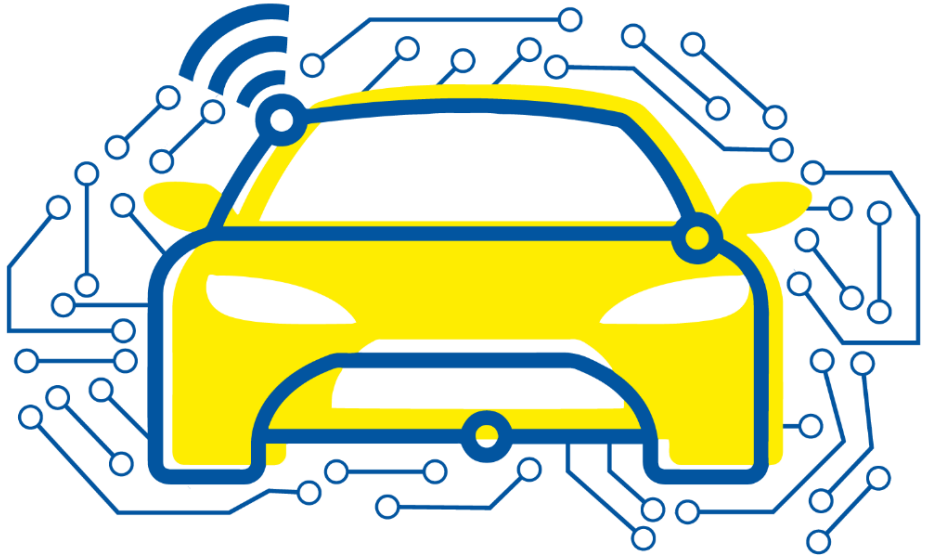
Automated and Connected Driving Challenges

Section 2 – Sensor Data Processing

Point Cloud Occupancy Grid Mapping

Introduction

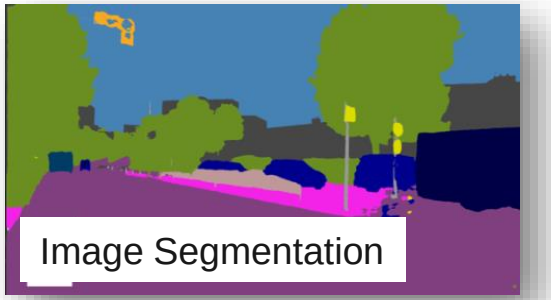


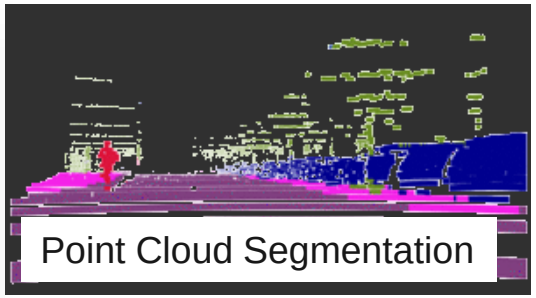
Bastian Lampe

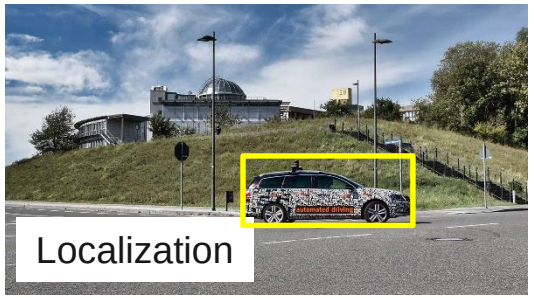
Institute for Automotive Engineering

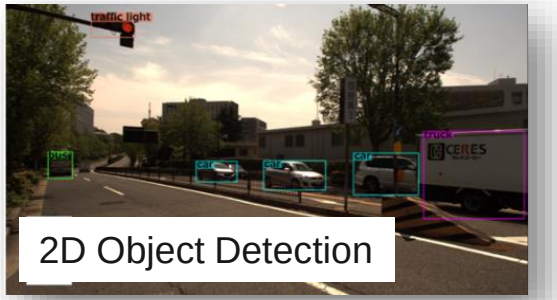
Point Cloud OGM - Introduction

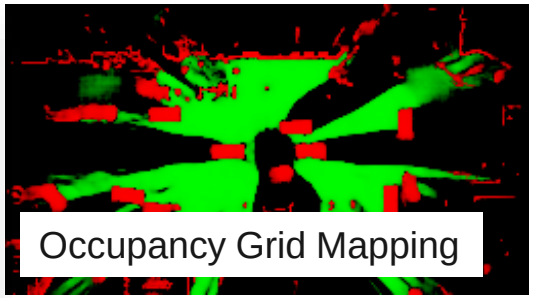
Computer Vision Approaches











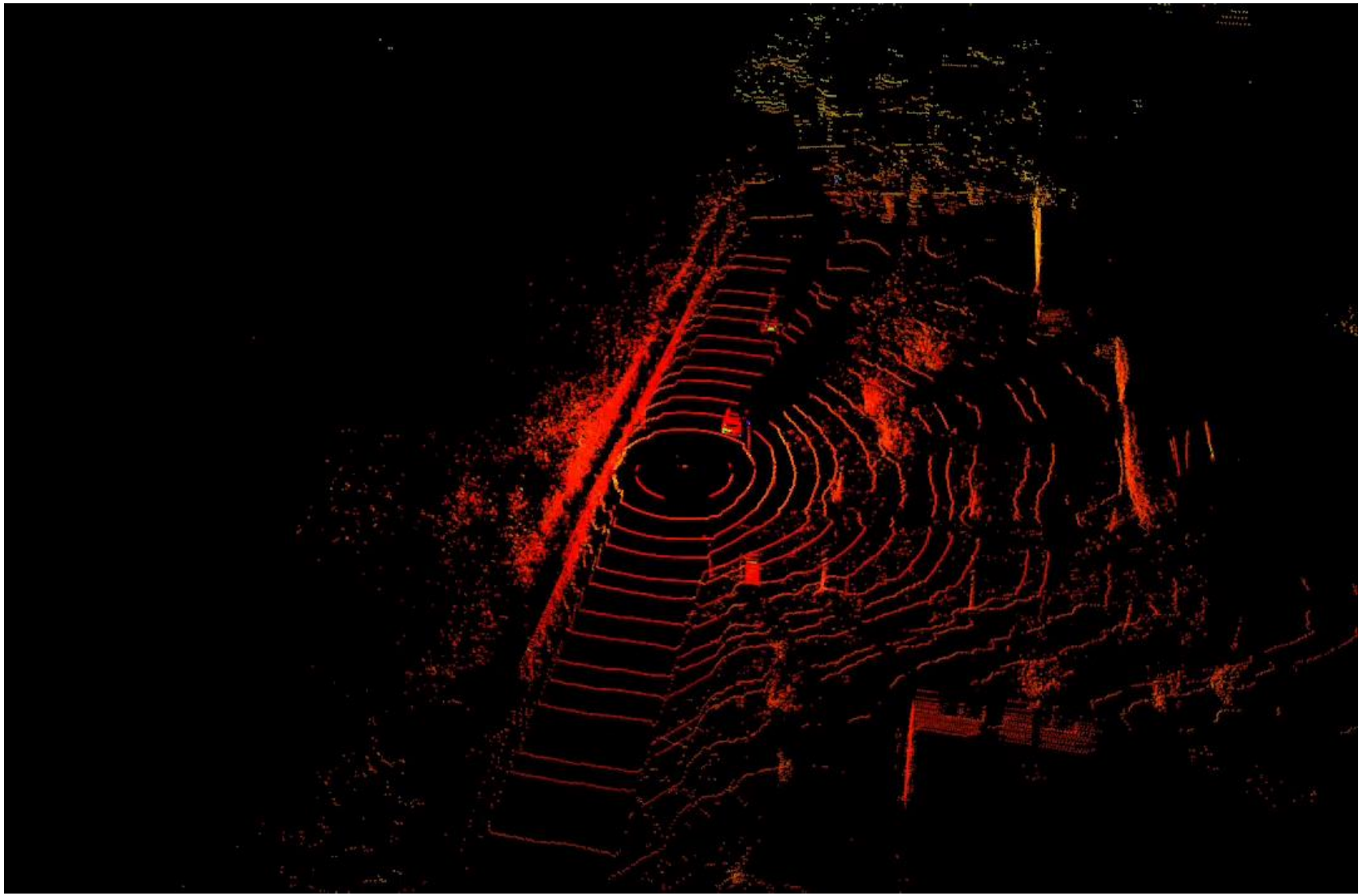
Single Object

Multi Objects

Images: fka, ika

Point Cloud OGM – Introduction

Overview



Video: ika

Point Cloud OGM – Introduction

Overview

- **Goal**: Distinguish drivable from occupied space

- Why?

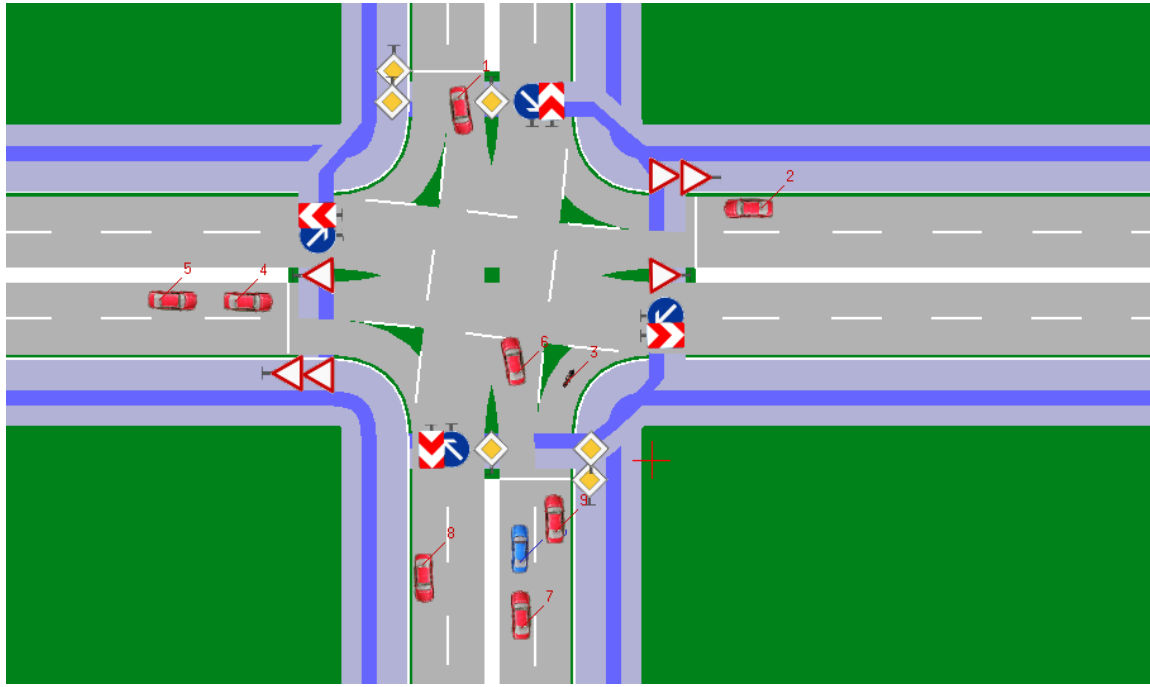


Image: ika

Point Cloud OGM – Introduction

Overview

- **Goal**: Distinguish drivable from occupied space

- Why?
  - HD map may be outdated or insufficient
  - Obstacles may not be recognized correctly
    - Obscure objects can slip through detection algorithms
    - False positive object detections
  - Redundant perception methodologies

Image: welt

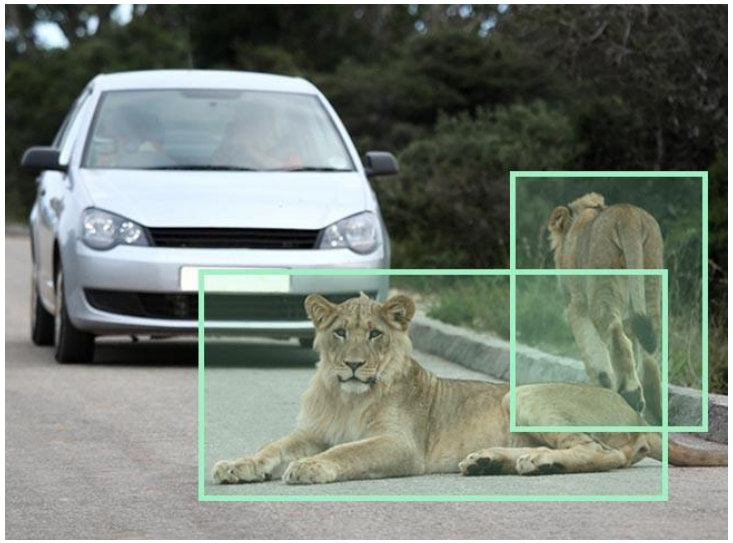
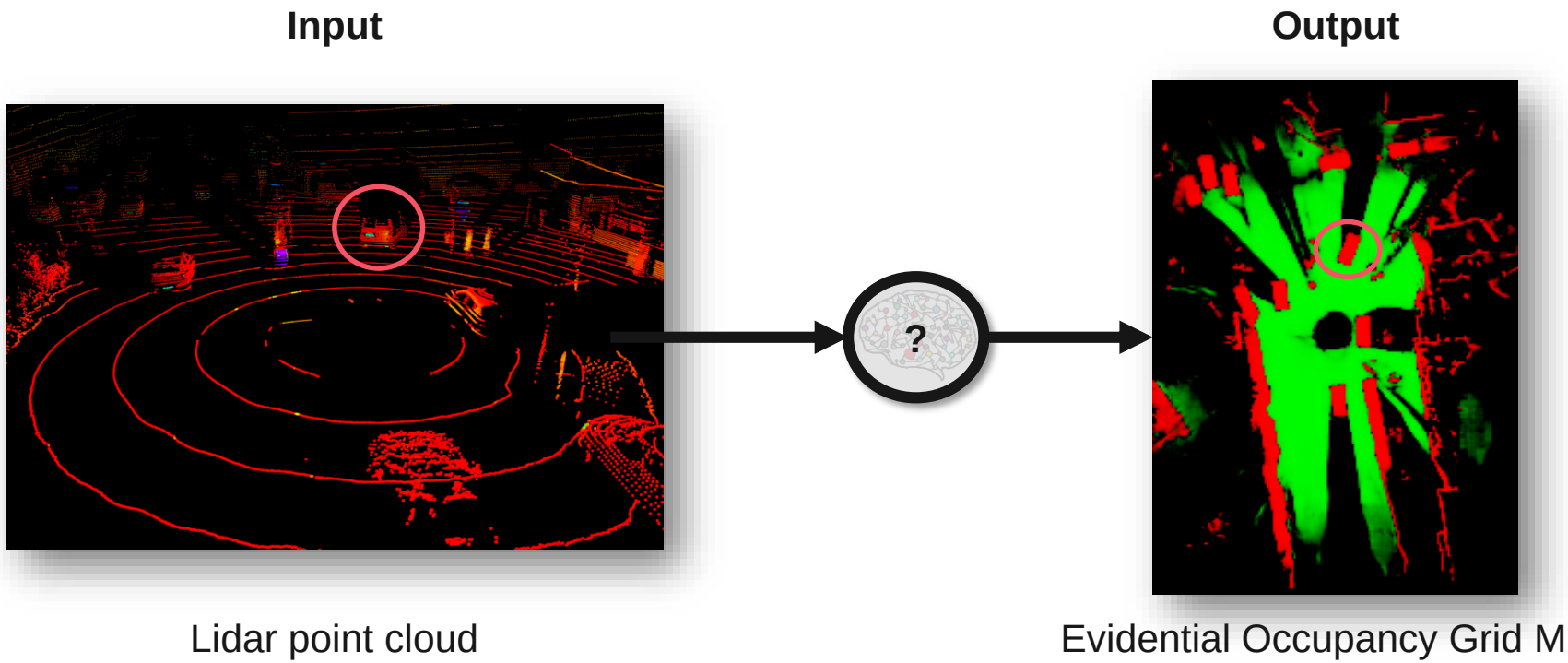


Image: imerit

Point Cloud OGM – Introduction

Overview

- World surface is discretized into **cells**
- Cells contain **occupancy information**

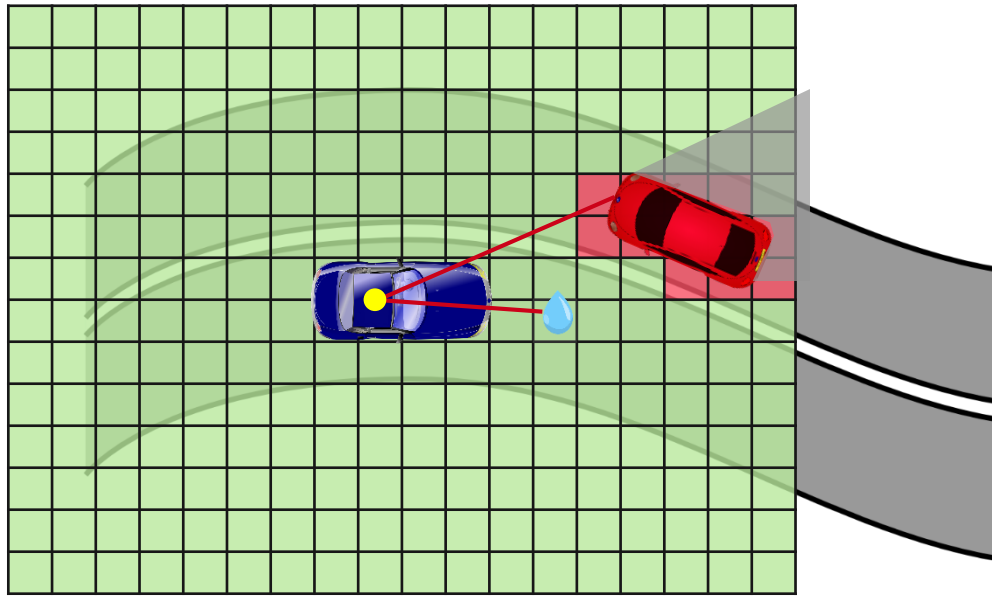


Images: ika

Point Cloud OGM – Introduction

Challenges

- **Challenges?**
  - Identify obstacles and non-obstacles
  - Unobservable areas



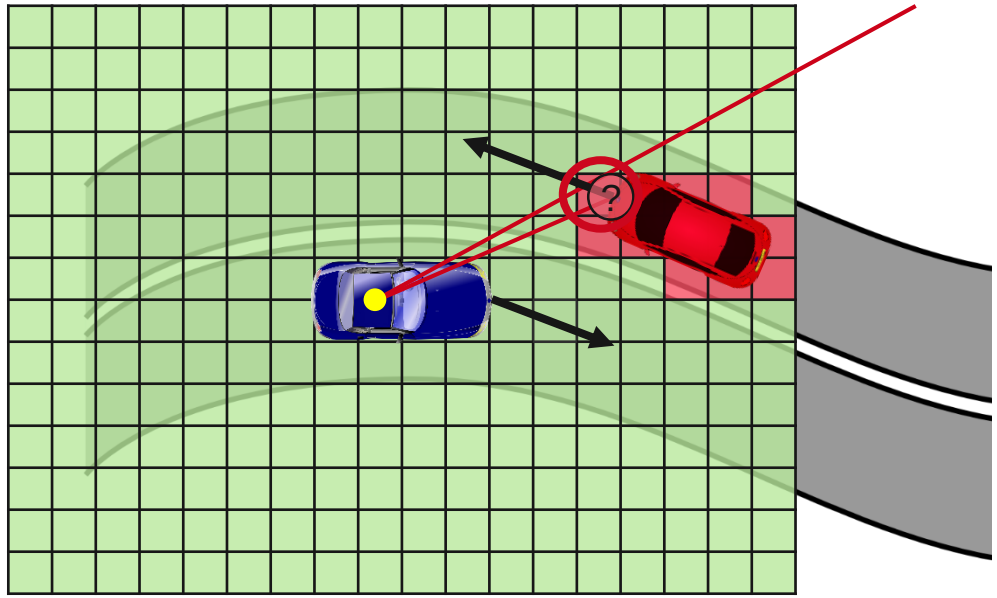
Simplified occupancy grid map

Image: ika

Point Cloud OGM – Introduction

Challenges

- **Challenges?**
  - Identify obstacles and non-obstacles
  - Unobservable areas
  - Conflicting measurements
  - Measurement uncertainty
  - Dynamic environments



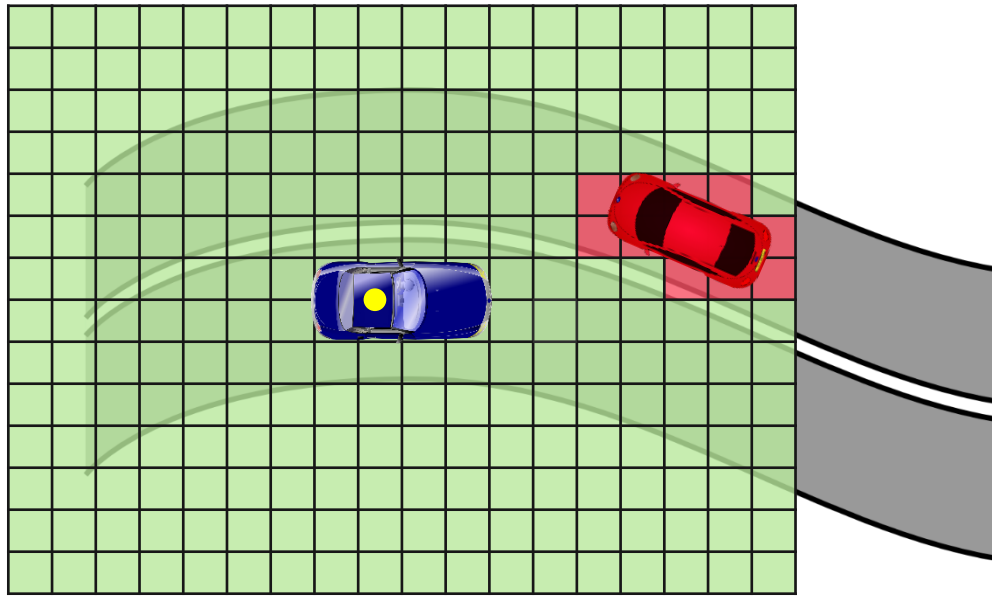
Simplified occupancy grid map

Image: ika

Point Cloud OGM – Introduction

Challenges

- **Challenges?**
  - Identify obstacles and non-obstacles
  - Unobservable areas
  - Conflicting measurements
  - Measurement uncertainty
  - Dynamic environments
  - Real-time capability



Simplified occupancy grid map

Image: ika

Point Cloud OGM – Introduction

Grid Map Representation

- Data Size (e.g. with float64 values):

$$S = \frac{W \cdot L}{C^2} \cdot D \cdot sizeof(\text{float64})$$
$$= \frac{150\ m \cdot 60\ m}{(0{,}3\ m)^2} \cdot 1 \cdot 8\ Bytes$$
$$\approx 781\ kB$$

→ efficient processing algorithms required

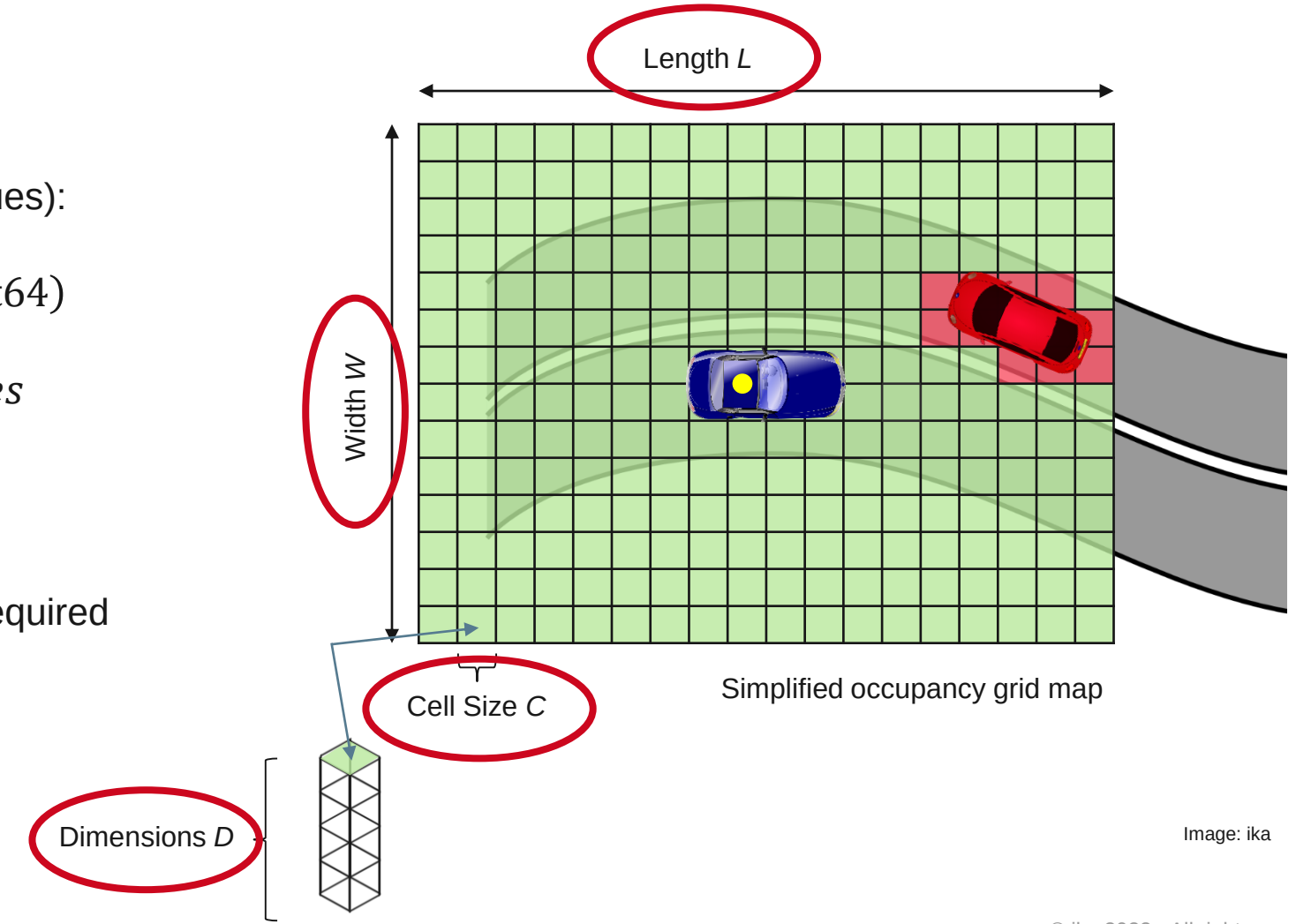
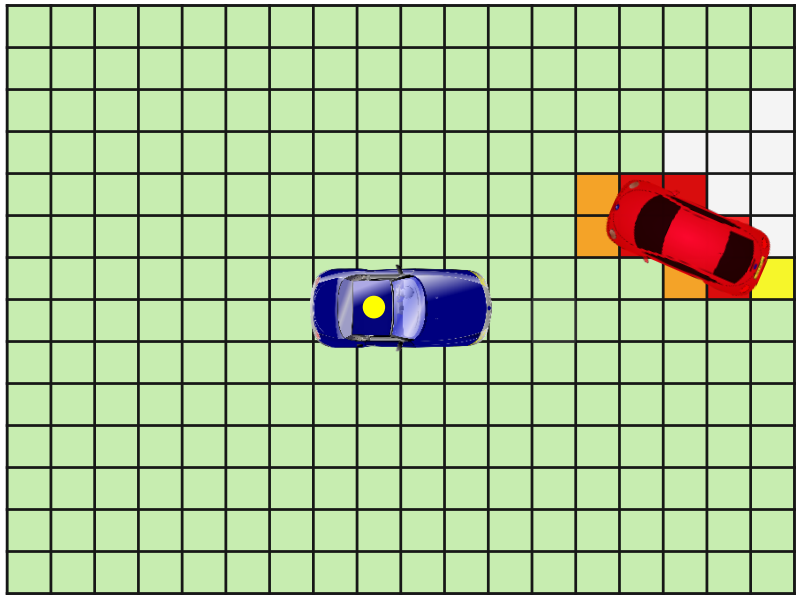


Image: ika

Point Cloud OGM – Introduction

Grid Map Representation

- Probablistic Occupancy Grid Maps
  - Probability of a cell being occupied (50 % = unknown)
  - Cannot distinguish between uncertain and unknown areas



- Evidential Occupancy Grid Maps
  - Each cell contains two belief masses:
    - b_O belief mass for the cell being occupied
    - b_F belief mass for the cell being free
  - Allows expressing **conflicting evidence**

$$0 \leq b_o \leq 1$$

$$0 \leq b_F \leq 1$$

  - Uncertainty mass $0 \leq u \leq 1$ addresses **uncertainty**

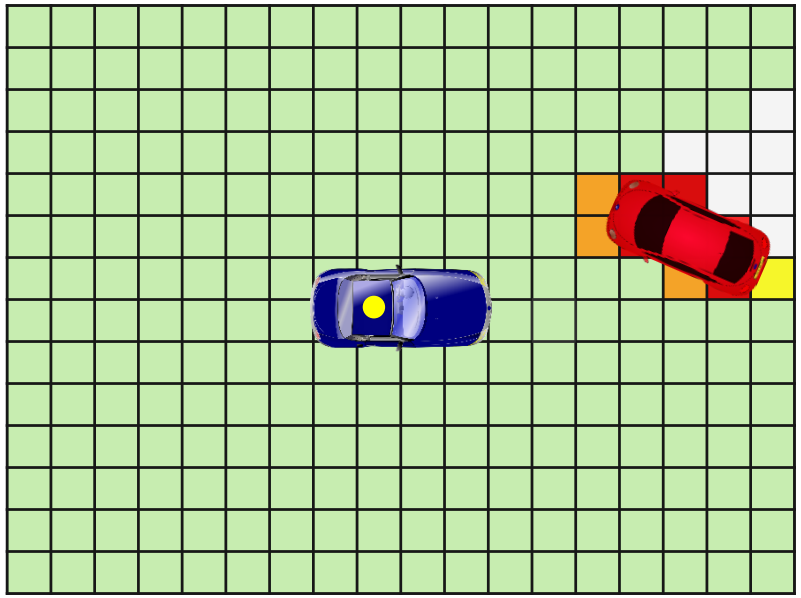
$$b_O + b_F + u = 1$$

Images: ika
Sources: Thrun et al. 2000, Reineking et al. 2014, Nuss et al. 2016

Point Cloud OGM – Introduction

Grid Map Representation

- Probablistic Occupancy Grid Maps
  - Probability of a cell being occupied (50 % = unknown)
  - Cannot distinguish between uncertain and unknown areas
  - Measurements can be combined using a binary Bayes filter



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  - Uncertainty mass $0 \leq u \leq 1$ addresses **uncertainty**

$$b_O + b_F + u = 1$$

  - Measurements can be combined using **subjective logic**
  - Belief masses can be computed from **evidence**, e.g. computed by a **deep neural network**

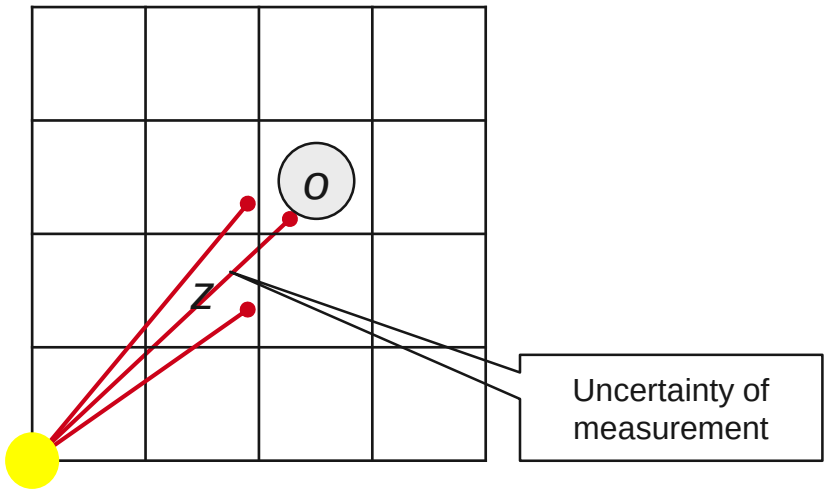
Images: ika
Sources: Thrun et al. 2000, Reineking et al. 2014, Nuss et al. 2016

Point Cloud OGM – Introduction

Inverse Sensor Models

- A **sensor model** approximates **sensor data** given a world model.
- What is the probability of a measurement in cell *z* if an obstacle is in cell *o*?

$$p(z|o)$$



- An **inverse sensor model** approximates a **world model** given sensor data.
- What is the probability of cell *x* being occupied given a reflection point in cell *z*?

$$p(o|z)$$

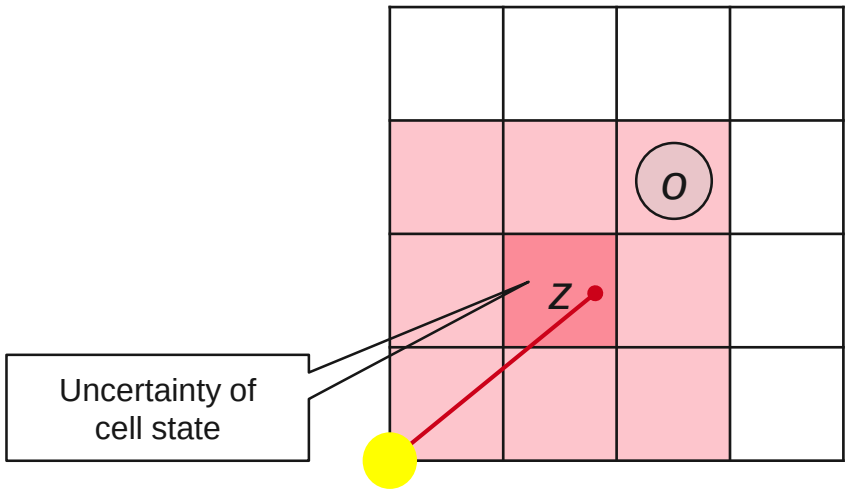


Image: ika

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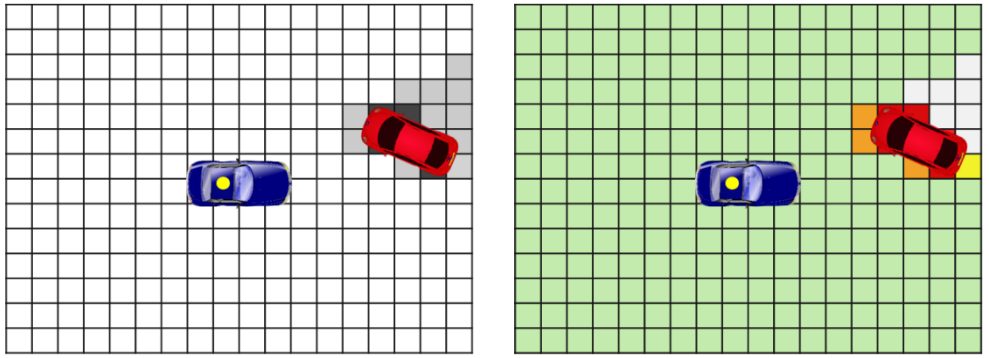
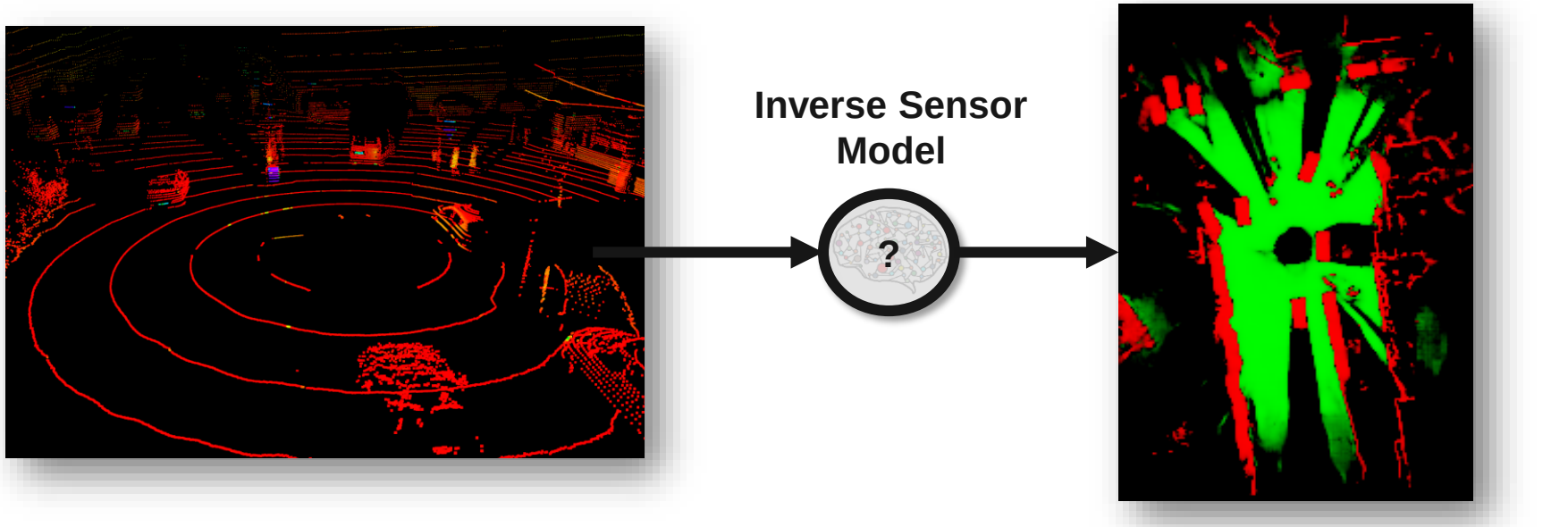
Summary

- **Free vs. occupied** areas in the vehicle's environment
- **Probablistic vs. evidential** occupancy grid maps



Input **Output**



Lidar point cloud

Evidential Occupancy Grid Map

Images: van Kempen et al. 2021, ika