Sensor Fusion and Calibration of Velodyne LiDAR and RGB Camera

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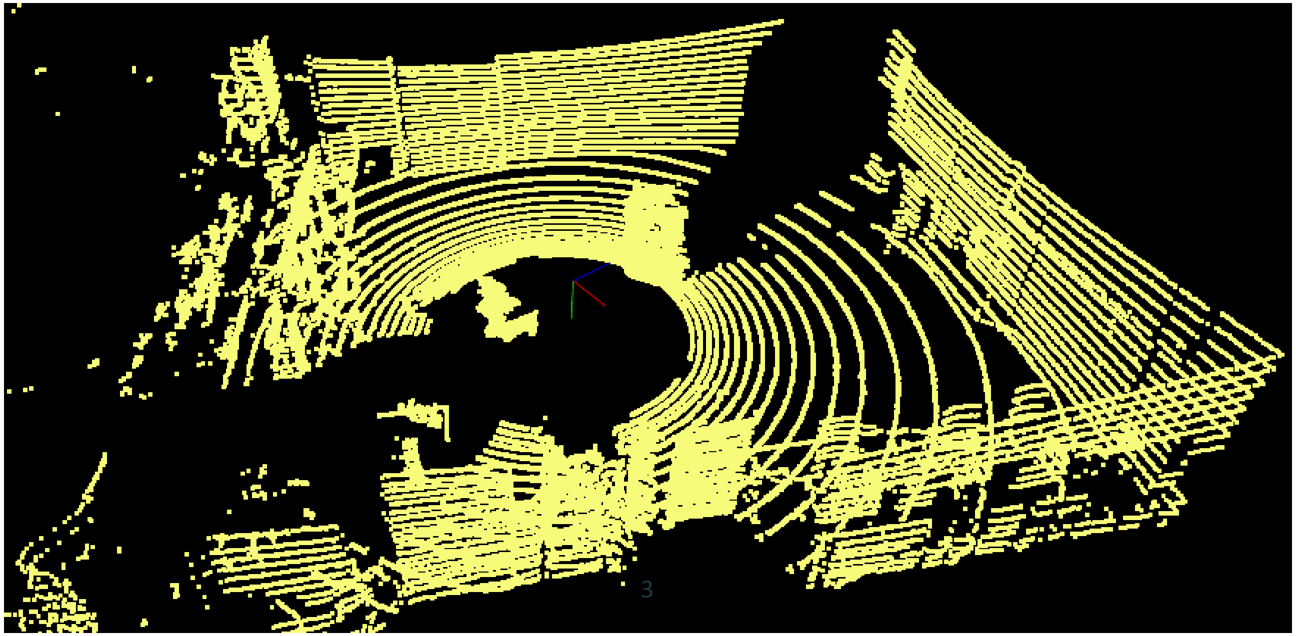
What is Velodyne LiDAR?

- LiDAR = Light Detection and Ranging
- HDL-32: 32 lasers scan the area around the sensor
- Beam is rotating (10Hz)
- Field of view
  - Horizontal 360°
  - Vertical <-30°; +10°>
- 70m range, 2cm accuracy

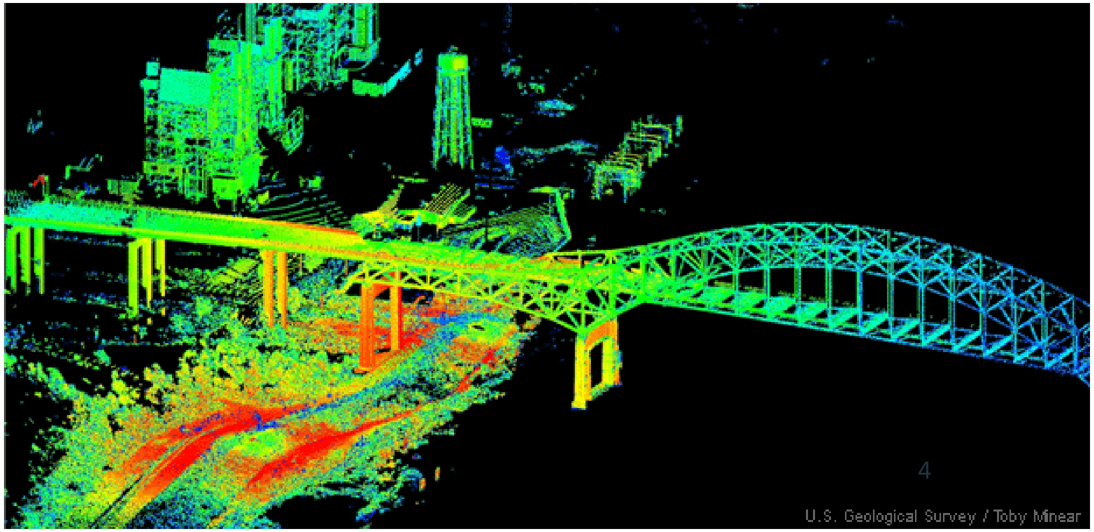
The data provided by Velodyne

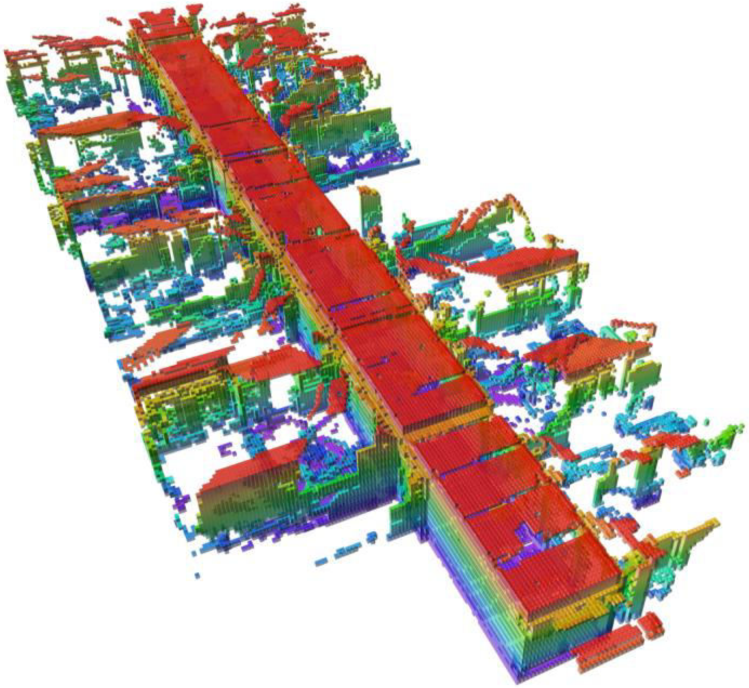
- Point cloud
- Velodyne captures 700k points per each scan (7M pt/s)
- Points are organized into the „rings“
  - ring = points captured by one lasser scanner/ray (32 rings)



Practical application (1/3)

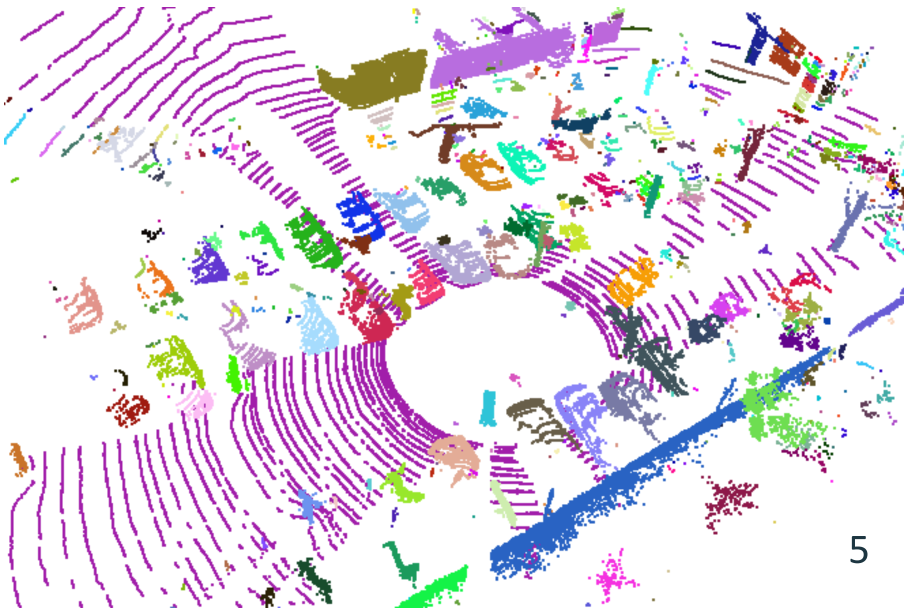
- Merging the point cloud (with proper alignment)
- 3D reconstruction (GPU acceleration)
- Creation of the environment map
  - Large data

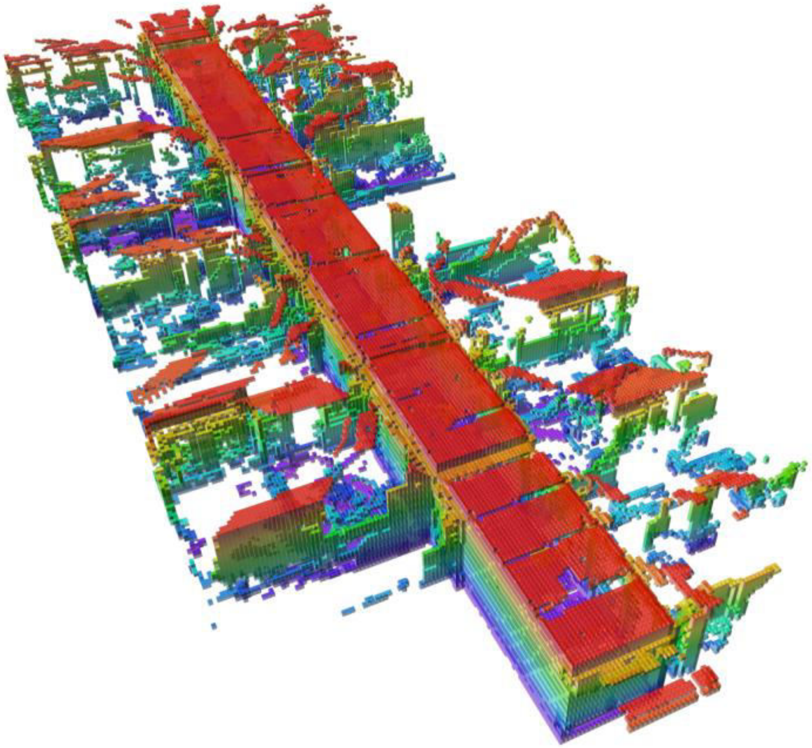




Practical application (2/3)

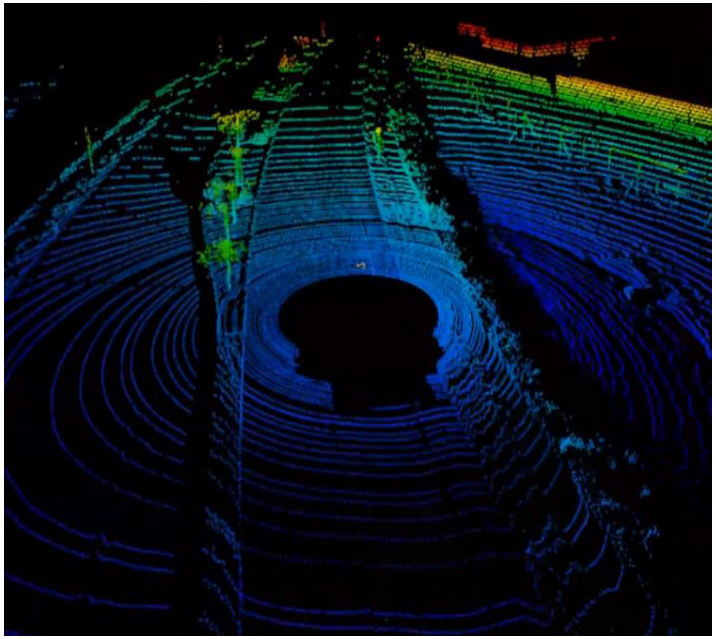
- Robotics ☺
- Navigation in 3D environment (using the map)
- Obstacle avoidance
- Object detection





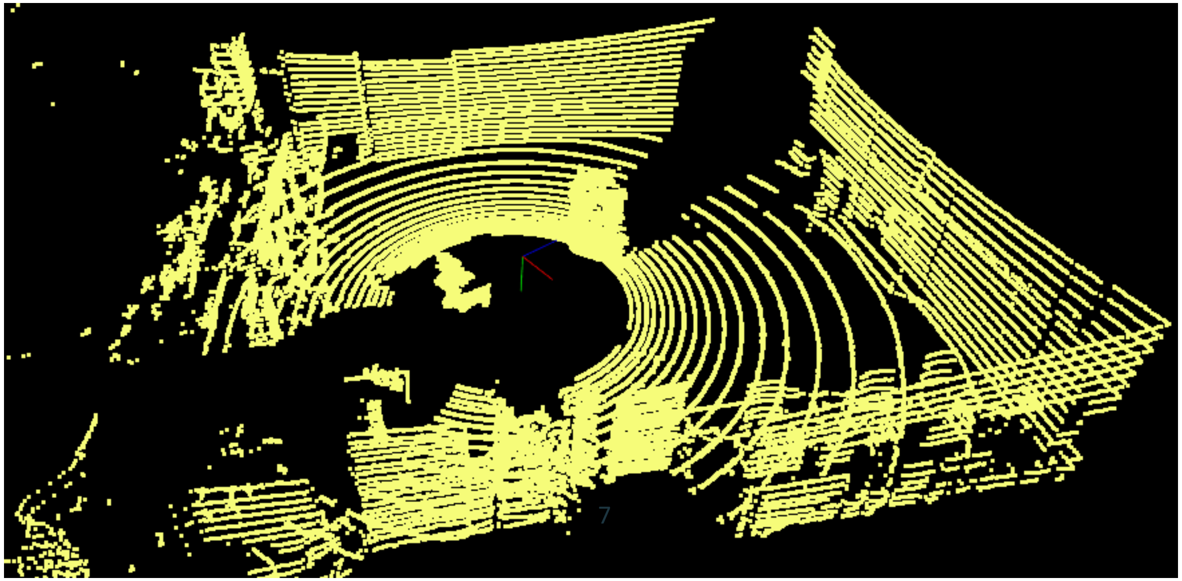
Practical application (3/3)

- **Google car**
  - Autonomous vehicle
  - Successful in **DARPA** Urban Challenge
  - Using Velodyne HDL-64
  - Navigation in the urban environment



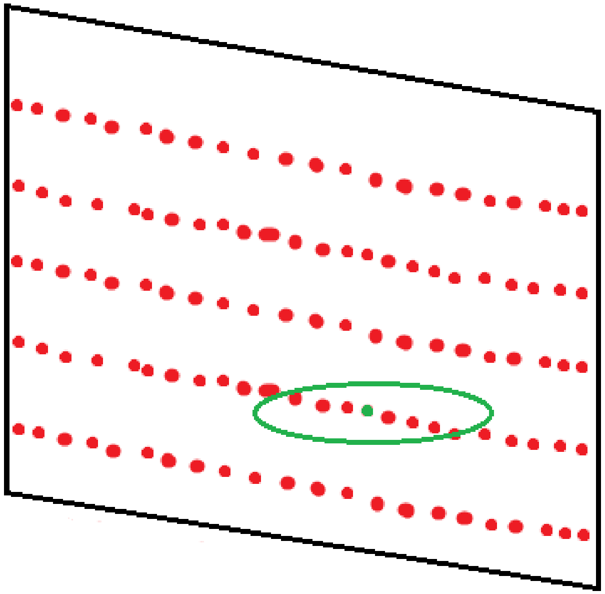
Common issues with Velodyne data

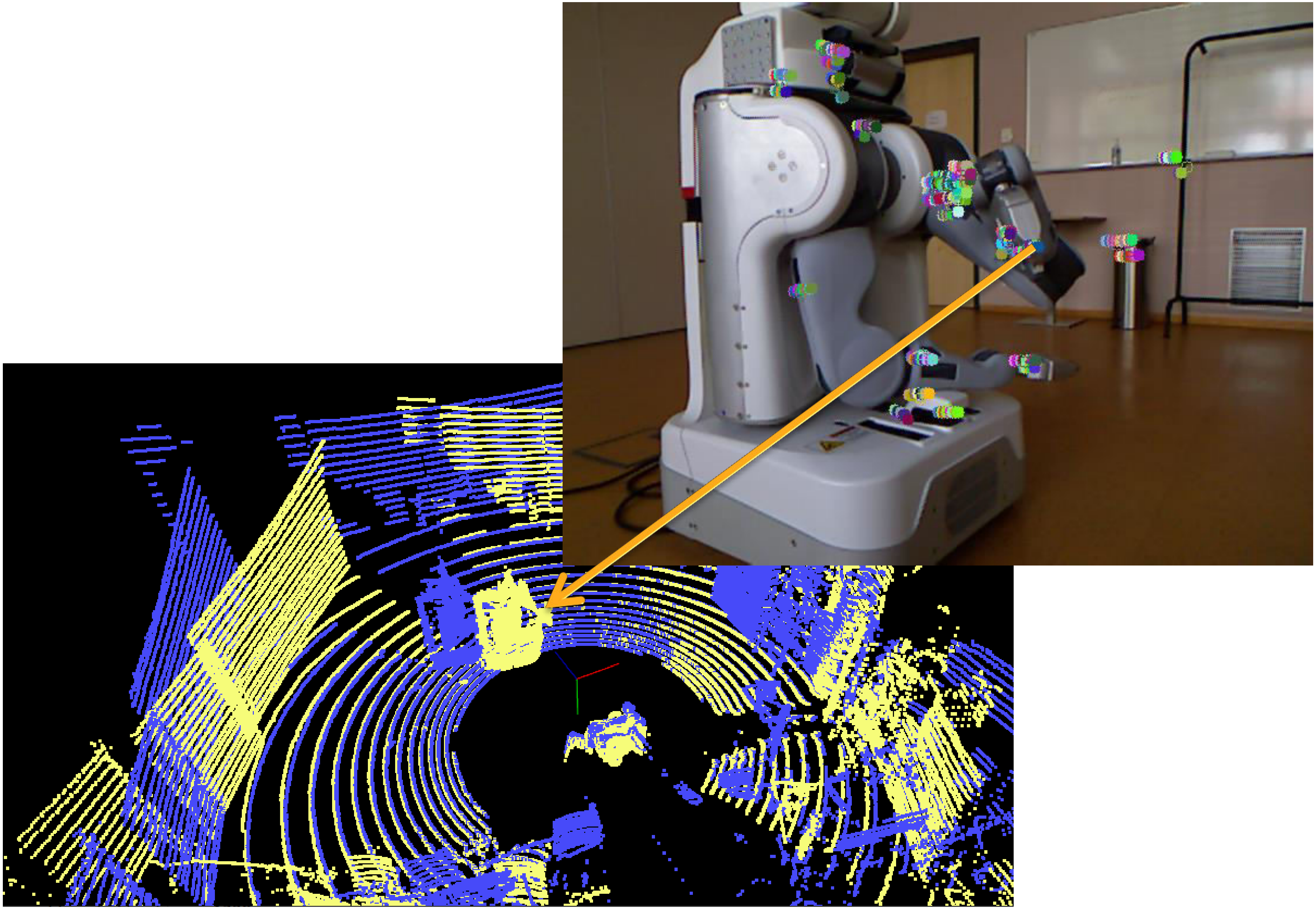
- Captured data are really large (7M pt/sec)
  - 20s record ~1GB
- Velodyne point cloud are very sparse
  - Large „gaps“ between the rings



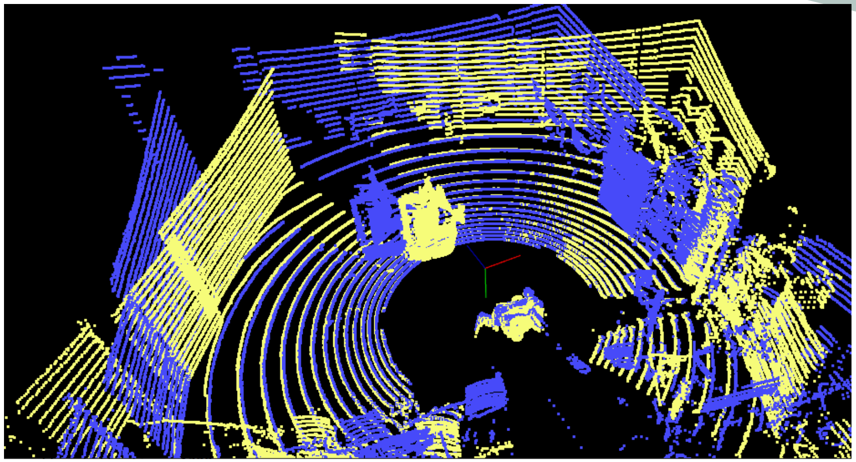
How to extract features?

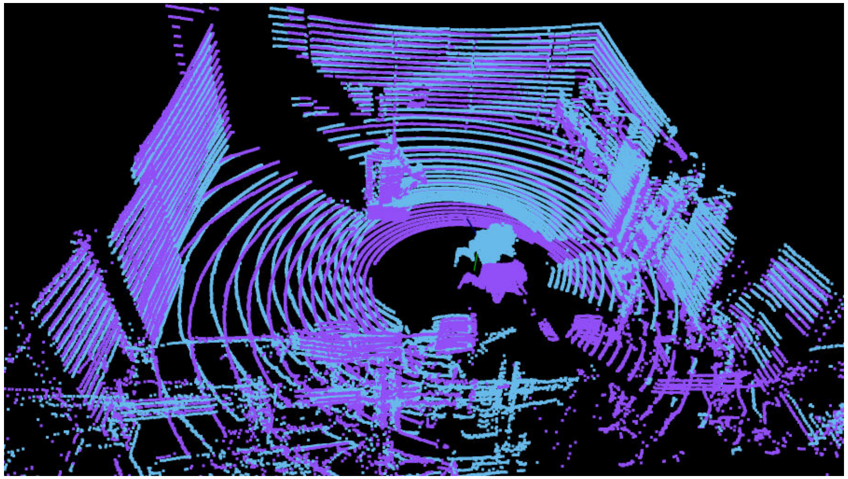
* We want to describe the point cloud by features
* 3D features:
  * Commonly based on the normals
  * How to compute the normal?
  * The neighbourhood of the point are the points of the ring
* Fusion with other data could help
  * Color, image features, ...





How to align the point clouds?

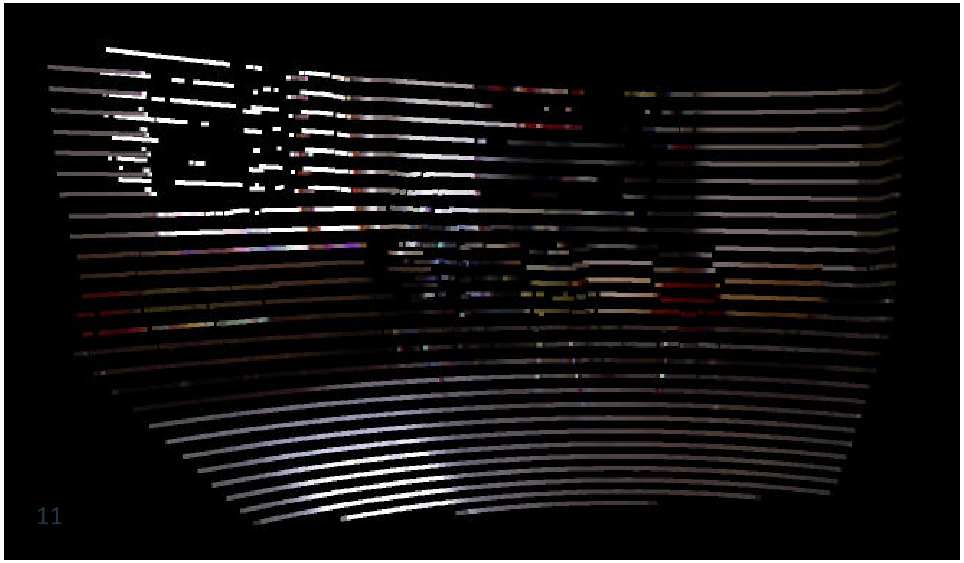




- We want to merge (register) multiple clouds
  - For 3D reconstruction & mapping
- Data are large – performance?
- Typical ICP approach fails
  - Rings will „fit“ to each other

How to calibrate Velodye with other sensors?

- Different modalities
- With other 3D scanner (Kinect, ToF camera, ...)
  - Dense point clouds of small area
  - Normals can be easily computed
- With **RGB camera**
  - Colored point clouds
  - Image feature for description

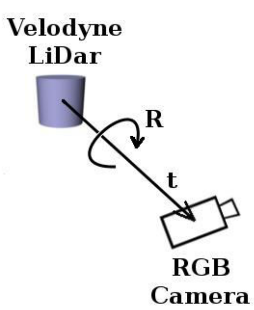


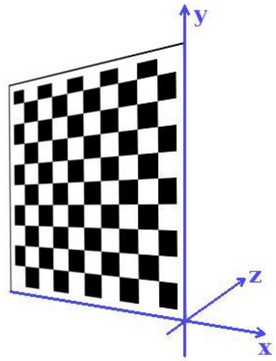
Camera-Velodyne calibration (1/2)

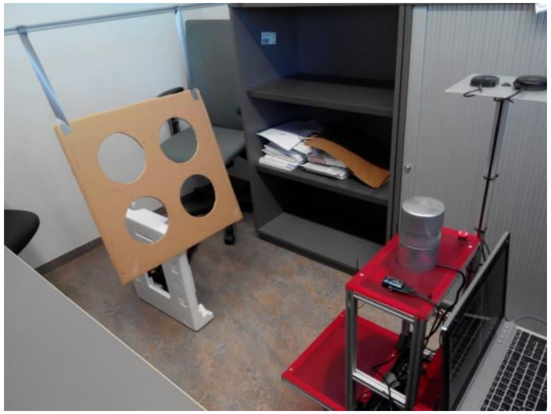
- Already solved:

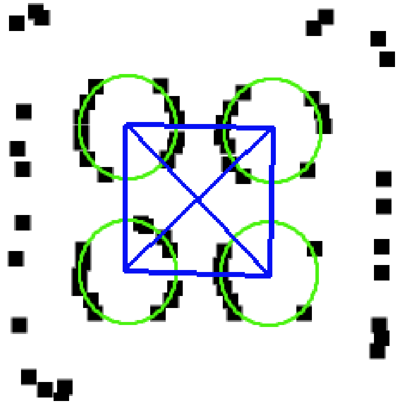
  Calibration of RGB Camera With Velodyne LiDAR

  M. Veľas, M. Španěl, Z. Materna, A. Herout
- Edges – easily detected in the image and point cloud
- Novel 3D marker and it‘s detection algorithm



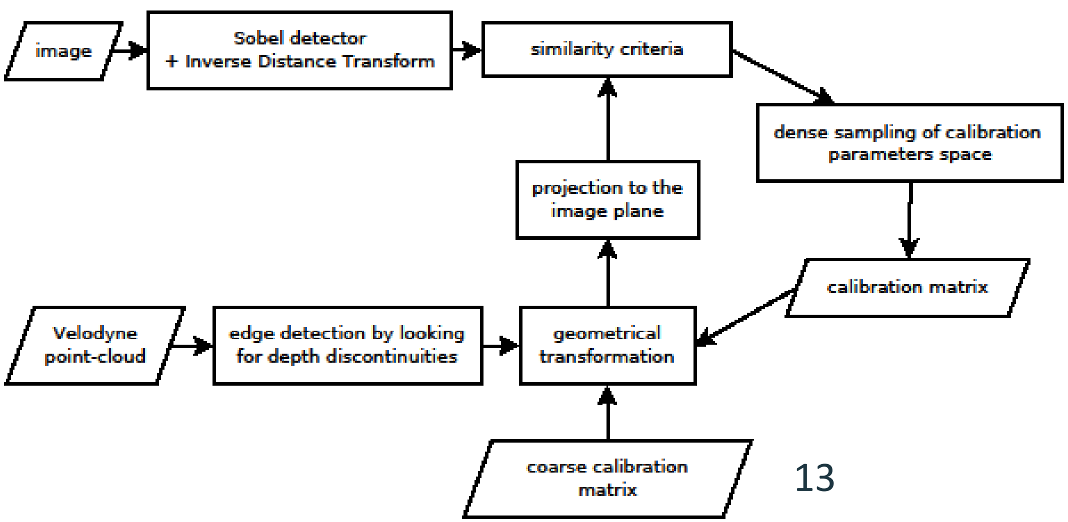


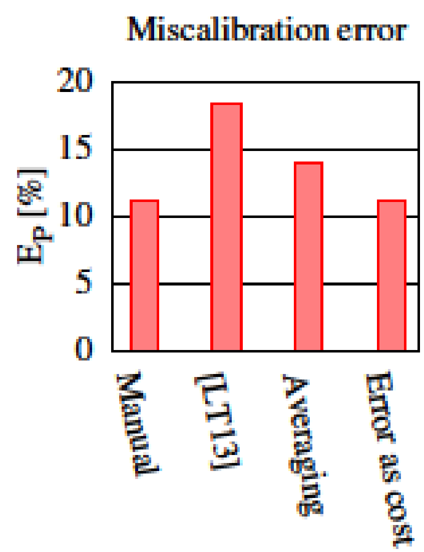




Camera-Velodyne calibration (2/2)

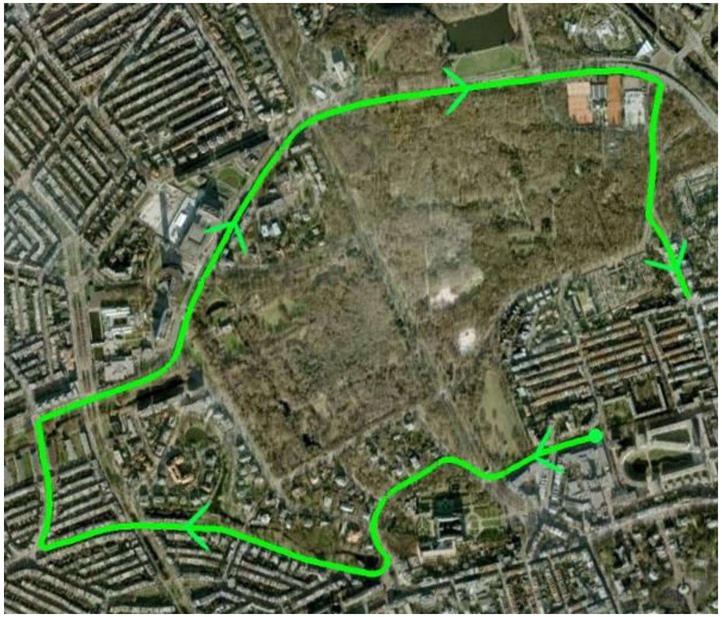
- 3D marker is used for the coarse calibration
- Refinement:
  - Grid search in small subspace of calibration parameters
  - 5% lower miscalibration error as [LT13]



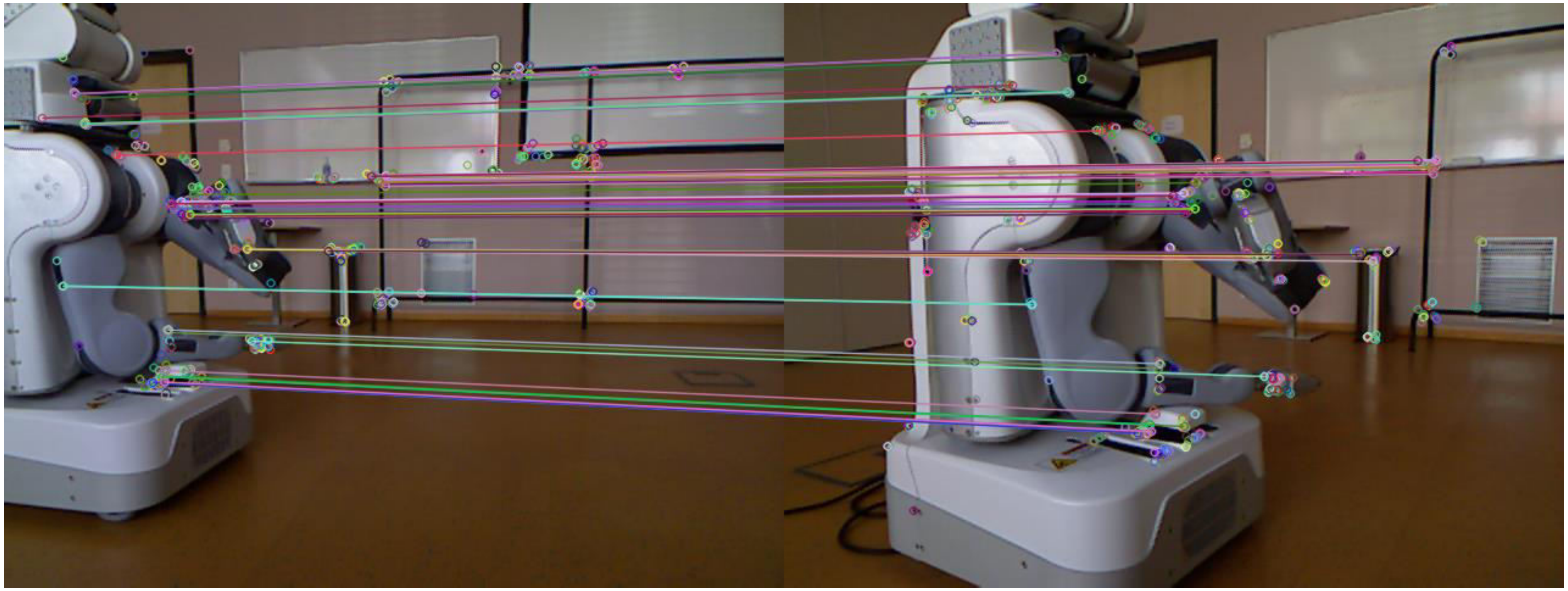


3D Visual odometry (1/5)

* We need to register (merge) multiple point clouds
* Visual odometry
  * How the robot was moving?
  * Pure:
    * Only camera images
    * 2D features
  * With Velodyne
    * Depth information

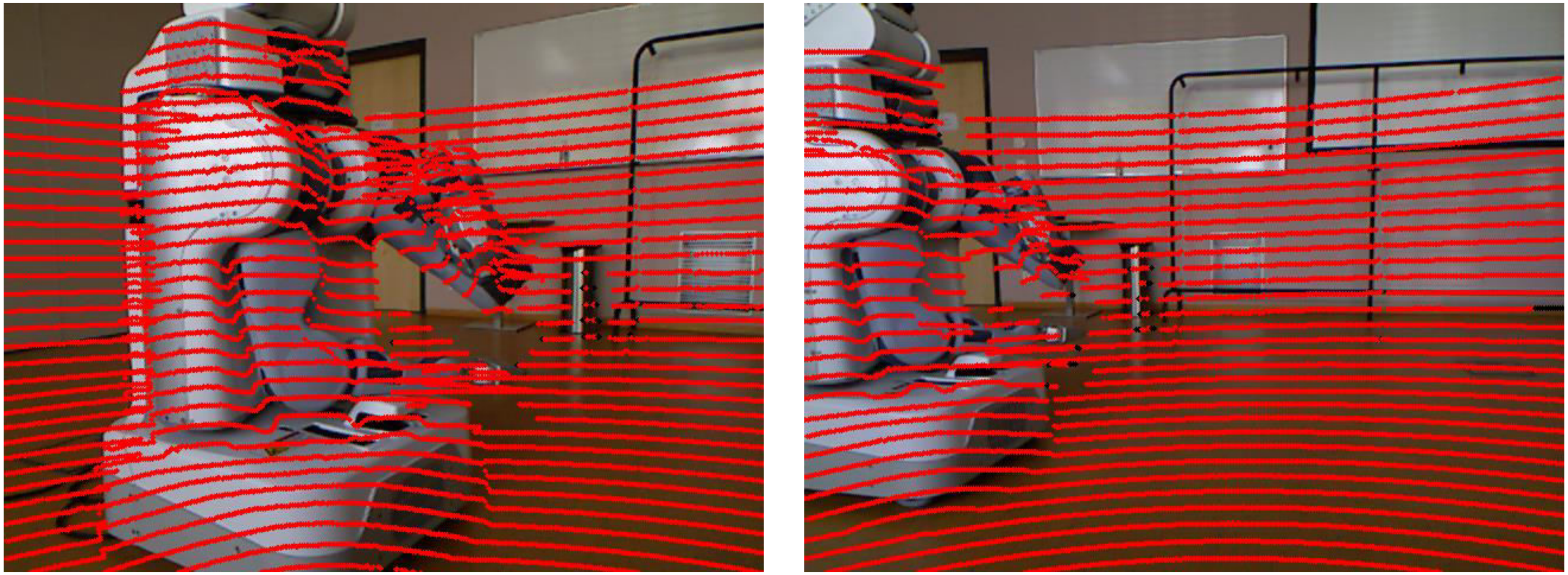


3D Visual odometry (2/5)



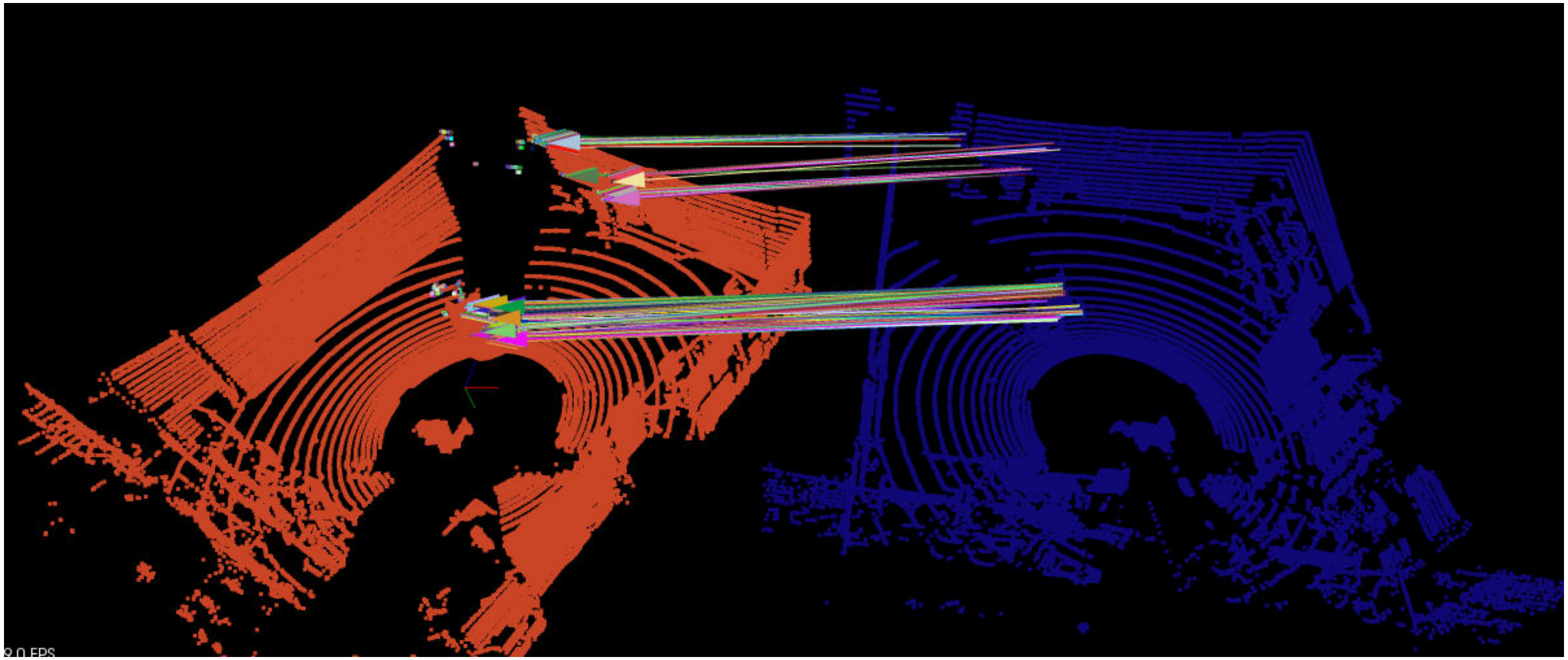
- Image features detection & matching
- RANSAC inliers of homography

3D Visual odometry (3/5)



- Projection of the point cloud on the image plane
- Assuming the calibration and the projection matrix are given

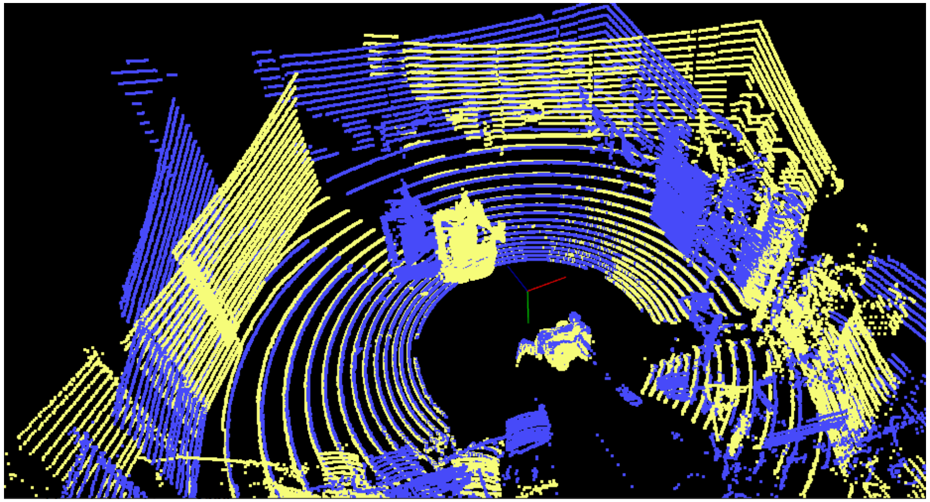
3D Visual odometry (4/5)

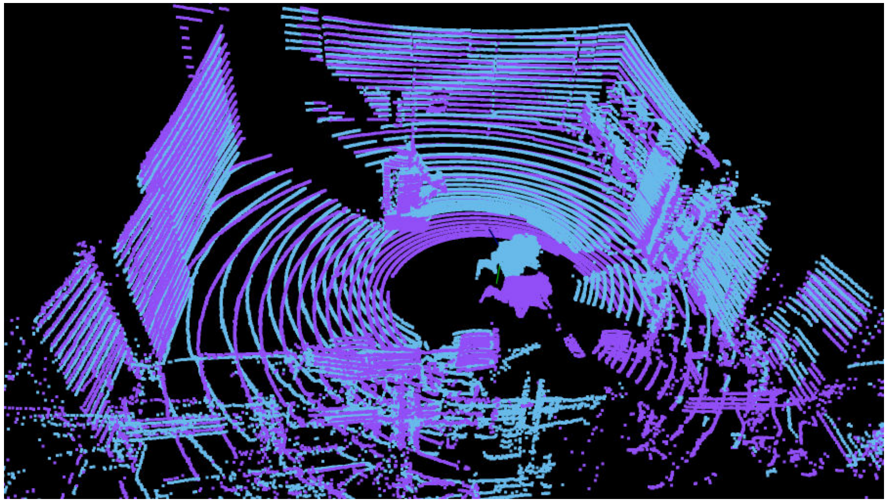


- 2D image correspondences assigned to the closest projected 3D point from Velodyne scan

3D Visual odometry (5/5)

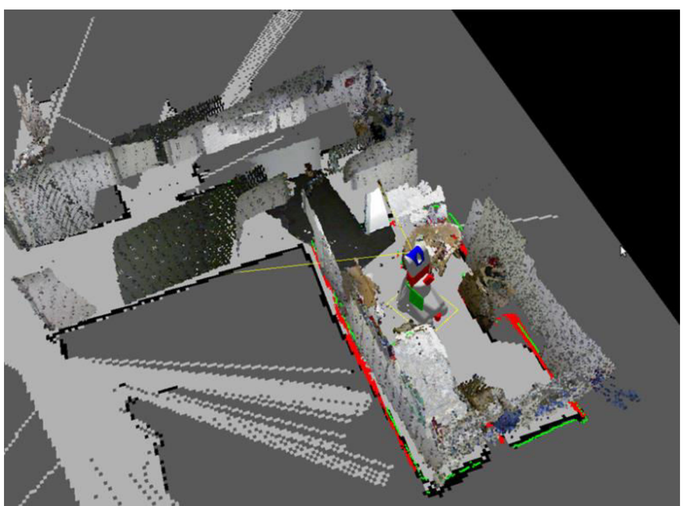
* From correspondences trajectory of the robot can be computed
  * EVD
* This trajectory can be used for point clouds registration

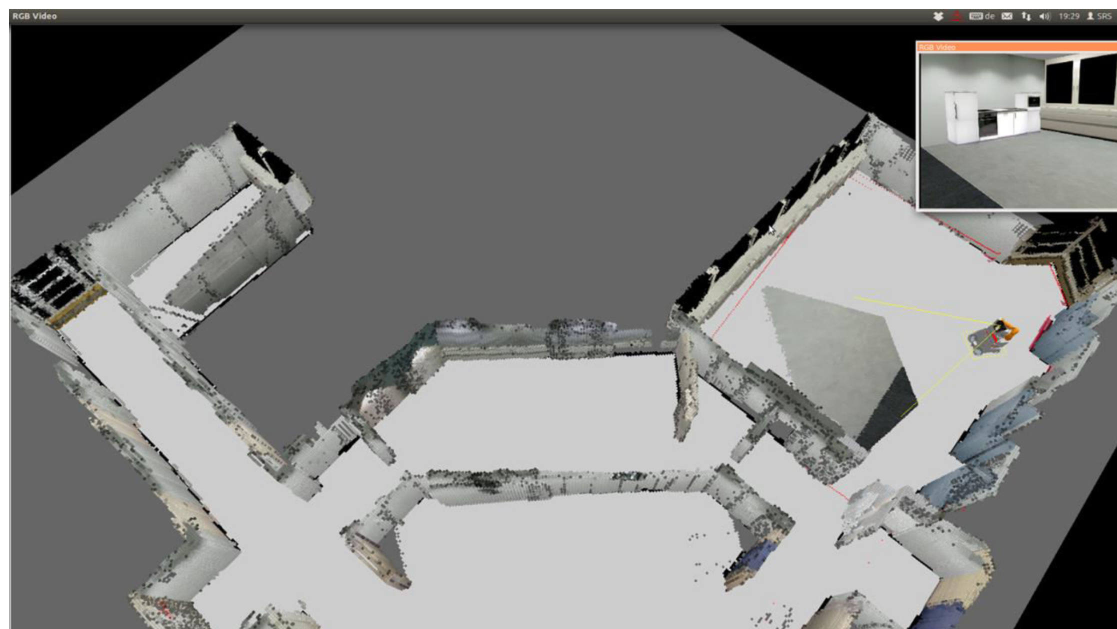




Building Large-Scale 3D Environment Maps

- We can:
  - Compute visual odometry
  - SLAM++
  - Building maps of small environments
- We start:
  - Building large maps

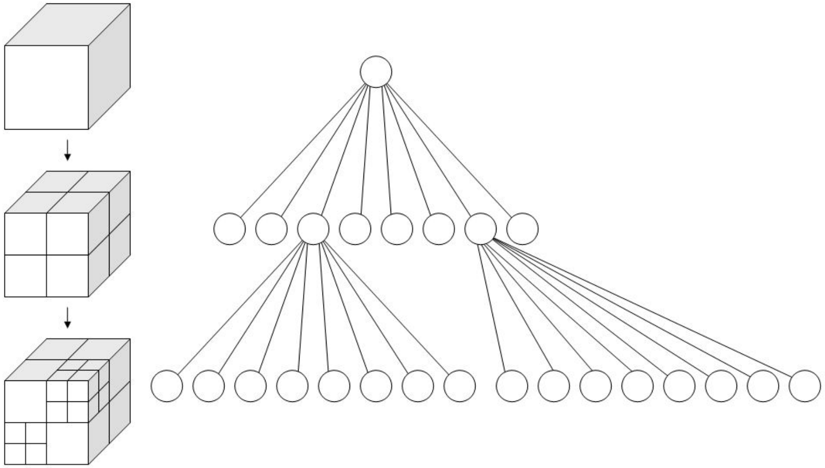




OctoMap

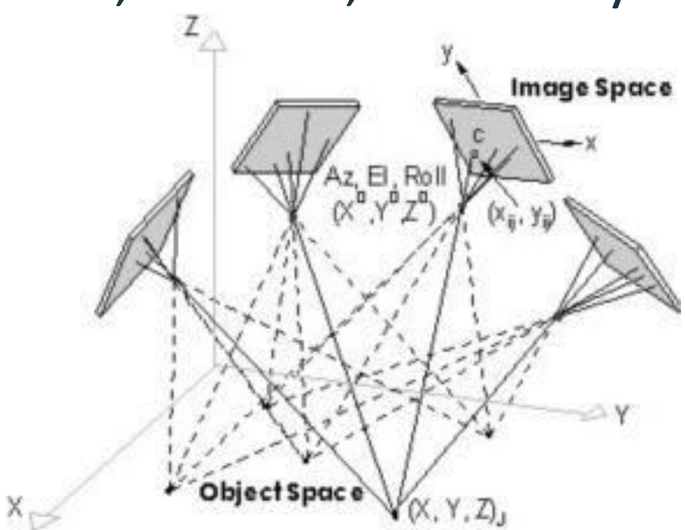
- Hierarchical scene representation
- Dealing with (very) large pointclouds
  - Each one individual pixel can not be storred
- OctoTree structure
  - Leaves = voxels (free/occupied)

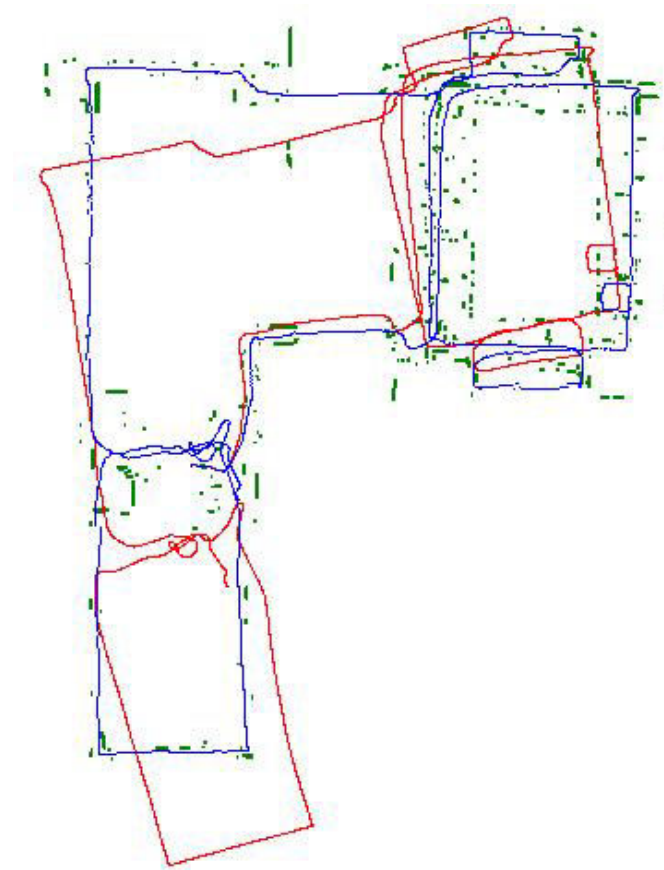
- Our improvements:
  - Better processing and visualisation
  - plugins



Block matrices operations

- Effecient operations with block matrices
  - Acclerated with GPUs
  - Possibly computed by the cluster
- SLAM++ and bundle adjustement
- V. Ila, L. Polok, M. Solony





Change Detection in Large-Scale 3D Maps

* What objects in the scene are moving?
* In OctoMap
  * State of the cell in the grid is not binary
  * Probability of being moving object
  * Updated with each observation
* **Anselm for the data processing** ☺

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