



HAL
open science

Toward a Generalized Risk Assessment Method on Occupancy Grids

Jérémy Morceaux, Johann Laconte, Elie Randriamiarintsoa, Ted Morell, Laurent Malaterre, Dieumet Denis, Romuald Aufrère, Roland Chapuis

► **To cite this version:**

Jérémy Morceaux, Johann Laconte, Elie Randriamiarintsoa, Ted Morell, Laurent Malaterre, et al.. Toward a Generalized Risk Assessment Method on Occupancy Grids. International Conference on Intelligence Robots and Systems, Sep 2021, Prague (on line), Czech Republic. <hal-03346213>

HAL Id: hal-03346213

<https://hal.science/hal-03346213v1>

Submitted on 24 Sep 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Toward a Generalized Risk Assessment Method on Occupancy Grids

Context & Motivations

- ▶ While occupancy grids are a good way to map the environment of a vehicle, they are not well-suited to assess risks of a specific path.
- ▶ Several recent works implemented a notion of risk in occupancy grids (e.g., [1]). In particular, [2] introduced the Lambda-Field, a mathematical theory where a physical risk can be computed for a specific path.

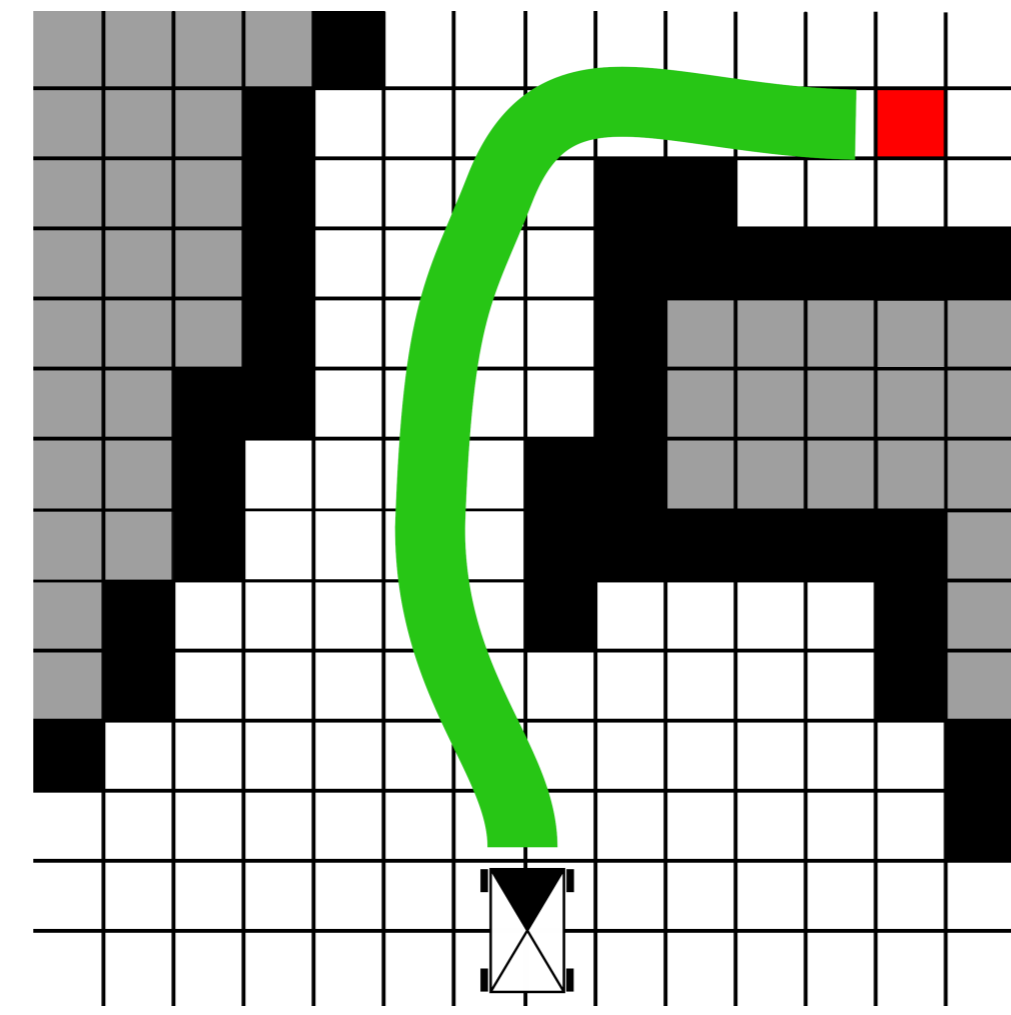


Figure: Even though the Bayesian Occupancy grid can allow to compute a path to reach a goal, it cannot assess the physical risk for a specific path.

Lambda-Field

- ▶ Lambda-Field, instead of storing the probability of occupation, stores the intensity of an event. The intensity of a cell can be seen as the likelihood to create an event leading for example to a collision. For this work, we defined our event as the deformation of the wheel (assumed unique) due to a collision.

- ▶ For each cell c_i :

$$\lambda_i = p_i \cdot \frac{1}{e} \ln \left(1 + \frac{u_i}{s_i} \right) \quad (1)$$

$$p_i = \min \left(\frac{|H_i|}{R}, 1 \right)$$

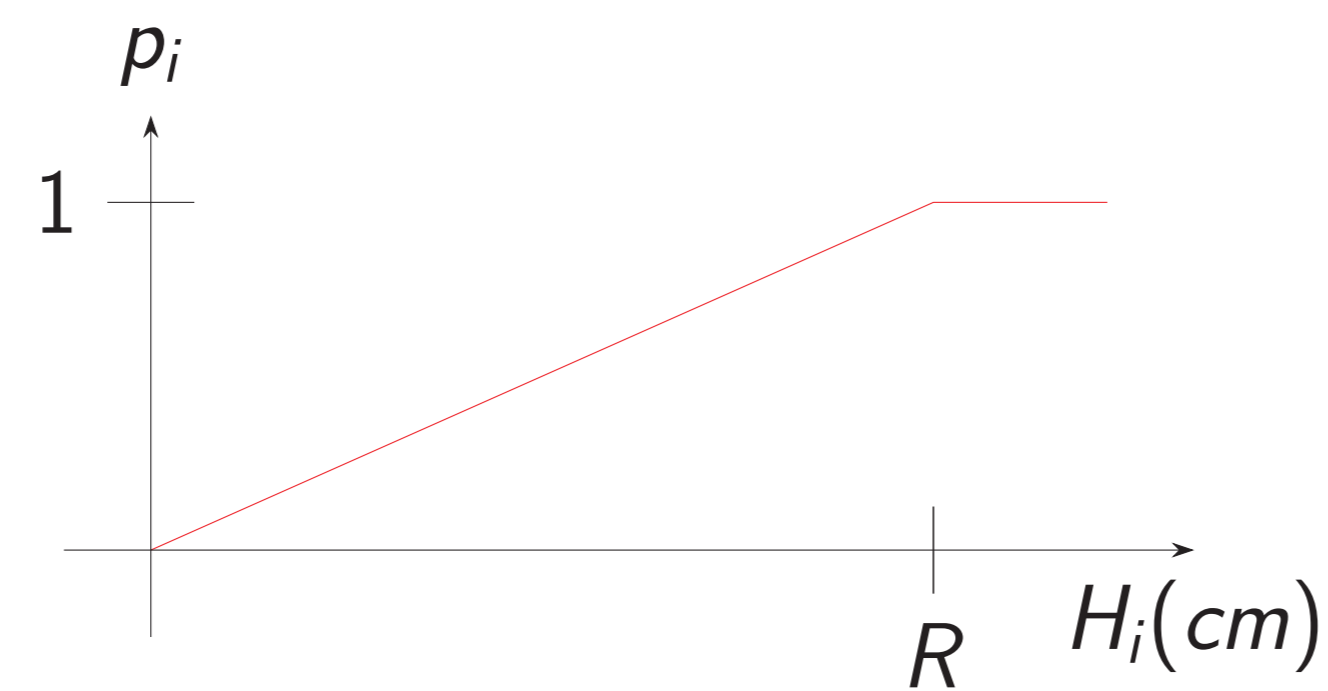


Figure: p_i , the probability to be harmful.

- ▶ To compute, s_i , u_i and H_i , we use a Digital Elevation Map (DEM).

H_i	Maximum elevation difference between the cell c_i and its neighbors
s_i	Cell c_i was measured s_i times safe (< 5 cm).
u_i	Cell c_i was measured u_i times unsafe (> 5 cm).
R	Radius of the wheel.

Table: List of parameters to compute the Lambda-Field.

Risk Function

- ▶ We use a spring to model the compression of the wheel during the collision.

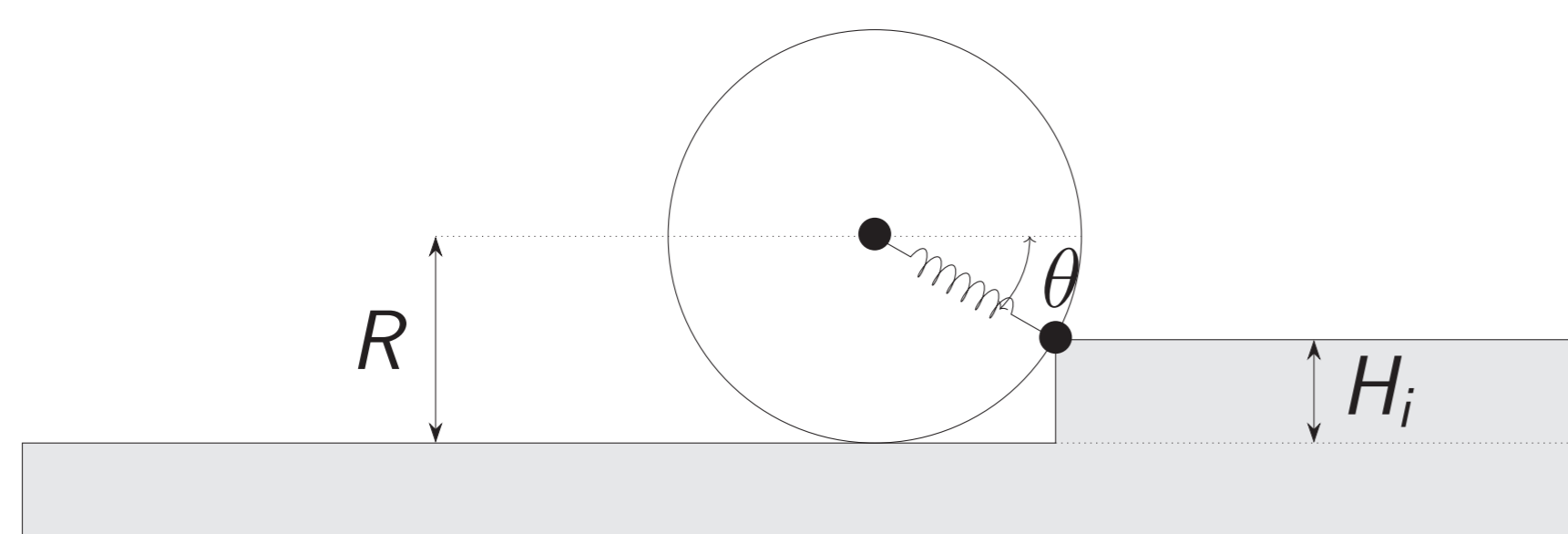


Figure: We model our wheel like a spring that will absorb the collision.

- ▶ Using the equation of an harmonic oscillator, we evaluate our risk function as the elastic energy absorbed by the spring:

$$r(v, H_i) = \frac{1}{2} \cdot k \cdot A(v, H_i)^2 \quad (2)$$

where A is the amplitude of the harmonic solution, v is the speed of the vehicle and k is the stiffness of the spring.

- ▶ As introduced in [2], we can compute the expected risk over a path with:

$$\mathbb{E}[r(\cdot)] = \sum_{i=0}^{N-1} K_i r(v, H_i), \quad \text{where} \quad (3)$$

$$K_i = \exp \left(-\Delta a \sum_{j=0}^{i-1} \lambda_j \right) \left[1 - \exp(-\Delta a \lambda_i) \right]$$

where Δa is the area of each cell.

Acknowledgments and References

This work has been sponsored by Sherpa Engineering and ANRT (Conventions Industrielles de Formation par la Recherche).

- [1] David D. Fan, Kyohei Otsu, Yuki Kubo, Anushri Dixit, Joel Burdick, and Ali-Akbar Agha-Mohammadi. STEP: stochastic traversability evaluation and planning for safe off-road navigation. *arXiv preprint arXiv:2103.02828*, 2021.
- [2] Johann Laconte, Christophe Debain, Roland Chapuis, François Pomerleau, and Romuald Aufrère. Lambda-field: A continuous counterpart of the bayesian occupancy grid for risk assessment. *International Conference on Intelligent Robots and Systems*, pages 167–172, 3 2019.

Experimental Setup

- ▶ During this experiment, we used a 4-wheel drive robot equipped with a velodyne VLP-16.
- ▶ The VLP-16 is tilted with a 15° angle on the pitch axis in order to get a better representation of the road ahead.



Figure: Robot used for this experiment.

Results

- ▶ First, a DEM was created by accumulating several point clouds generated by a 3D LIDAR sensor.

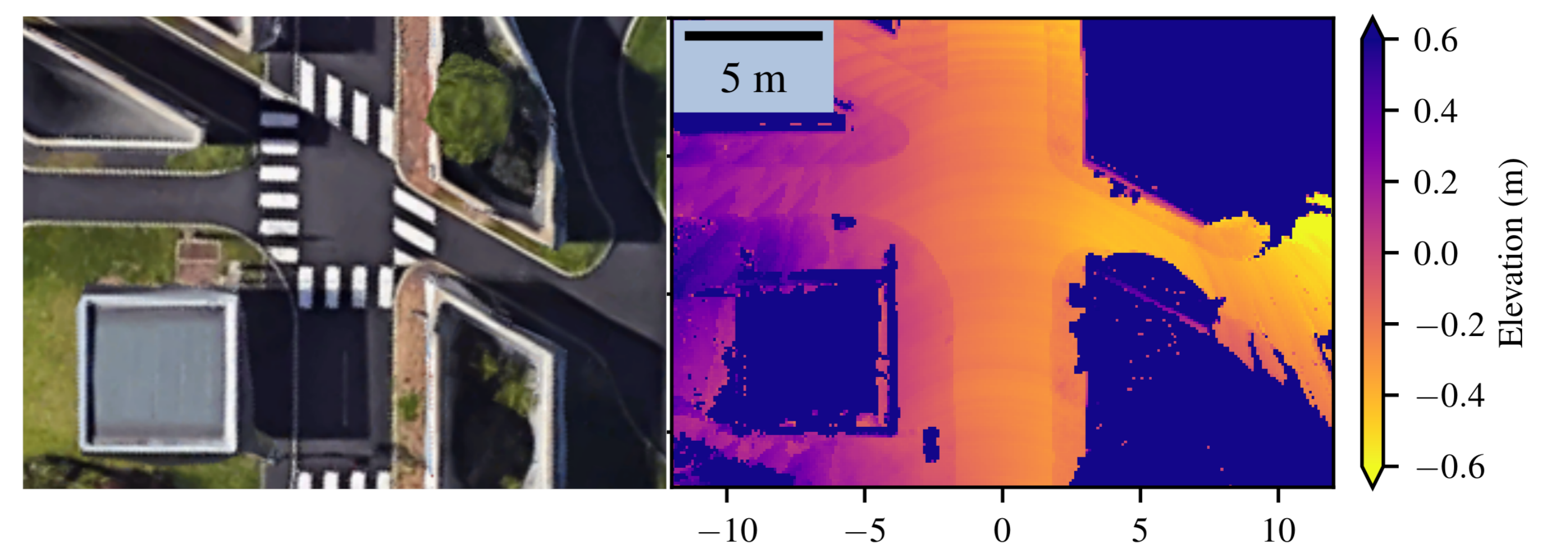


Figure: Left: Aerial view from our urban-like test site with sidewalks that may be hazardous. Right: DEM is computed from the accumulation of LIDAR points over time.

- ▶ Then, we constructed a Lambda-Field using a wheel radius of $R = 25$ cm.

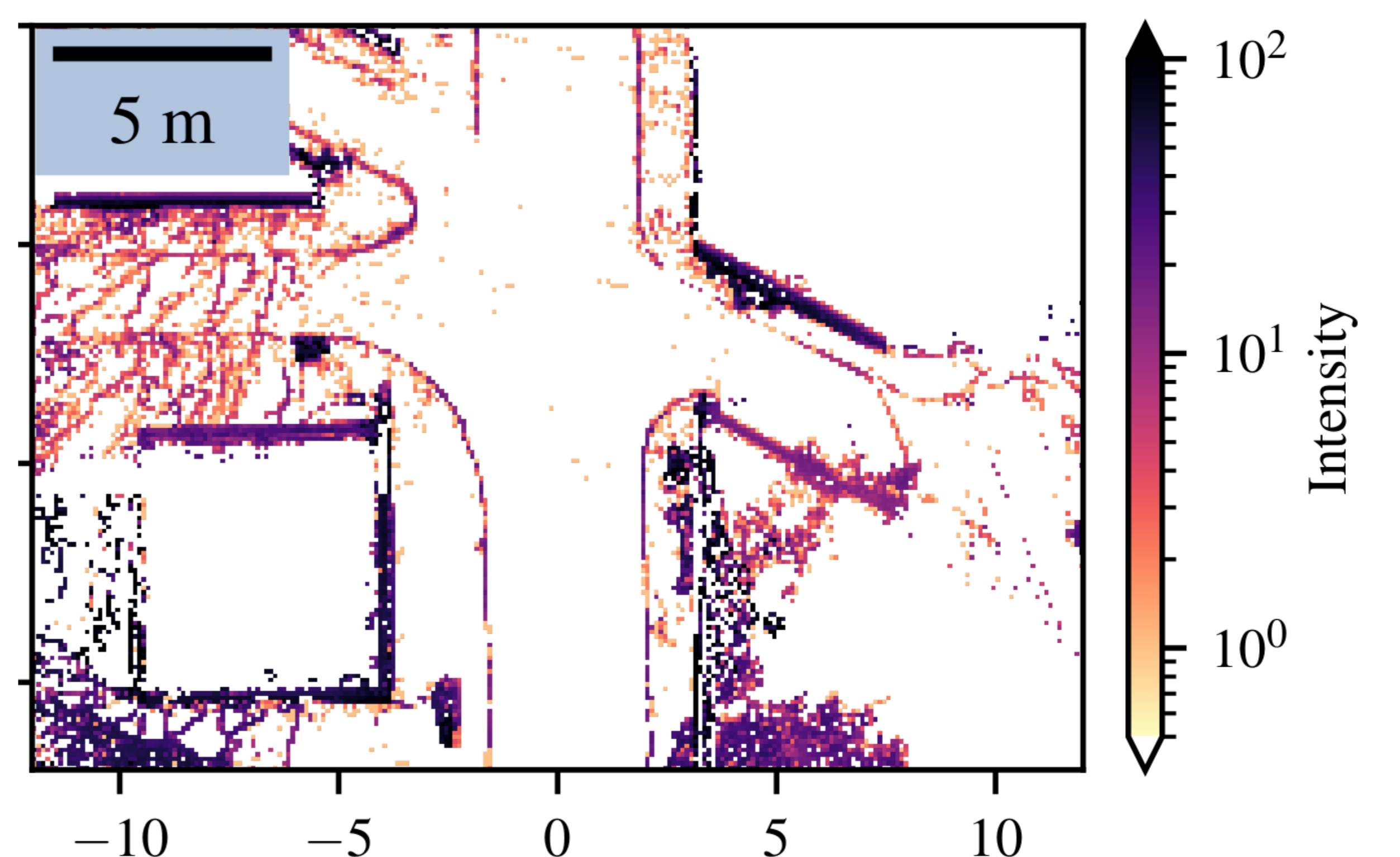


Figure: Lambda-Field computed from the DEM. We can see that curbs and walls have a high intensity, meaning that they are hazardous for the robot.

- ▶ Road curbs and walls have a high intensity, indicating that if the robot goes through, the event of collision will be very likely to occur. As our robot doesn't have any suspension, the VLP-16 experiences some vibration causing some cells (middle of the road) to appear higher/lower than they actually are.

Perspectives

- ▶ We intend to create different Lambda-Field to model different events such as roll over, lane invasion or high deceleration.
- ▶ After fusing several maps into the Lambda-Field for more generic risk assessments, we intend to provide it to a path planning algorithm and control our robot on our test site.