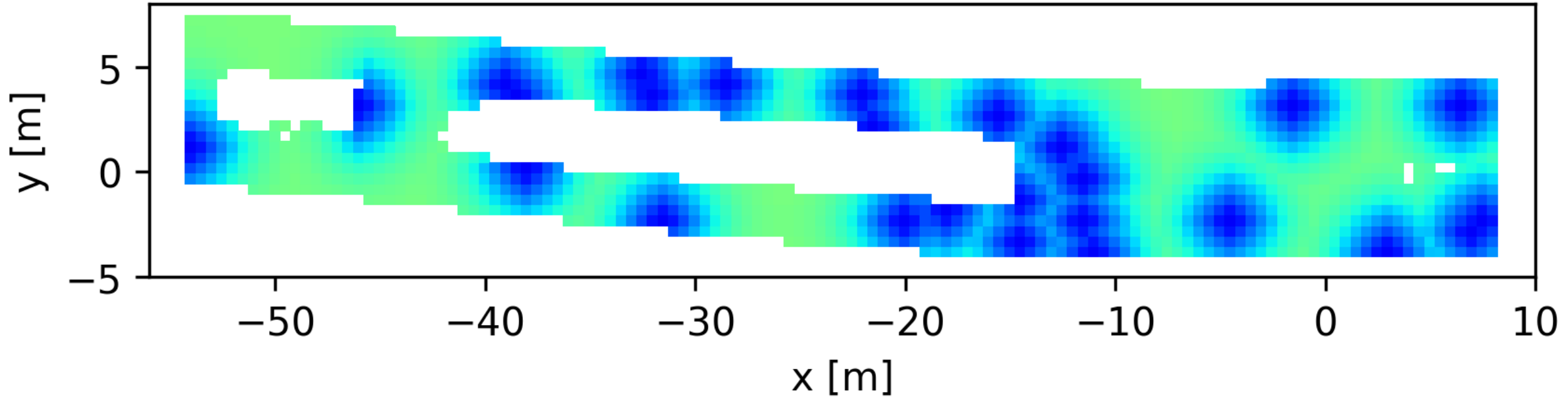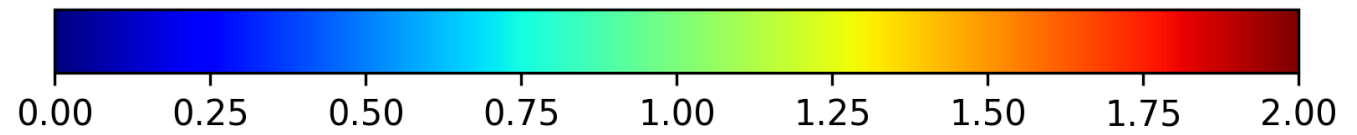
COMBINED FLOOR FIELD

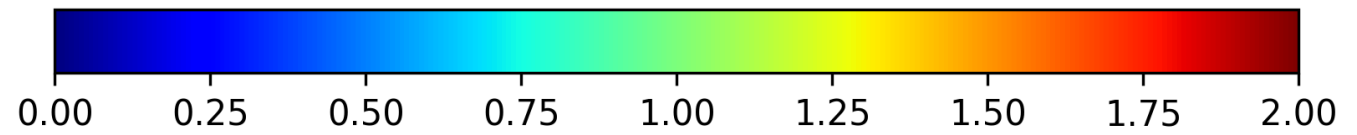**Static and Repulsive floor field**

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

JÜLICH
Forschungszentrum
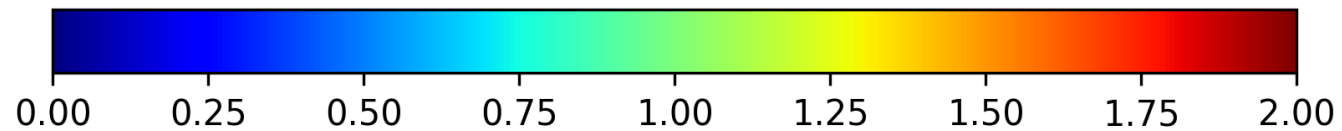
DISTANCE FLOOR FIELD

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

JÜLICH
Forschungszentrum

COMBINED FLOOR FIELD

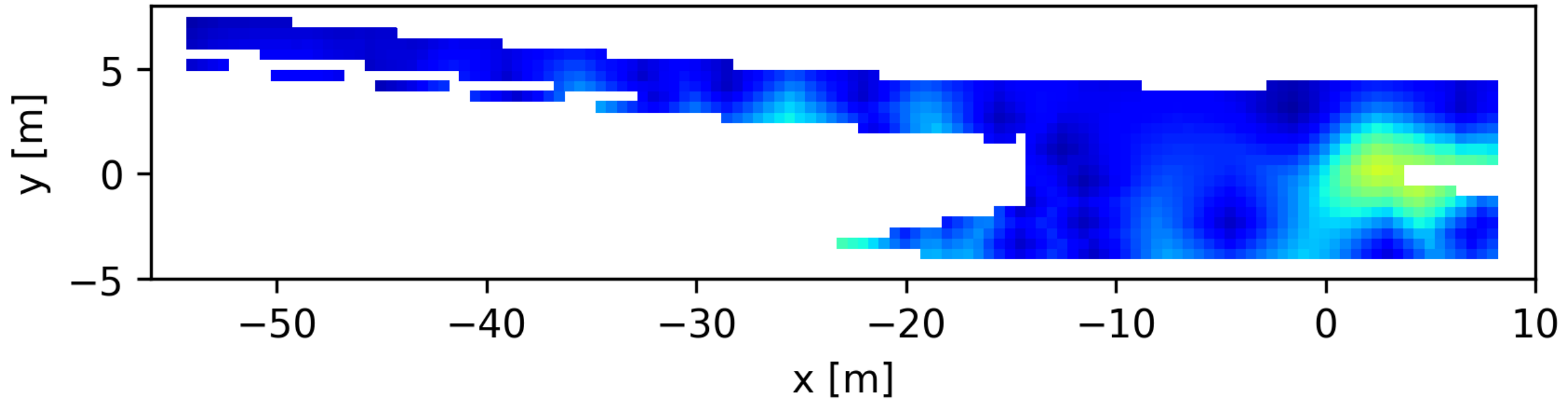$$W_{i,j}^k \left[S_{i,j} \cdot R_{i,j}^k \right]$$

JÜLICH
Forschungszentrum
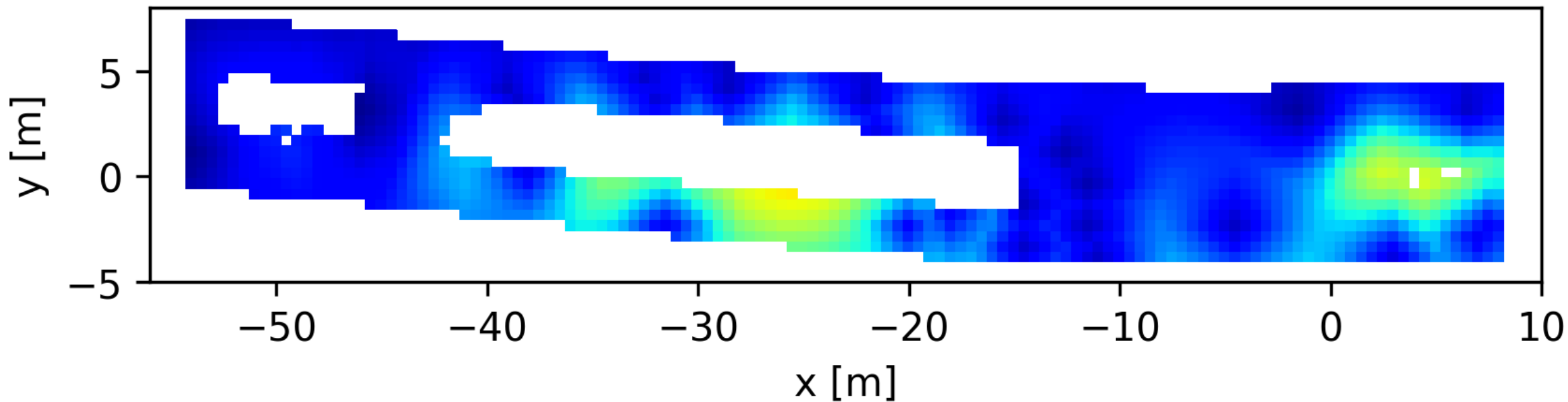
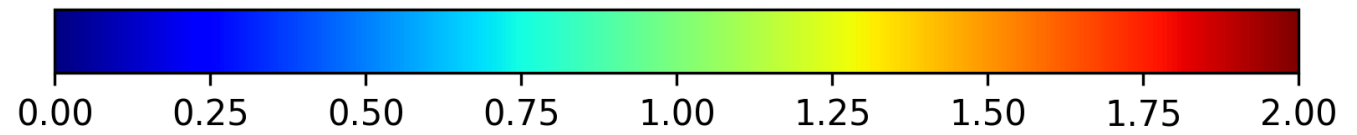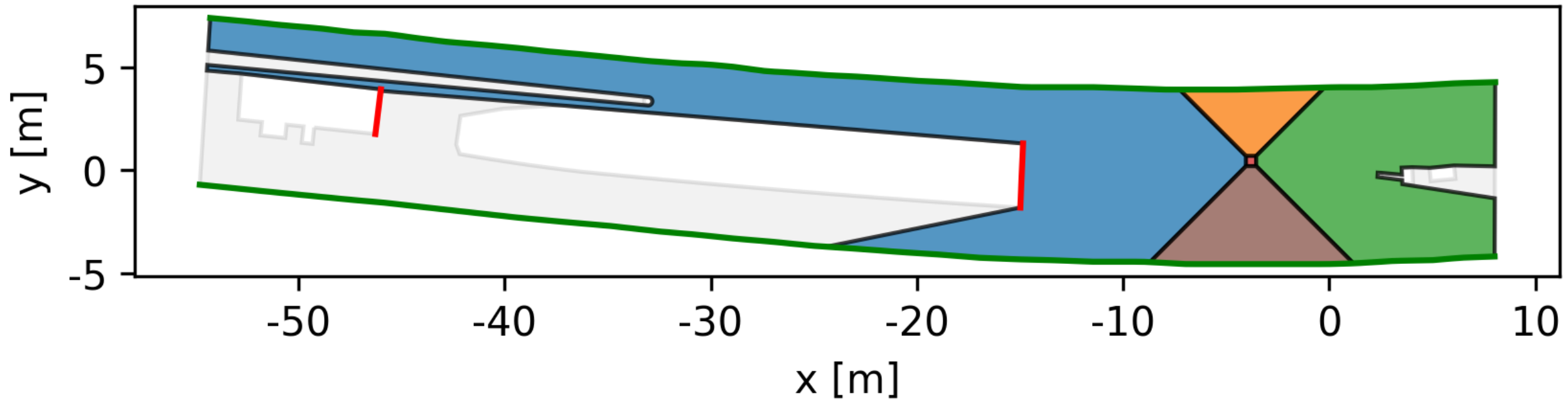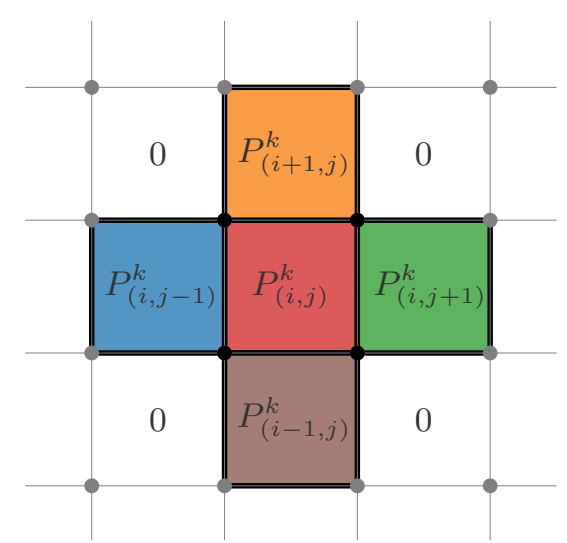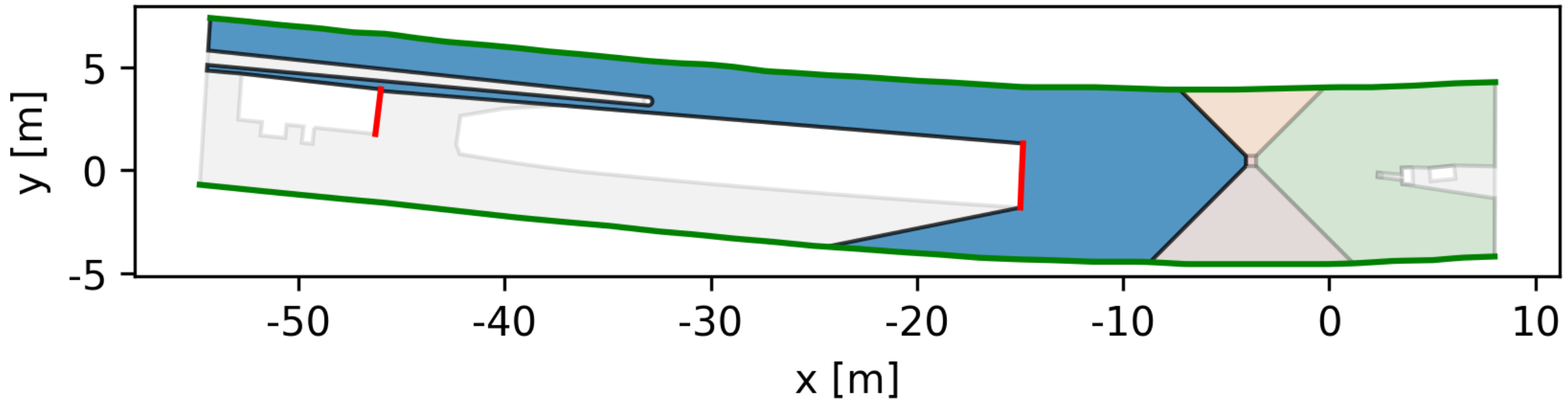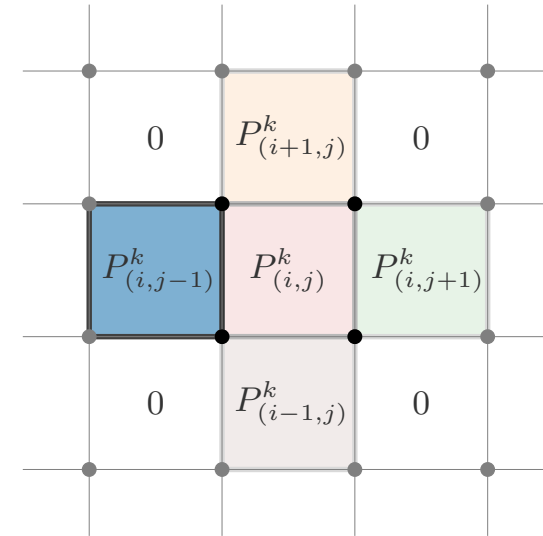# VISIBILITY CONSTRAINT
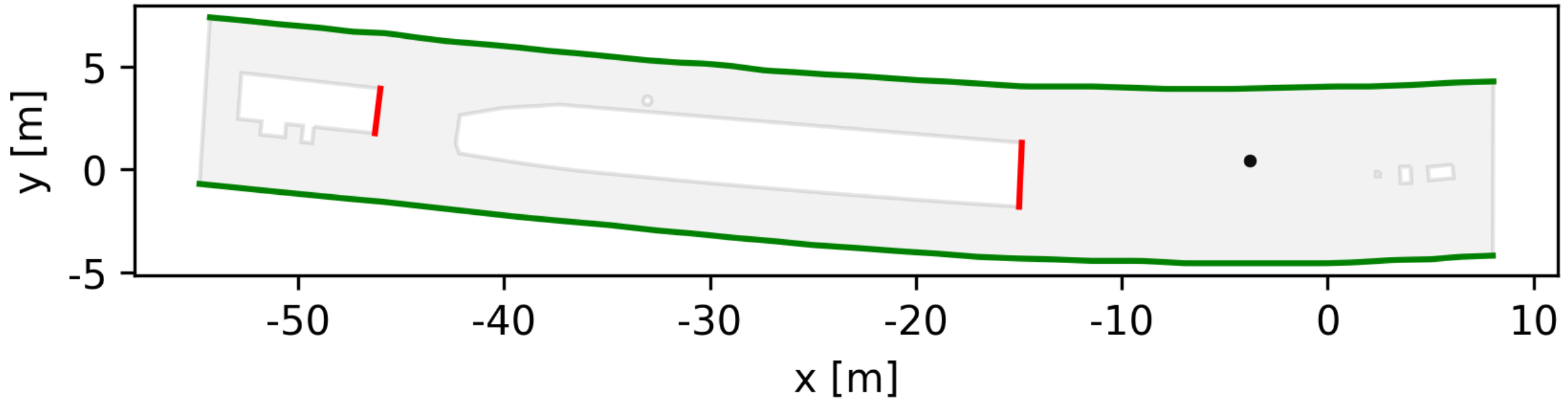
VISIBILITY CONSTRAINT
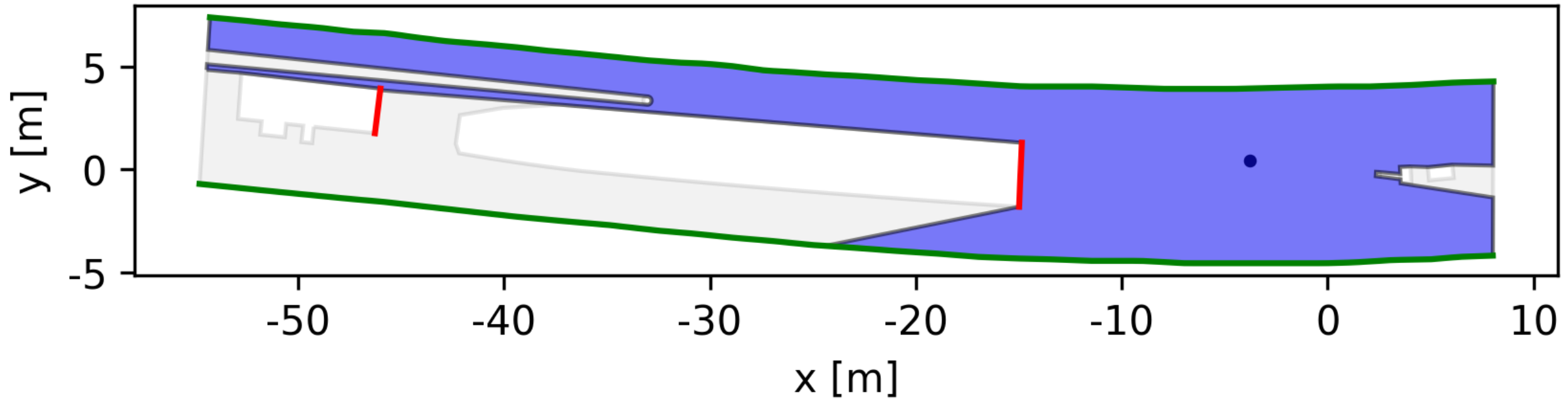
REPULSIVE FLOOR FIELD

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

JÜLICH
Forschungszentrum

VISIBILITY CONSTRAINT

VISIBILITY CONSTRAINT

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

VISIBILITY CONSTRAINT

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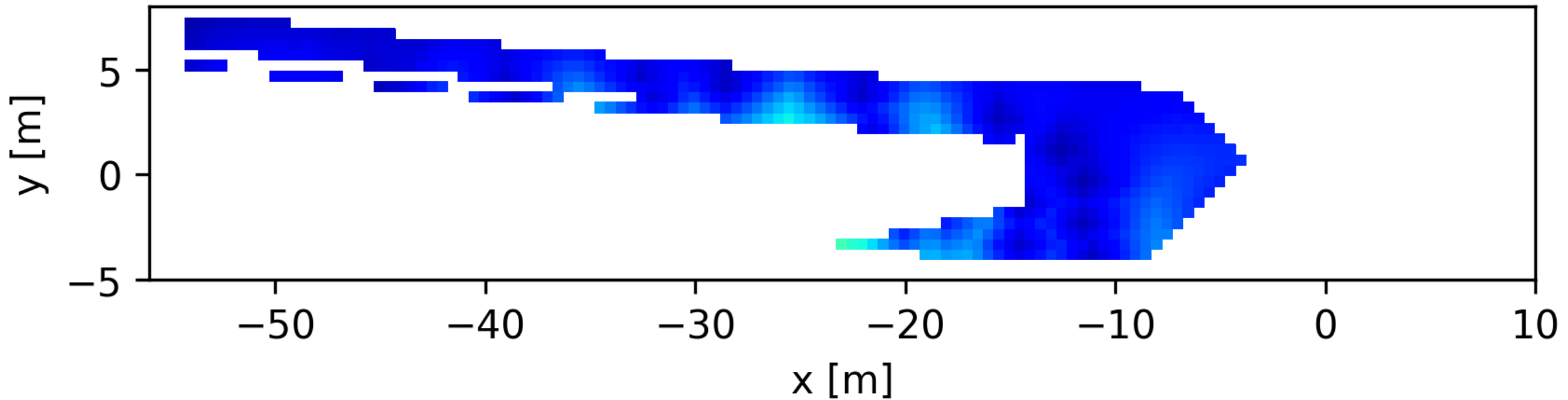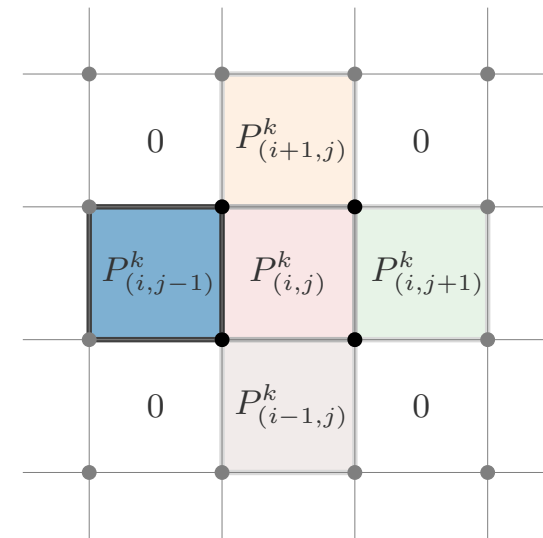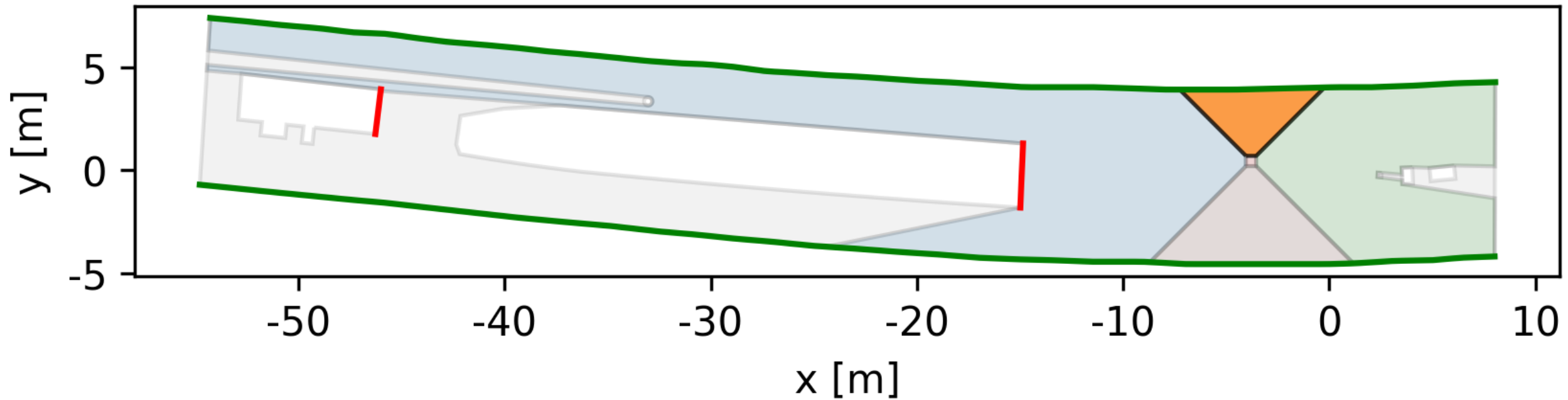
VISIBILITY CONSTRAINT

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

VISIBILITY CONSTRAINT

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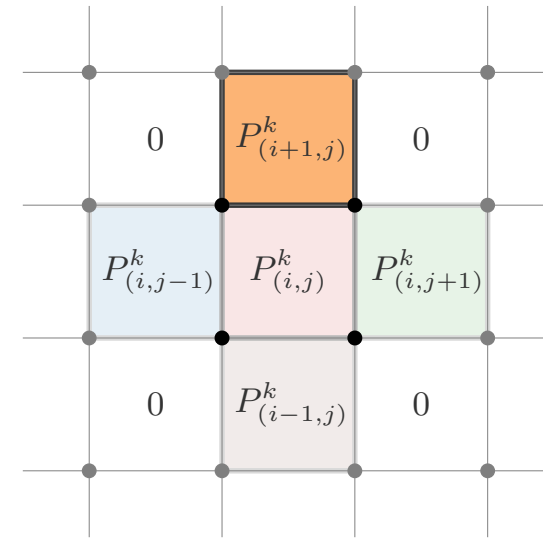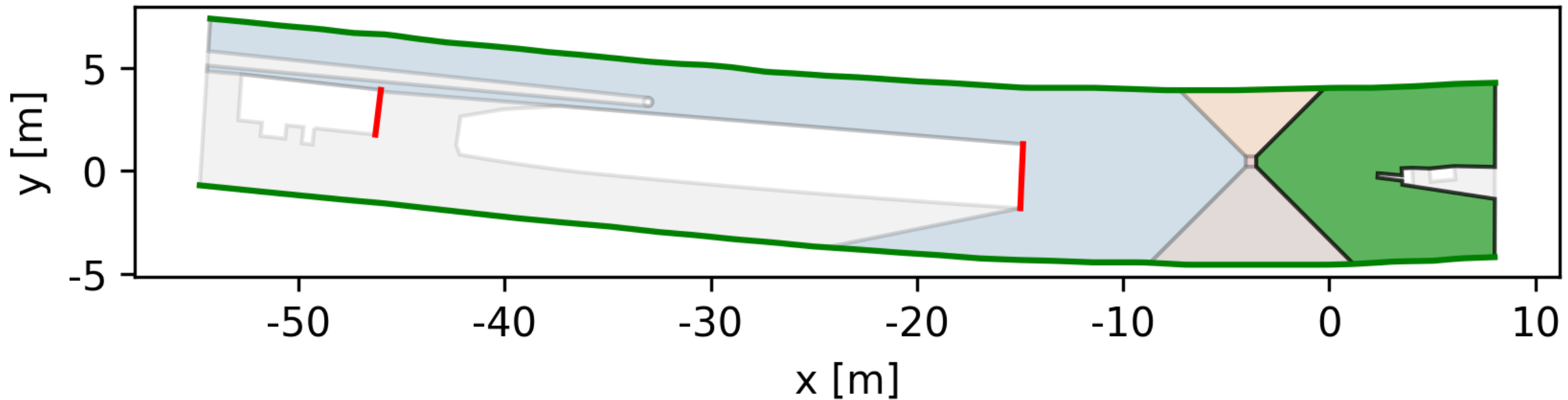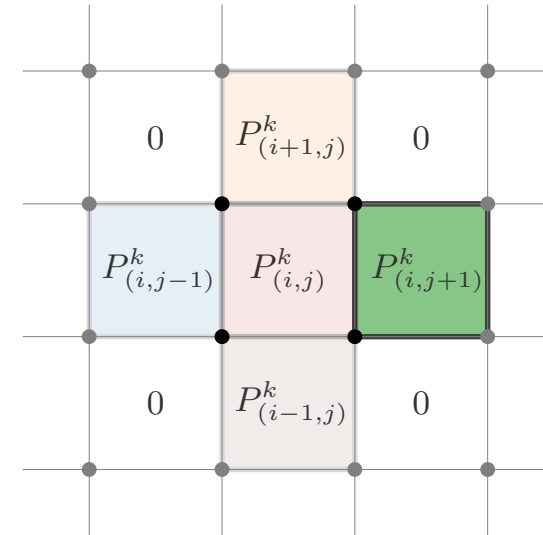
VISIBILITY CONSTRAINT

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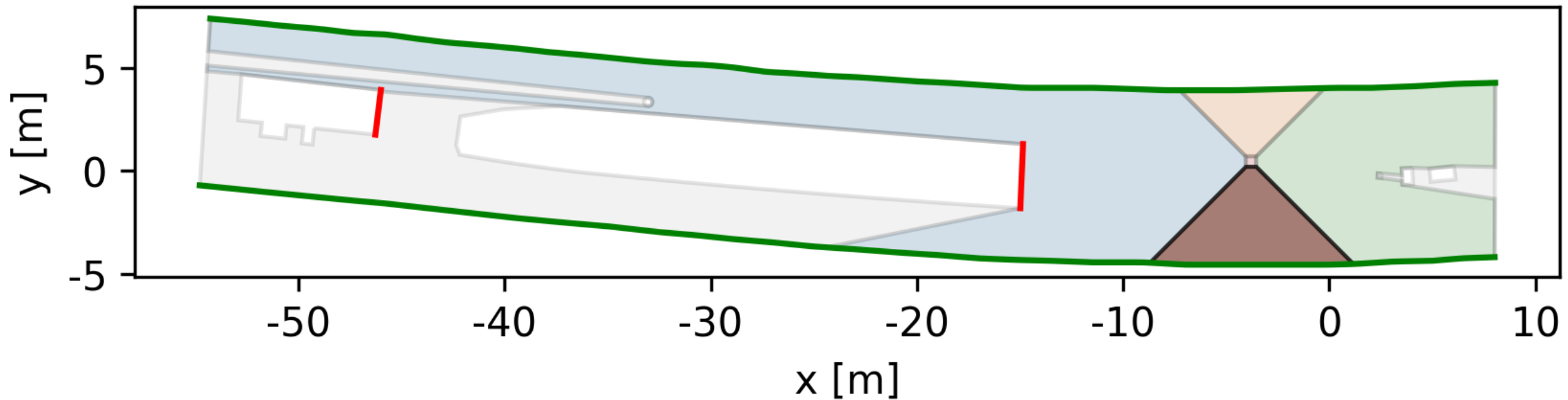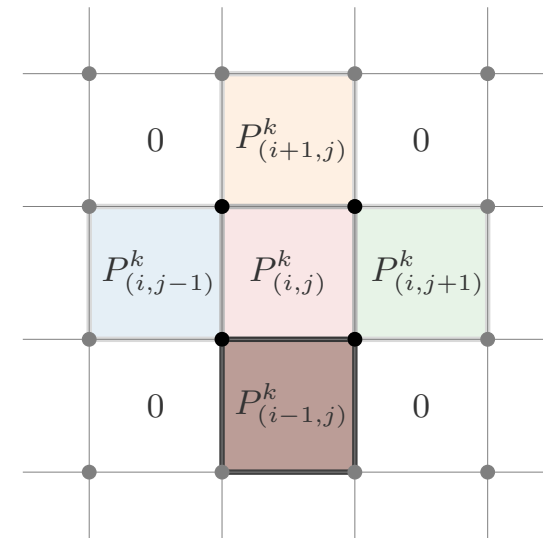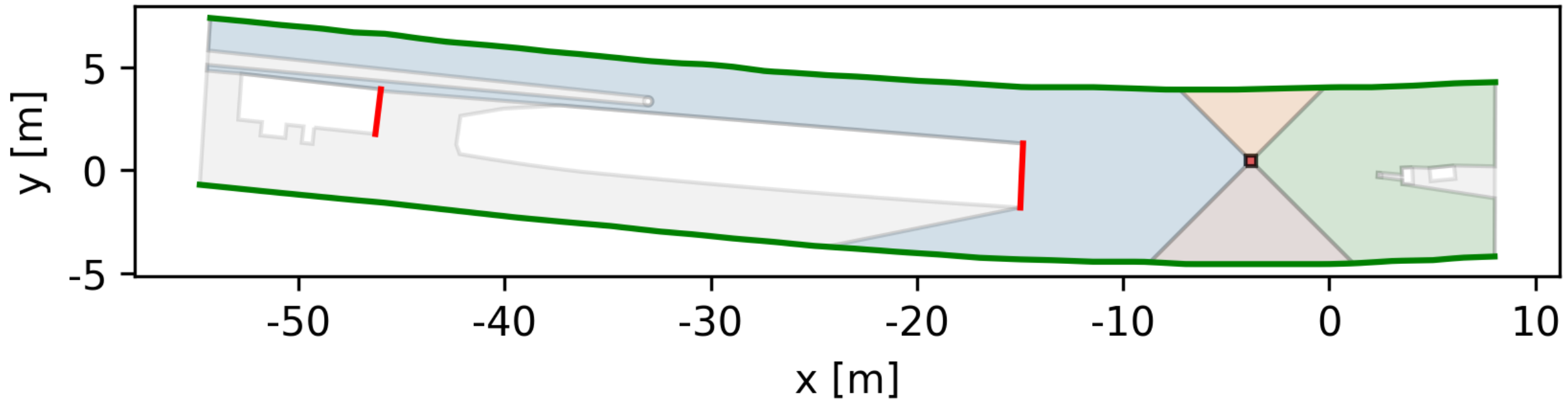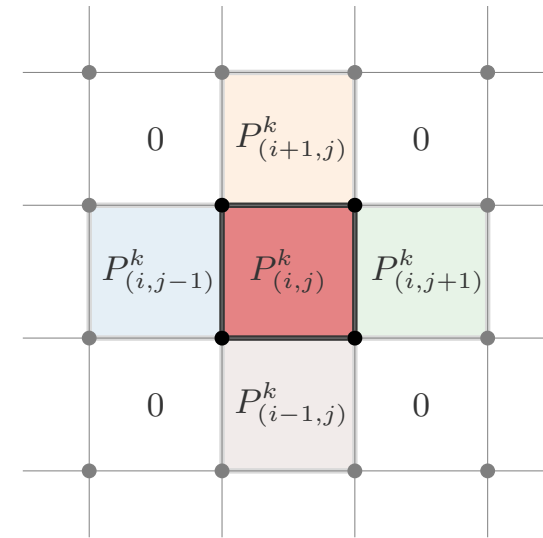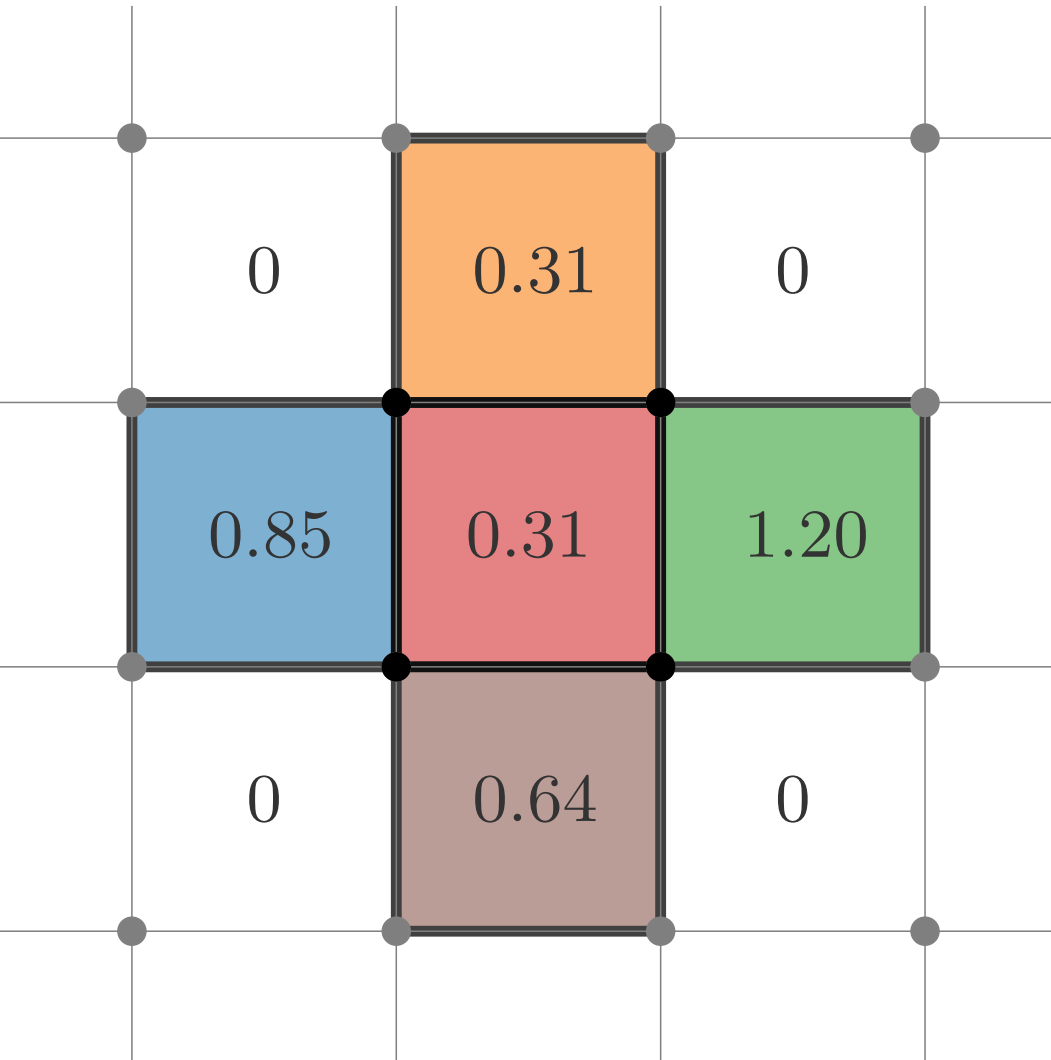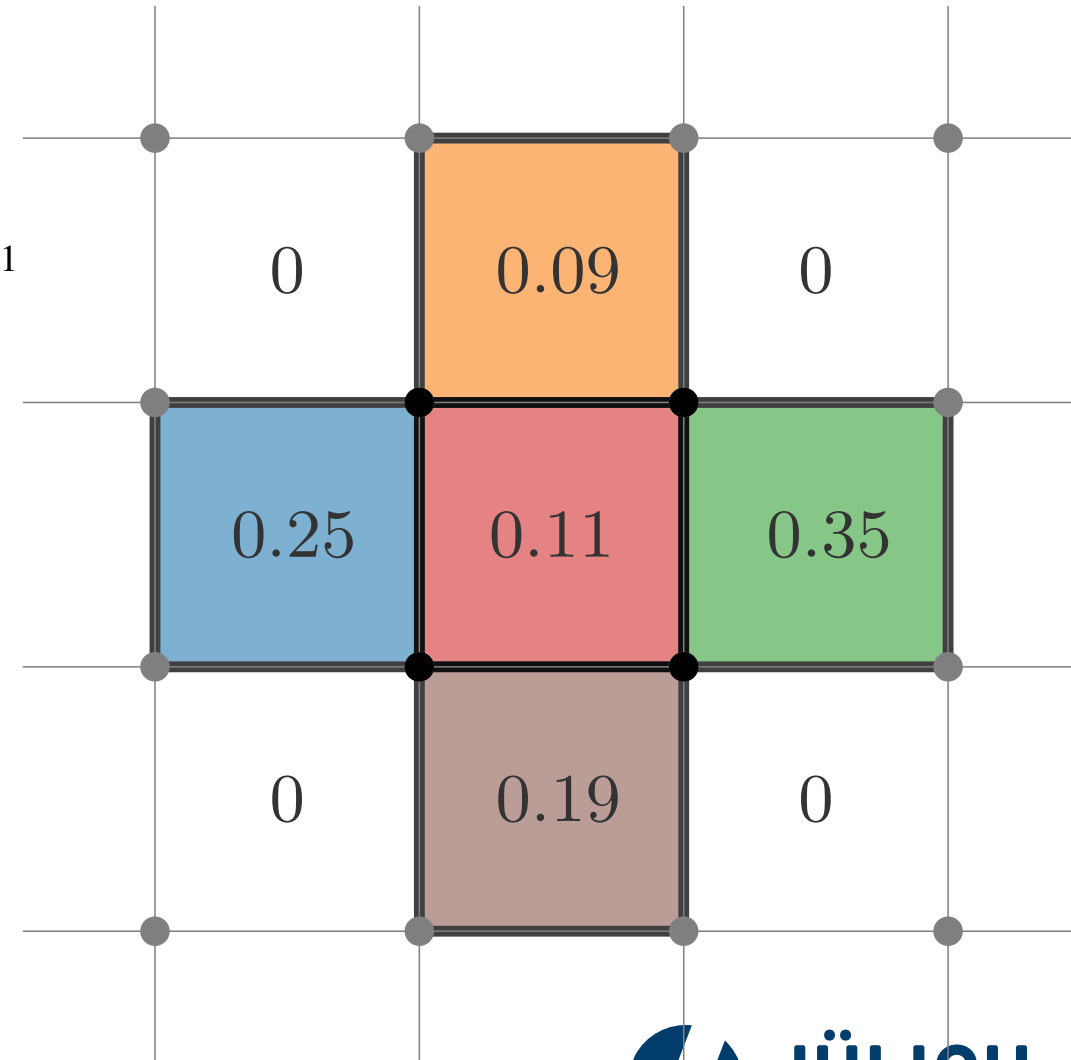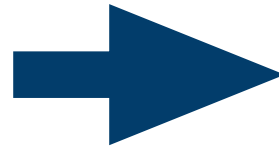
VISIBILITY CONSTRAINT

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

CELLULAR AUTOMATA
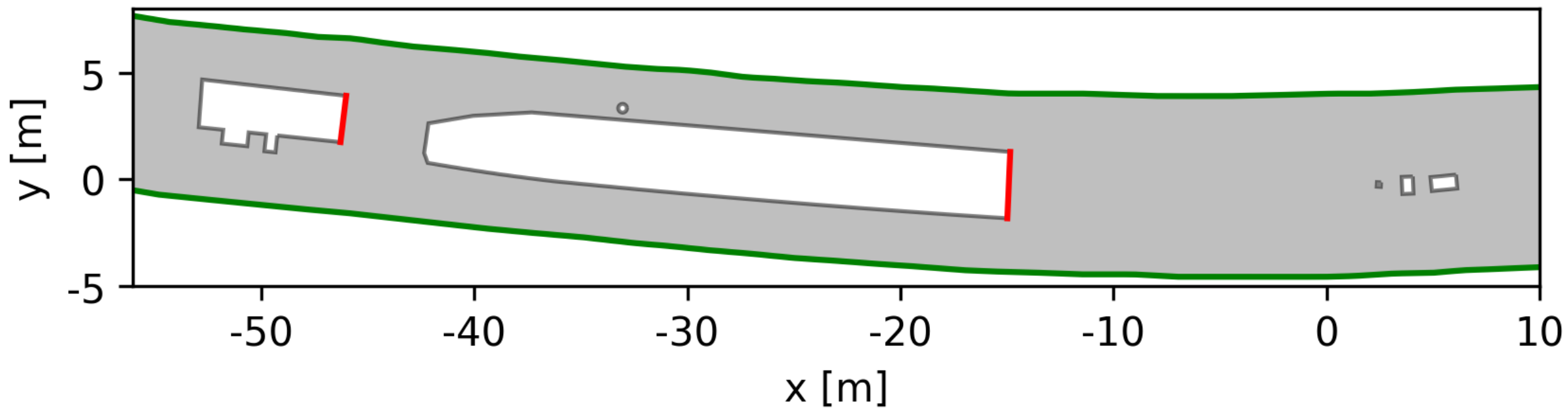

$$M = \left(\sum_{n \in N} P_n^k \right)^{-1}$$

JÜLICH
Forschungszentrum

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
```

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

JÜLICH
Forschungszentrum

COMPARISON

JÜLICH
Forschungszentrum
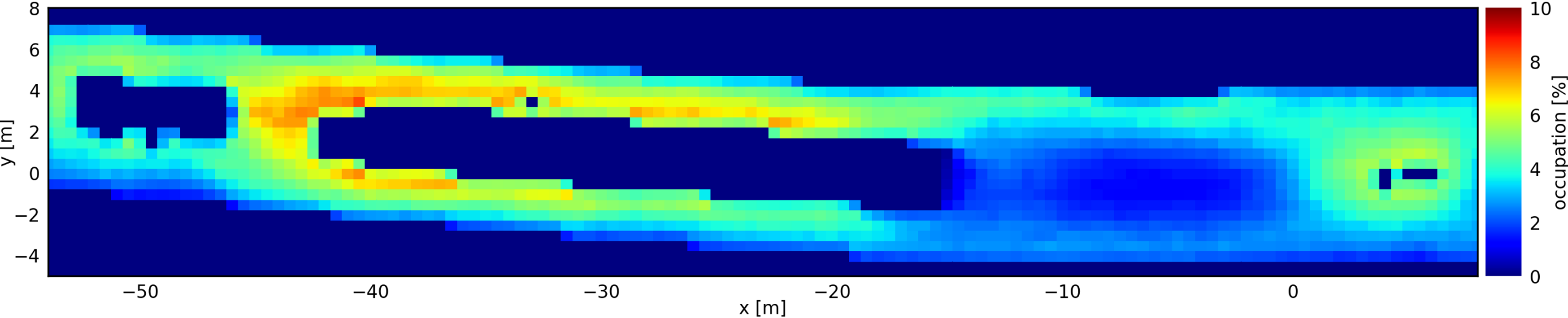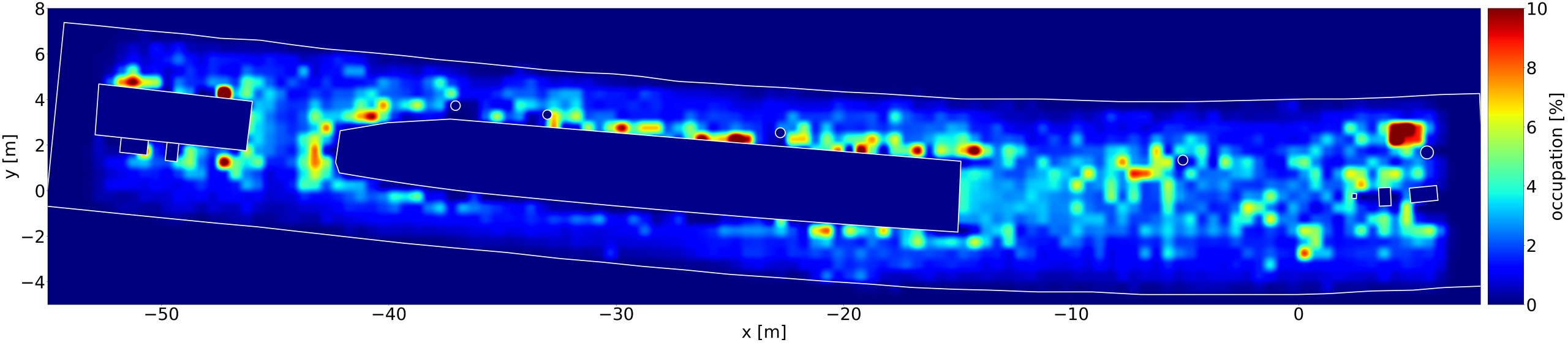
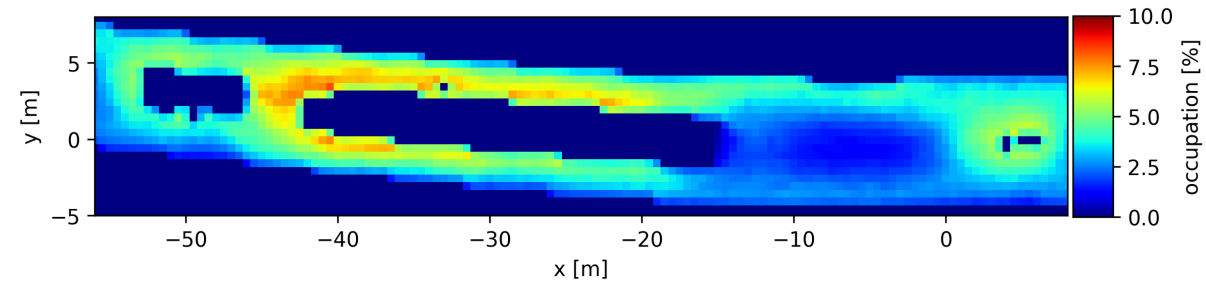# CONCLUSION & OUTLOOK

- 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

JÜLICH
Forschungszentrum