Toward a Generalized Risk Assessment Method on Occupancy Grids

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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.

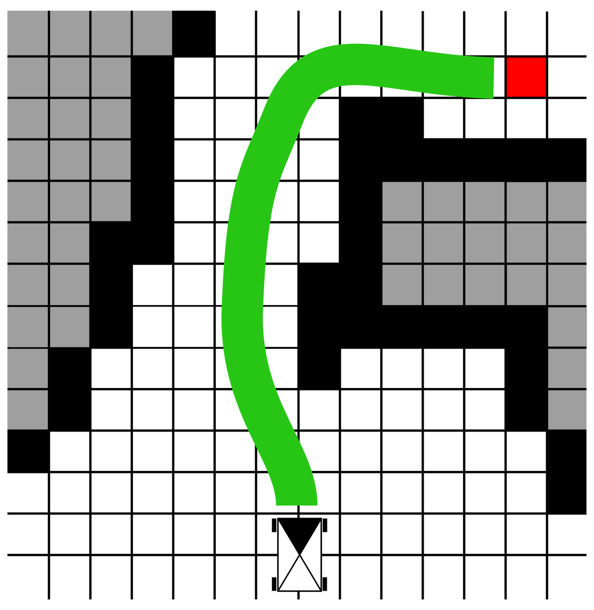

Figure: Even thought the Bayesian Occupancy grid can allow to compute a path to reach a goal, it cannot assess the physical risk for a specific path.

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:

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

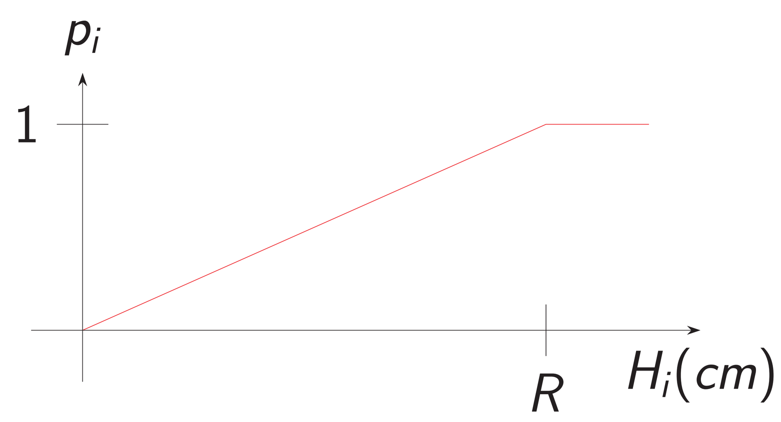

Figure: p_i, the probability to be harmful.

- 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 ($< 5\,\text{cm}$).
u_i	Cell c_i was measured u_i times unsafe ($> 5\,\text{cm}$).
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.

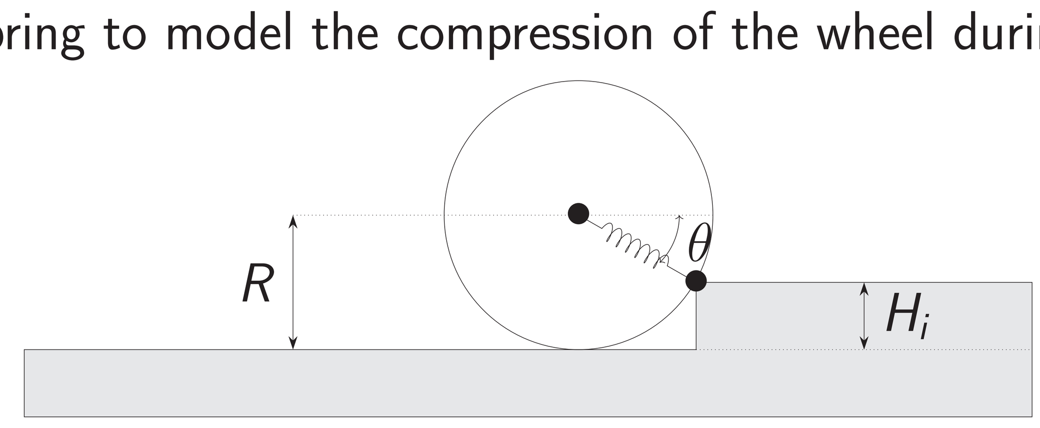

Figure: We model our wheel like a spring that will absorb the collision.

- 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:

$$\mathbb{E}[r(\cdot)] = \sum_{i=0}^{N-1} K_i r(v, H_i), \quad \text{where}$$
$$K_i = exp\left(-\Delta a \sum_{j=0}^{i-1} \lambda_j\right)\left[1 - exp\left(-\Delta a \lambda_i\right)\right] \quad (3)$$

where Δa is the area of each cell.

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.

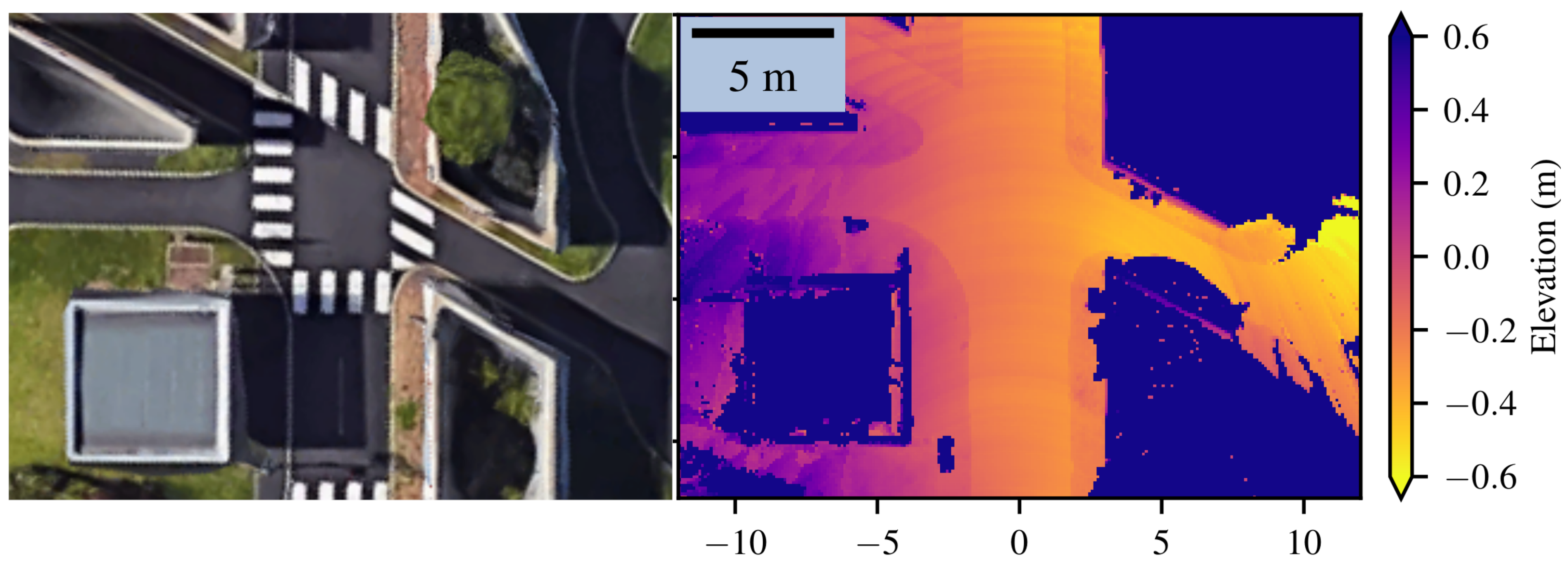

Figure: *Left*: Aerial view from our urban-like test site with sidewalks that may be hazardous. *Right*: DEM is computed from the accumulation of LIDAR points over time.

- Then, we constructed a Lambda-Field using a wheel radius of $R = 25\,\text{cm}$.

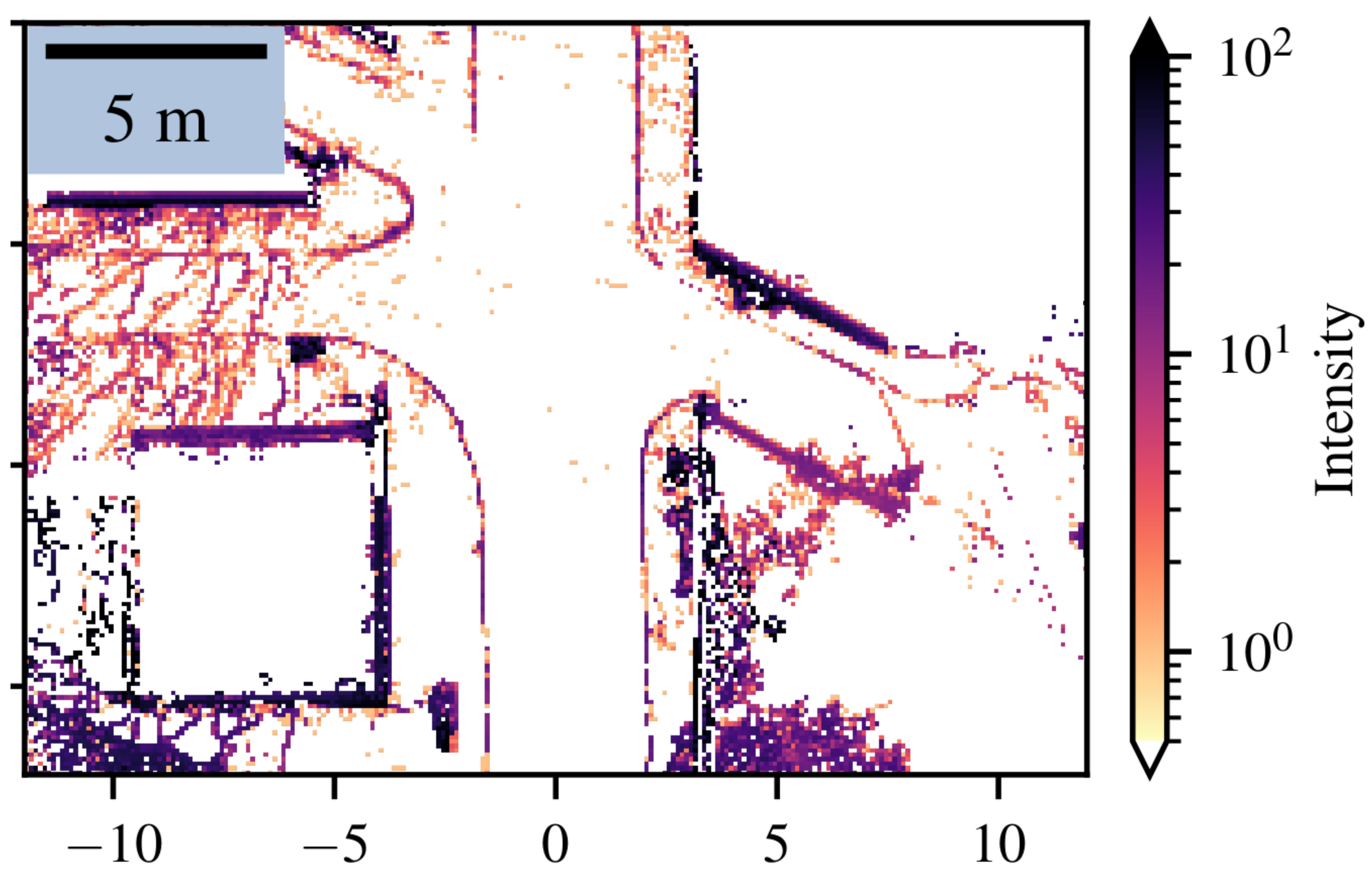

Figure: Lambda-Field computed from the DEM. We can see that curbs and walls have a high intensity, meaning that they are hazardous for the robot.

- 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 then 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.

Acknowledgments and References

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[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.

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