



ECTRI – FEHRL – FERSI
Young Researchers Seminar 2015

High Performance Database for Automated World Modeling

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Knowledge for Tomorrow

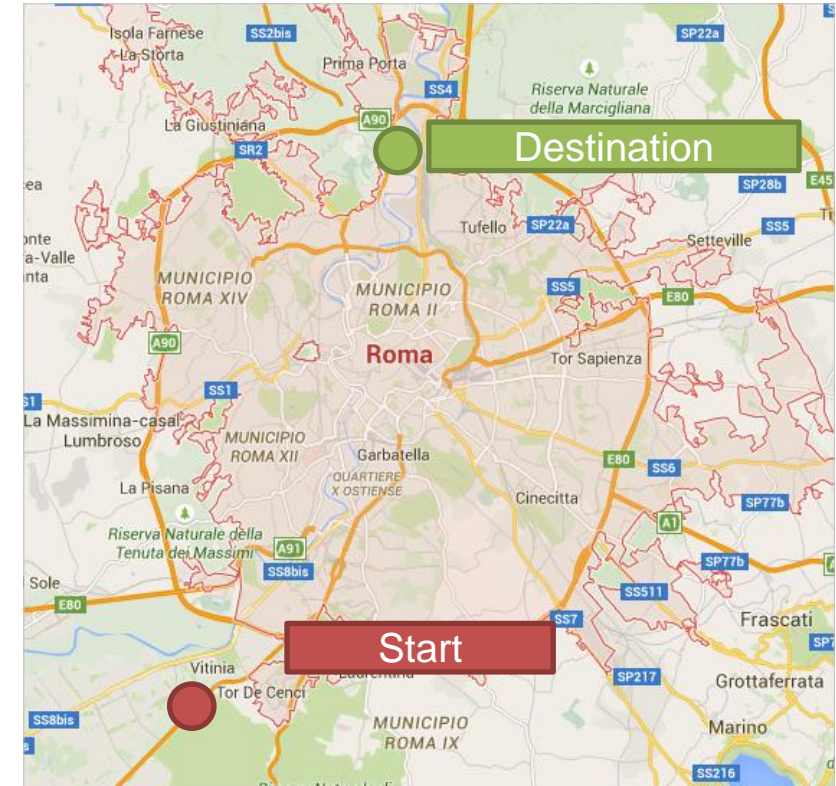


Background – Autonomous Vehicles



What an autonomous car must do:

1. Plan the route to destination - Use a map



Background – Autonomous Vehicles



What an autonomous car must do:

2. Find the current location while driving – Use GPS



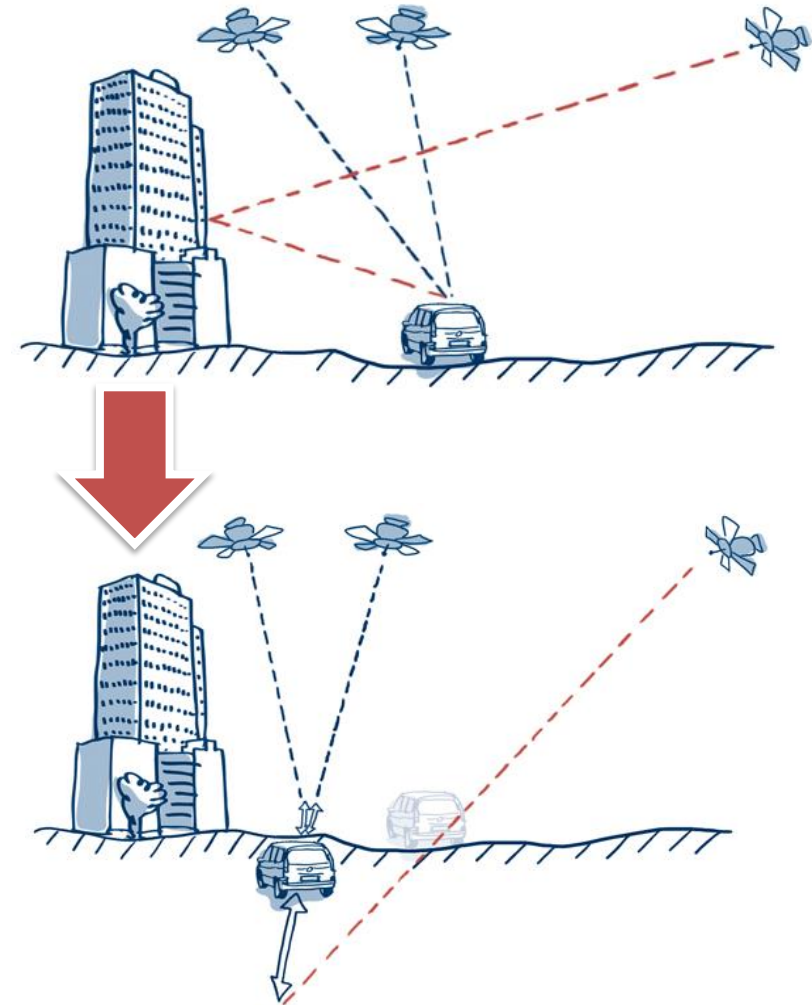
Background – Autonomous Vehicles



2. Find the current location while driving – Use GPS

BUT: GPS has a too large uncertainty

- The error can be up to 100m
- The car will likely not stay in a lane and crash as soon as it enters an urban area or a tunnel.
- More accurate localization is required.



Background – Autonomous Vehicles

2. Find the current location while driving

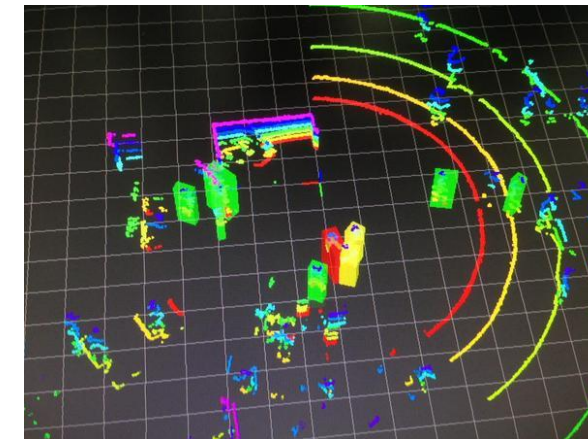
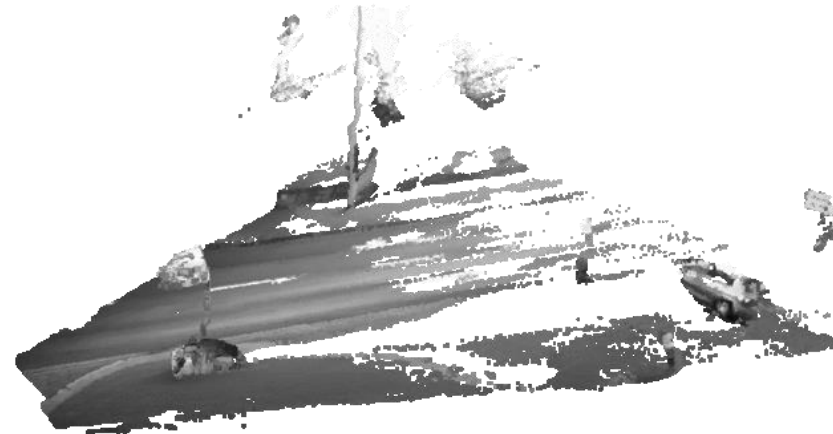
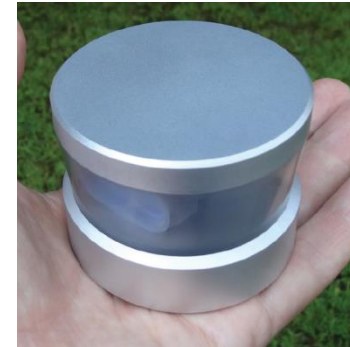
Approach:

Use 3D Sensors to sense the environment



3D Scanner (LIDAR)

Stereo Camera



Background – Autonomous Vehicles



Approach:

Use 3D Sensors to sense the environment

BUT2: No forecast: High speed driving is impossible.

- Sensors can only „see“ up to 30 meters
- Recognition quality decreases quadratically with the distance

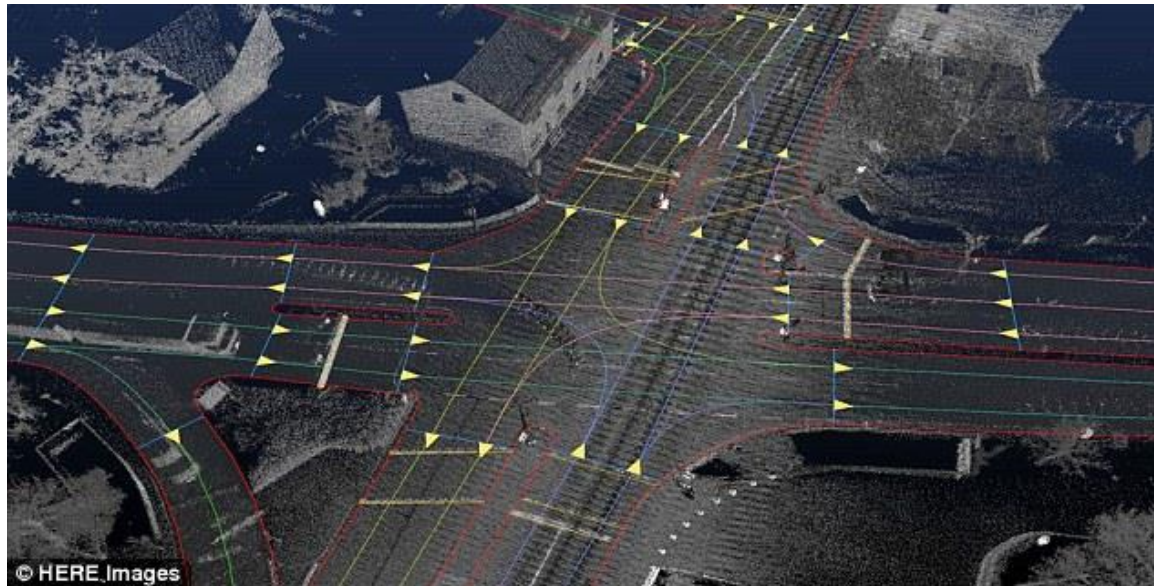


Background – Autonomous Vehicles

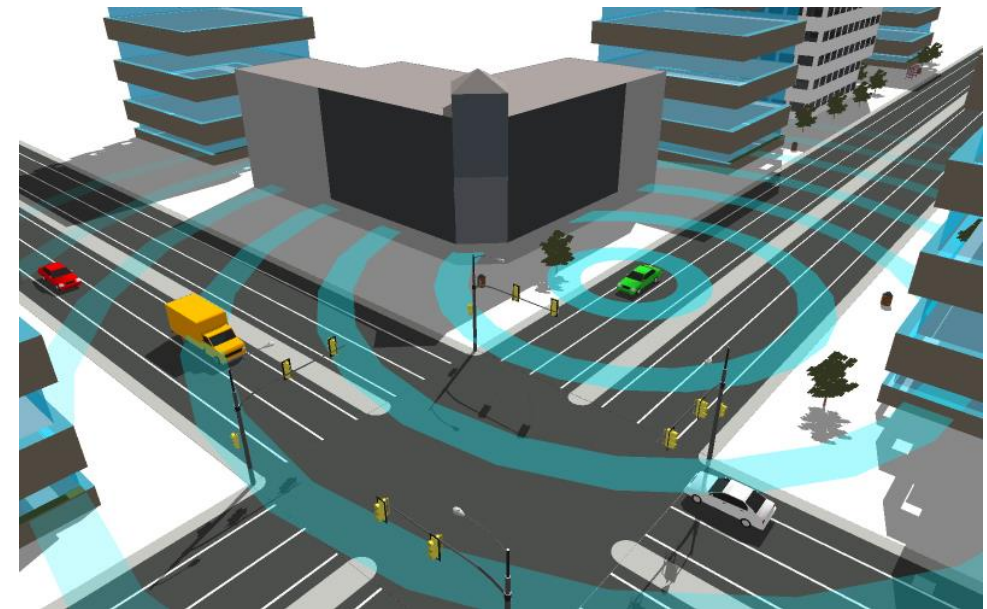


Current research focus:

Interconnected vehicles and high resolution world maps updated in real time.



High resolution map concept: lanes, driving paths, static obstacles



Transmitting observations to neighbouring cars

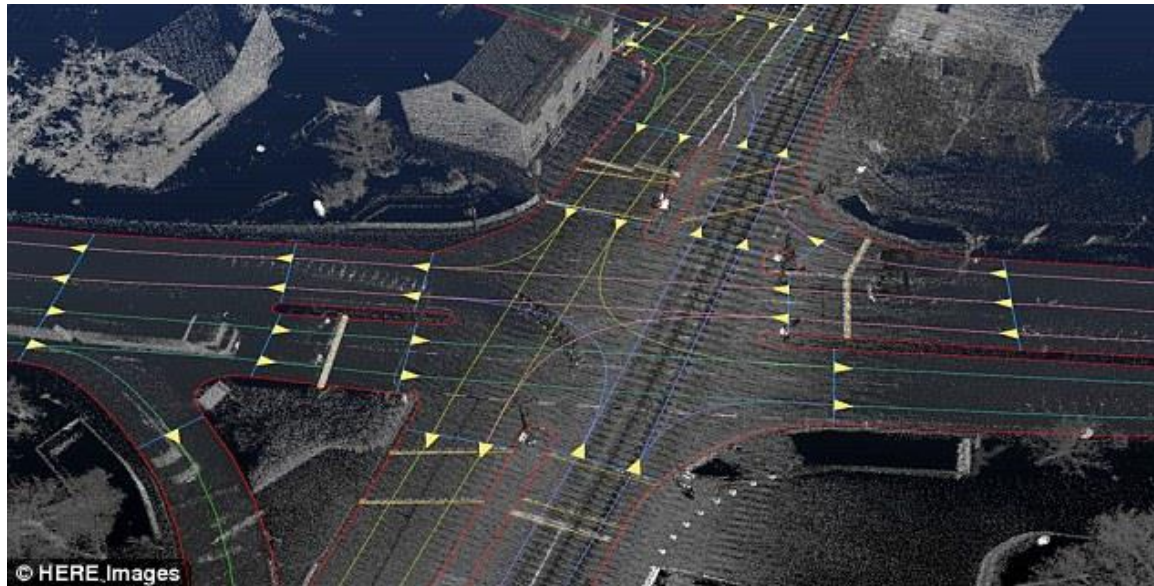


Background – Autonomous Vehicles



Current research focus:

Interconnected vehicles and high resolution world maps updated in real time.



HD map concept from HERE: lanes, driving paths, static obstacles

Challenges:

- For efficient world updates a novel data structure is required
- Huge data sets need to be considered (43GB per hour per vehicle)
- Handling noise in data



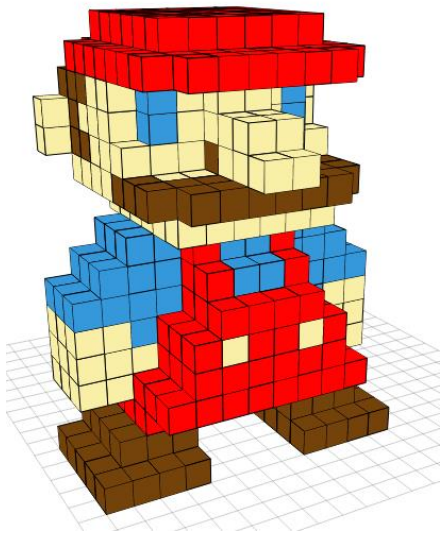
Research objectives

1. Development of a 3D database enabling storage of geometrical models or 3D maps of unlimited size.
2. Integrate multiple levels of detail for efficient transmission and visualization.
3. Develop a 3D modelling technique for building a 3D world model from 3D sensor data.



Data structure for unlimited 3D models

Voxel representation



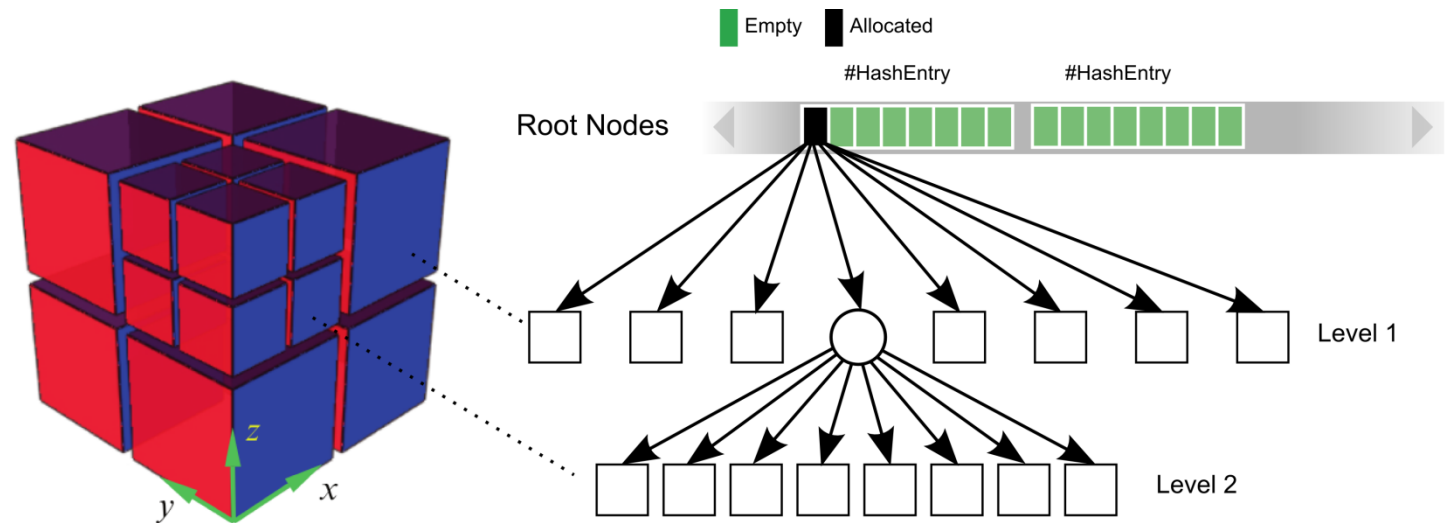
Similar to images, a voxel is a 3D pixel

Levels of detail (LOD)



Data structure for unlimited 3D models

- Organize the voxels (cubes) in a hierarchical tree.
- Store each tree in a hash-map.



| Method | Access time | Max. resolution |
|---------------------------|--------------|--------------------------|
| Octree ($d = 16$) | $6.43 \mu s$ | $32768^3 (327m)^3 @ 1cm$ |
| Octree [5] ($d = 16$) | $2.55 \mu s$ | $32768^3 (327m)^3 @ 1cm$ |
| Hashed-Octree ($d = 2$) | $0.45 \mu s$ | ∞ |

Access time for different data structures.

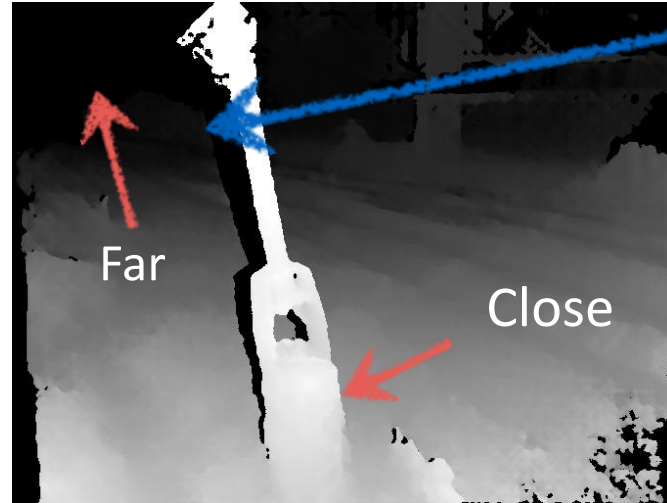


3D Modeling

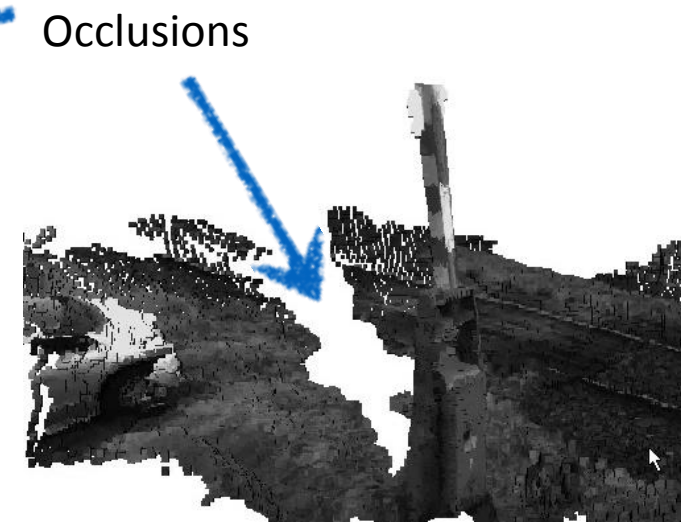
Input range camera data:



Original Image



Depth Map

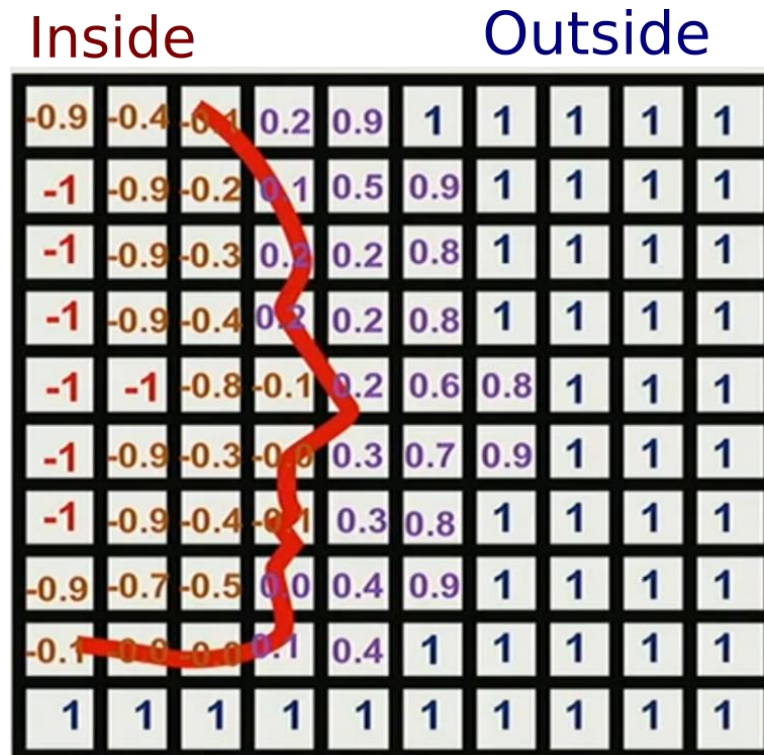


3D point Cloud



3D Modeling

Introducing „implicit voxels“:



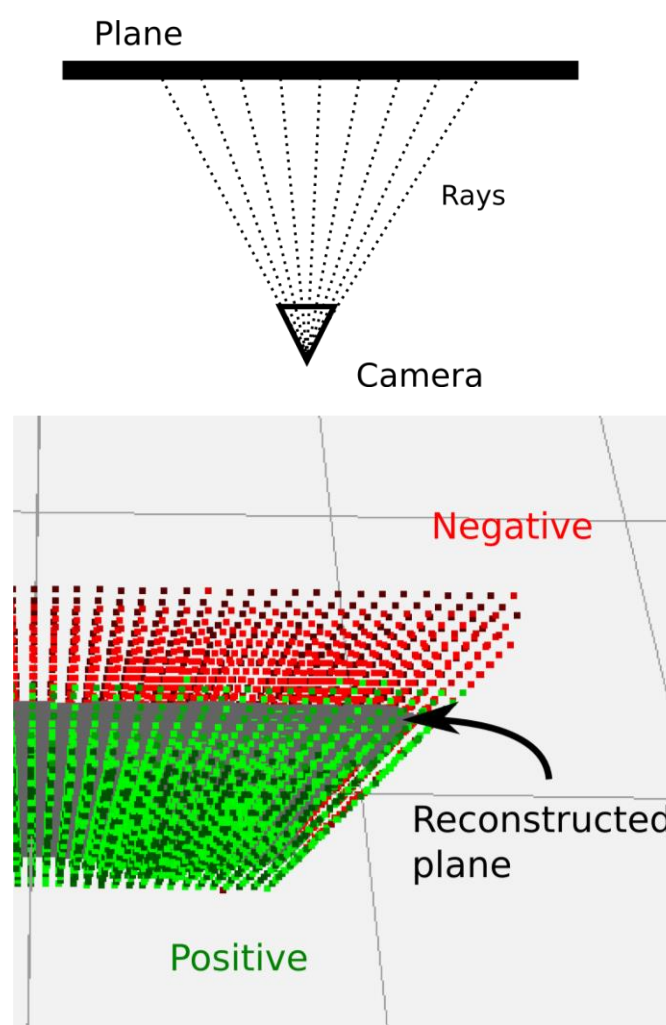
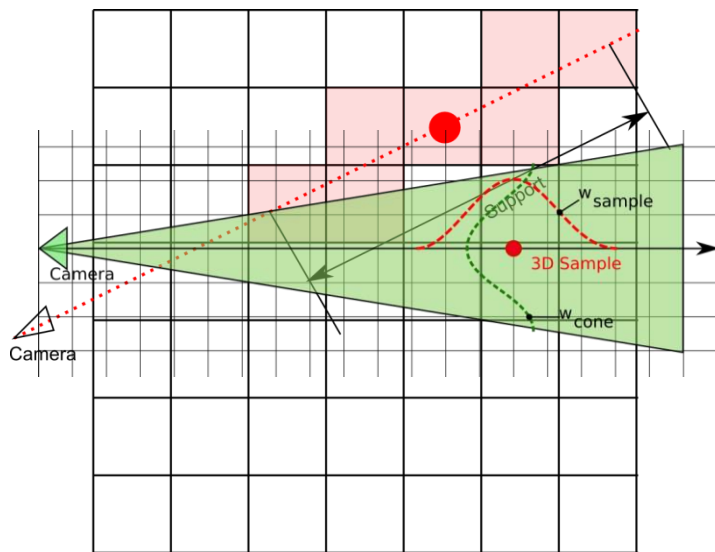
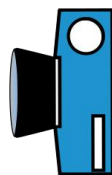
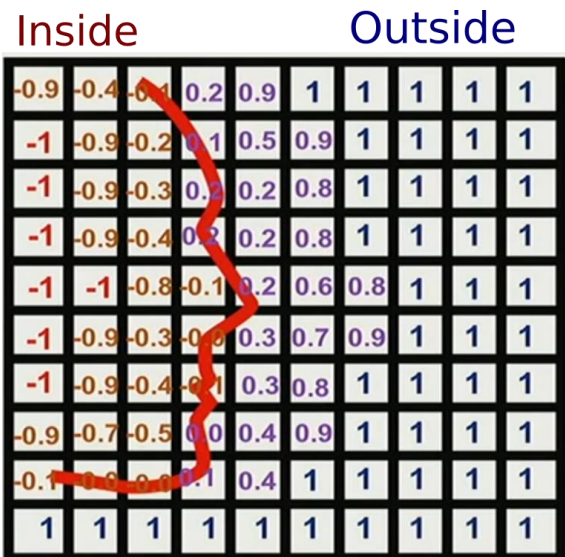
$V < 0$: Inside of an object

$V > 0$: Outside of an object



3D Modeling

Introducing „implicit voxels“:



$V < 0$: Inside of an object

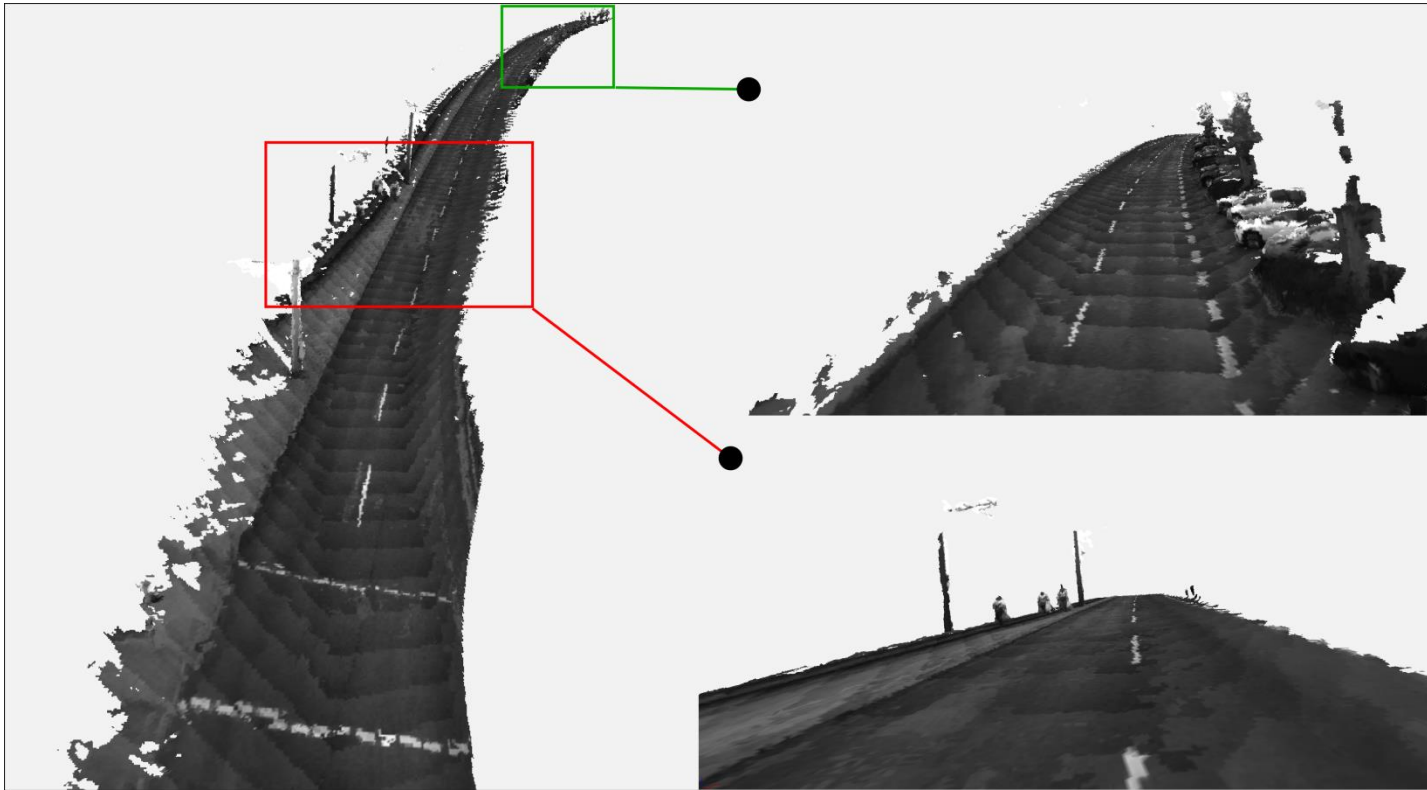
$V > 0$: Outside of an object

Restrict the area around the measurement ●



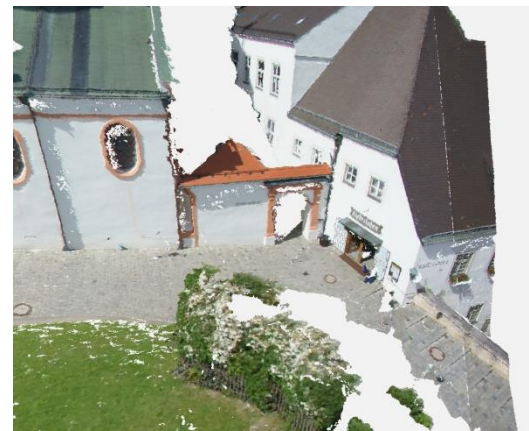
3D Modeling

Application demo 1:



3D Modeling

Application demo 2:



Future Directions

- Integrate the voxel modeling approach into a cloud architecture (OutOfCore)

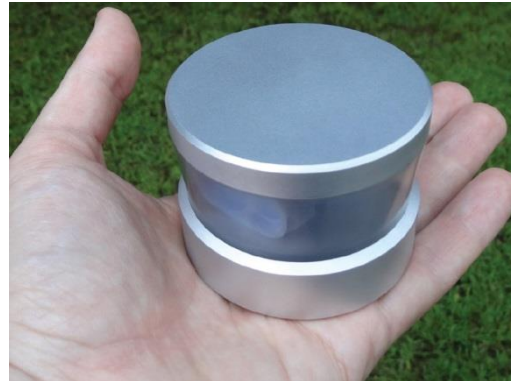


Future Directions

- Develop open API (interfaces) for other common sensors



Google Tango



Lidar

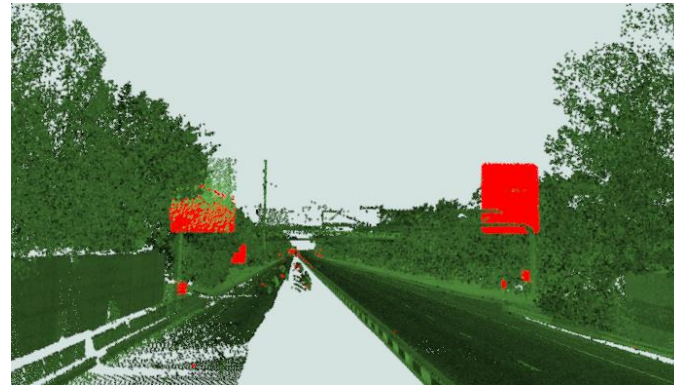


Any other mobile 3D sensors



Future Directions

- Integrate object recognition and visualization



Summary

- An efficient database structure for automated world modelling has been developed
- Implementation on standard computer hardware (no GPU) has been validated
- The size of the world is only limited by the physical memory



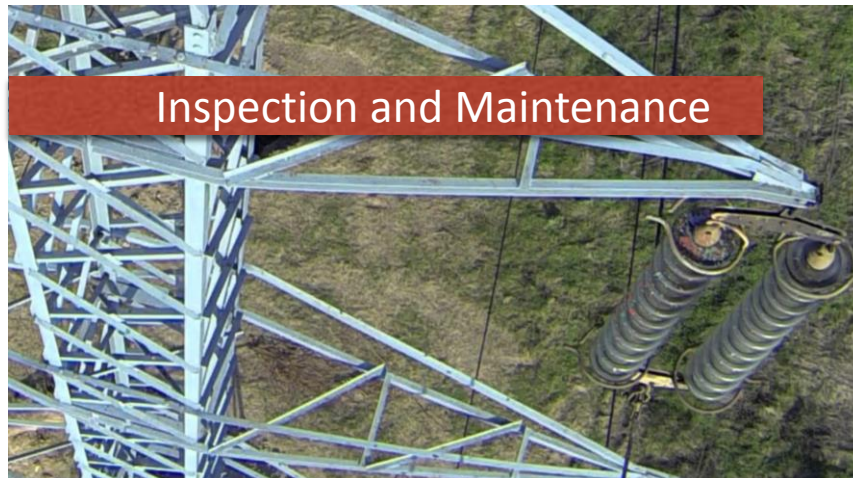
The Impact



Kiva systems



Local Motors



FAE Drones



Thank you

Eugen Funk

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