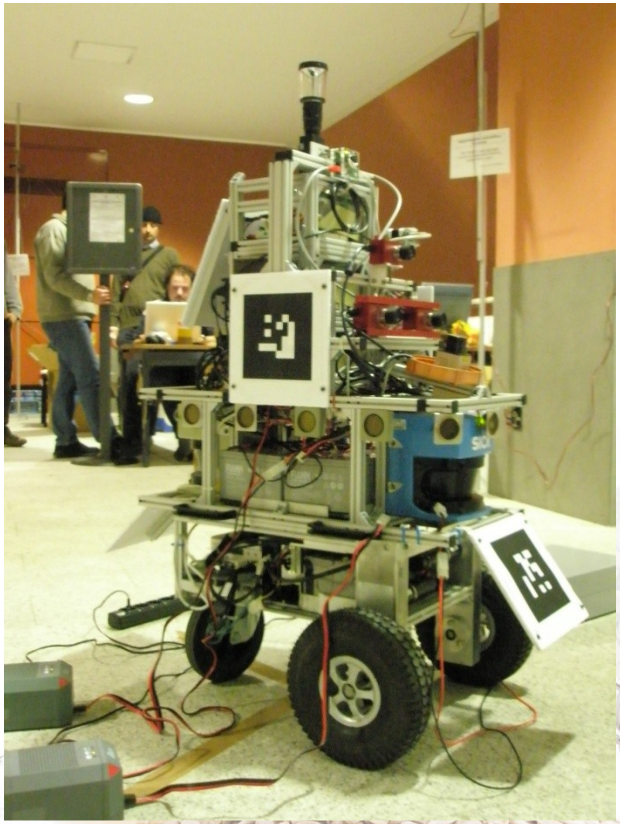
RAWSEEDS: Robotics Advancement through Web-publishing of Sensorial and Elaborated Extensive Data Sets

M. Matteucci

RAWSEEDS @ ICAR 2009 – 22nd June 2009 Munich

Today's Special!

- RAWSEEDS in a Nutshell
  - Project Introduction and Aims
- Project activities and results
  - Dataset Collection
  - Dataset Validation
  - Benchmark Problems
  - Benchmark Solutions
- What a future for RAWSEEDS?



What is RAWSEEDS ?

- EU Funded Project in the VI Frame Program from the 1st of November 2006 to July 2009

Rawseeds is a Specific Support Action funded under the European Union's Sixth Framework Programme (FP6)

- A ***Specific Support Action*** to collect and publish a benchmarking toolkit for (S)LAM research

- Involved Institutions:
  - Politecnico di Milano (Italy – Coordinator)
  - Università di Milano-Bicocca (Italy – Partner)
  - University of Freiburg (Germany – Partner)
  - Universidad de Zaragoza (Spain – Partner)

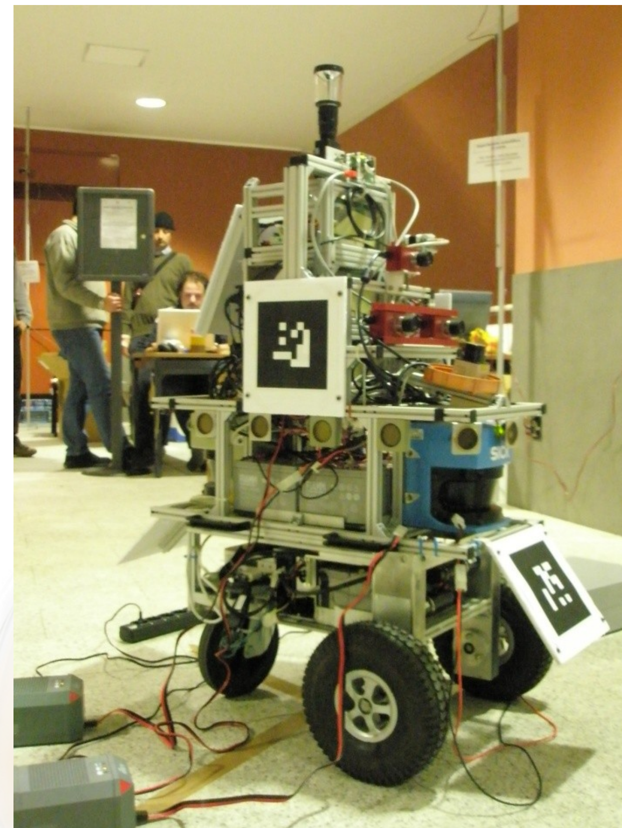
Benchmarking Beyond Radish

- Nowadays we feel the lack of tools and methods to compare and evaluate market strength products. To aim at this RAWSEEDS fosters publishing of:
  - Extended multi-sensor data sets for the testing of systems on real-world scenarios from different sensor perspectives
  - Benchmarks and methodologies for quantitative evaluation and comparison of algorithms (and eventually sensors)
  - Off-the-shelf algorithms, with demonstrated performances, to be used for research bootstrap and comparison.

www.rawseeds.org

RAWSEEDS Datasets

- Use of an extensive sensing suite
  - B/W + Color cameras (moncular)
  - Stereo cameras (SVS by Videre)
  - LRFs (SICK 2D & Hokuyo)
  - Omnidirectional camera (V-Stone)
  - Sonar belt
  - GPS and RTK-GPS (Outdoor GT)
  - Other proprioceptives (e.g., odometry, Inertial Measurement Unit)
- Sensors are synchronized and data acquired at the maximum frequency allowed by the three onboard PCs



Benchmarks Problems & Solutions

- Benchmark Problems (BPs) aim at testing algorithms:
  - Include detailed description of the task
  - Multi-sensor Data Set related to the task
  - Evaluation Methodology and Tools

- Benchmark Solutions (BSs) extend BPs with:
  - Description of the algorithm for solving the BP and possible implementation (src or binary)
  - Algorithm output on the BP dataset
  - Evaluation (using the BP methodology)

Data Collection & Validation

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Design of the Datasets

- Defined relevant scenarios beforehand
  - Indoor scenarios with offices, halls, corridors, flat and non-flat walls, doors & passages, windows, horizontal floors, ramps, stairs, elevators, and several pieces of furniture.
  - Outdoor scenarios where the robot moves in the open between buildings and the obstacles are comparable with those found along urban roads.
  - Mixed scenarios parts of the robot trajectory is surrounded by walls and/or roof and parts are located in the open.

- Different acquisition setups
  - Static and Dynamic environments (i.e., people walking around)
  - Different lighting conditions (i.e., natural daylight & artificial light)

Indoor Locations in Bicocca



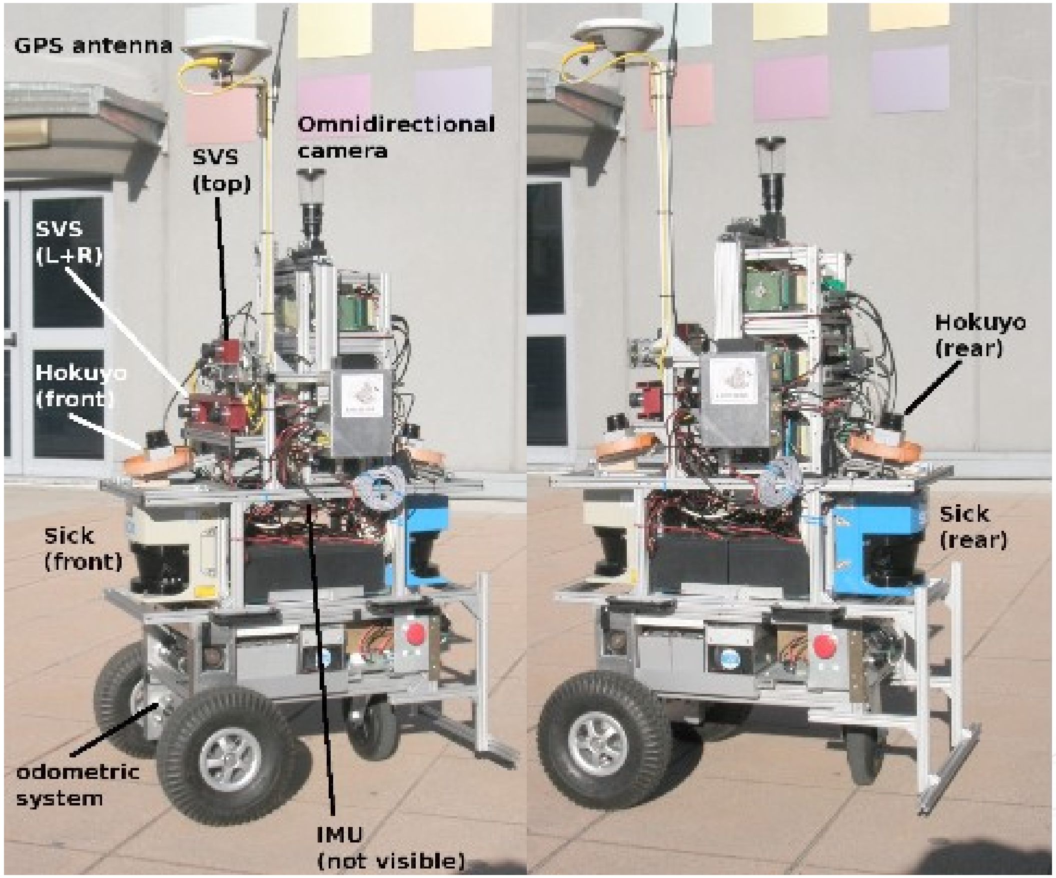


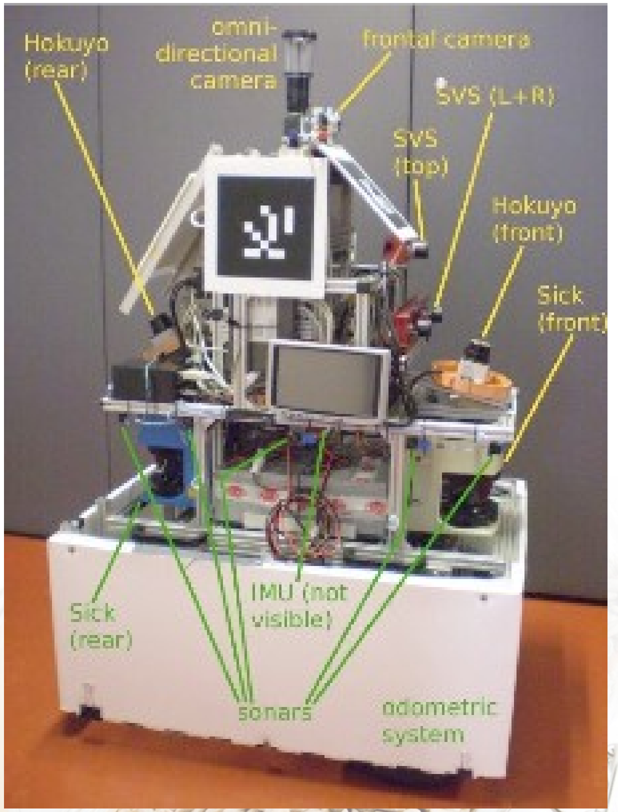

Outdoor and Mixed Locations in Bovisa






Sensors and sensor frame

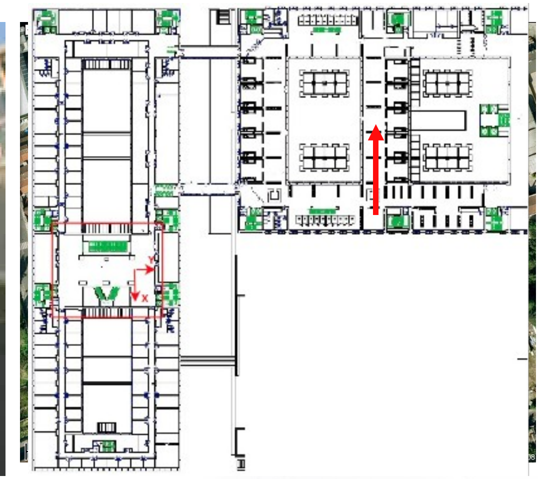


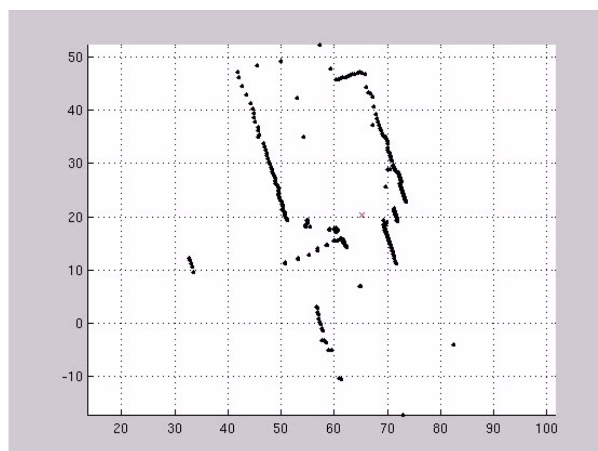


11 Datasets Collected

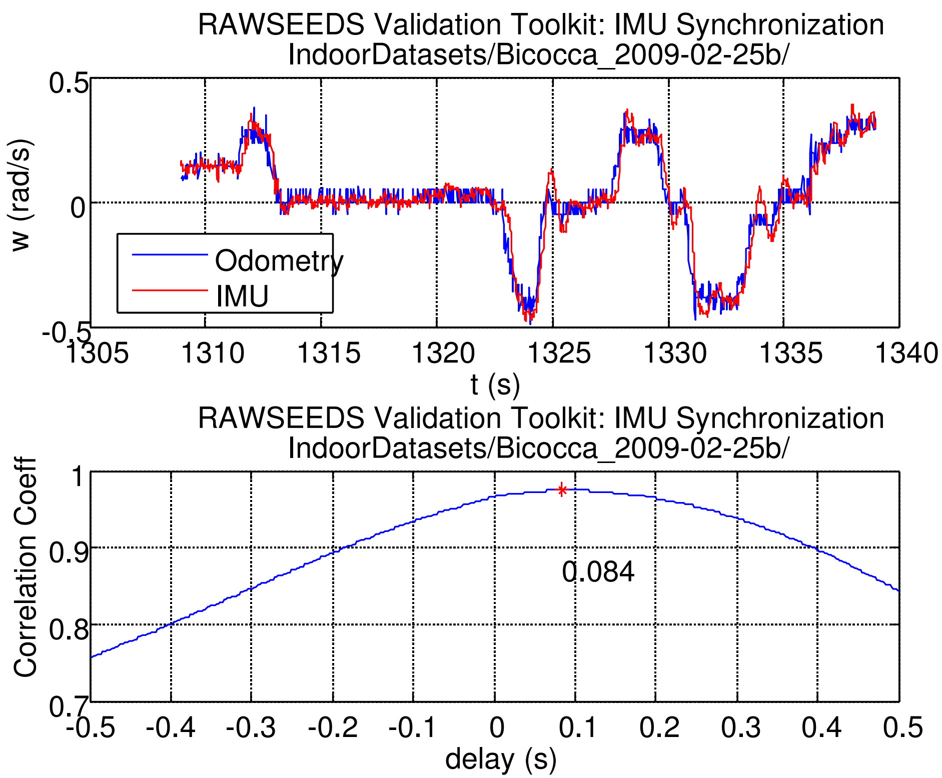
Many different scenarios:

- Indoor
  - 1 static lamps
  - 1 static daylight
  - 1 dynamic lamps
  - 2 dynamic daylight
- Outdoor
  - 2 static
  - 1 dynamic
- Mixed
  - 2 static
  - 1 dynamic





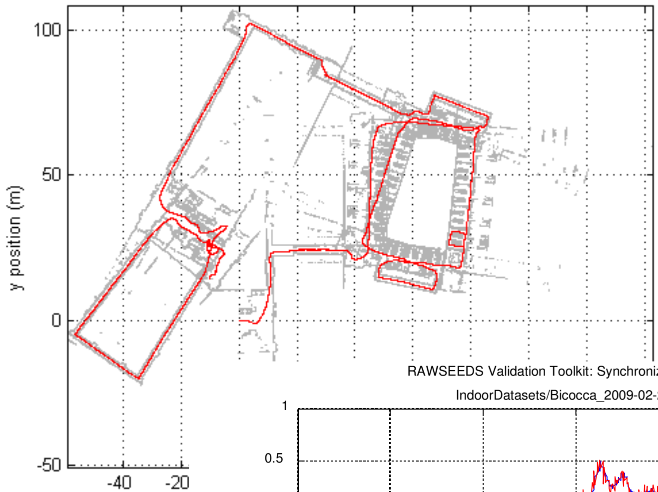
Validation: IMU and Odometry

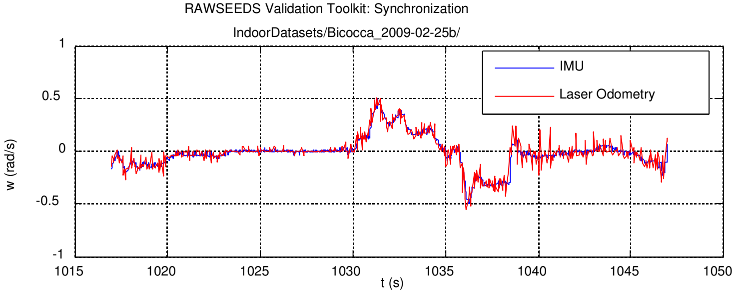


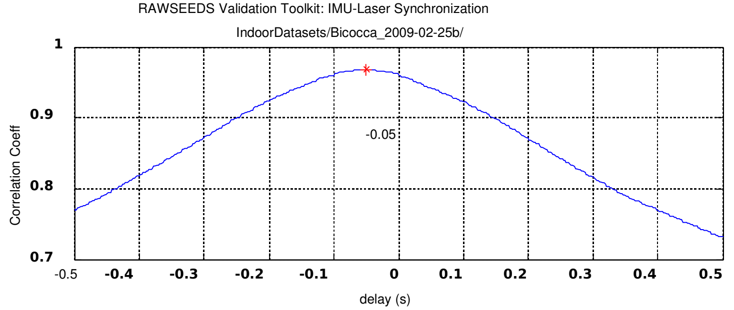
- IMU used as time base
- Delays found by correlation of angular velocities

Validation: SICK Laser

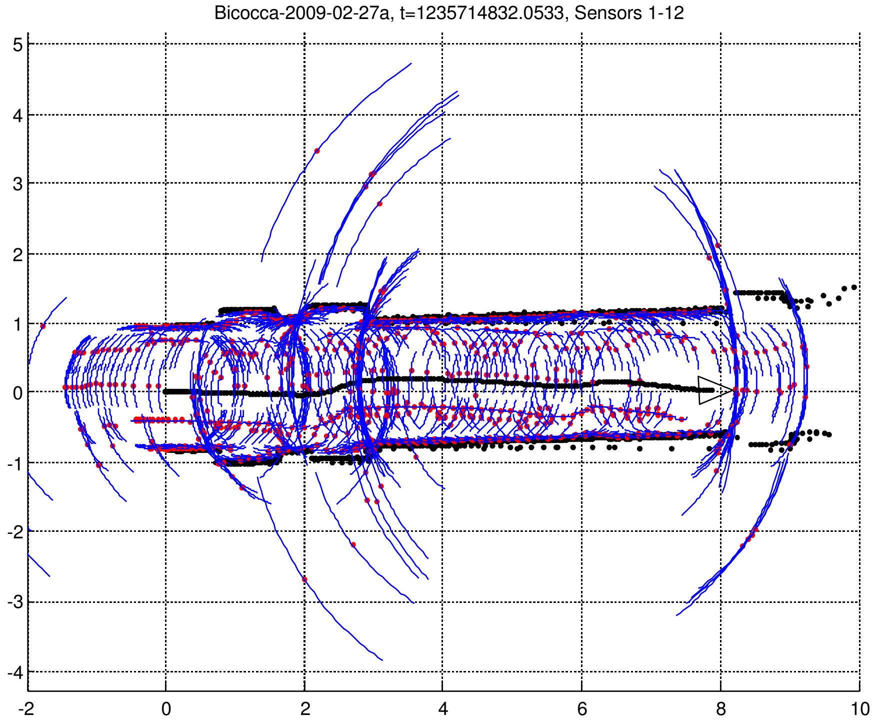
- Scan matching
- Correlation of angular velocities
- Map building with ALUFR Graph-SLAM





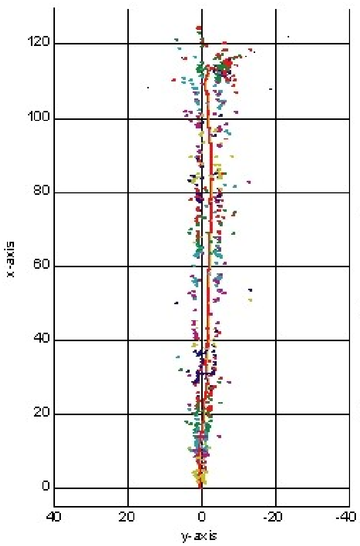


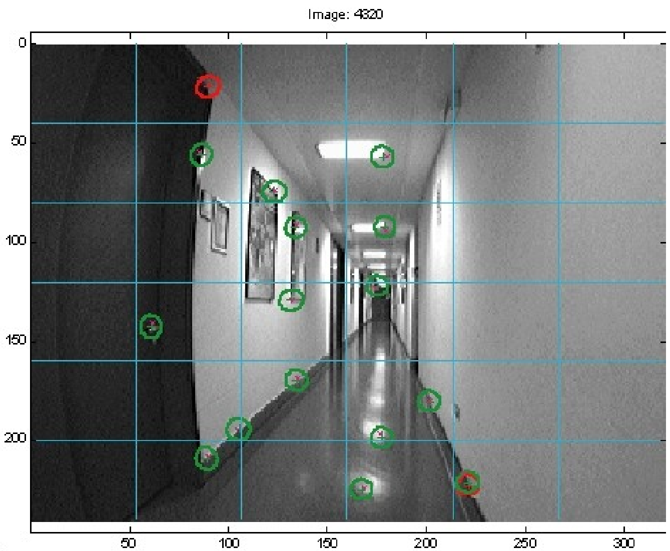
Validation: Sonar Belt

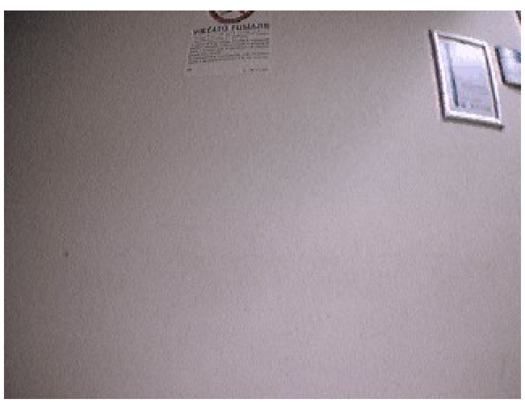


- Plot sonar returns + visual inspection
- Some spurious returns
  - typical in sonar data

Validation: Monocular Vision



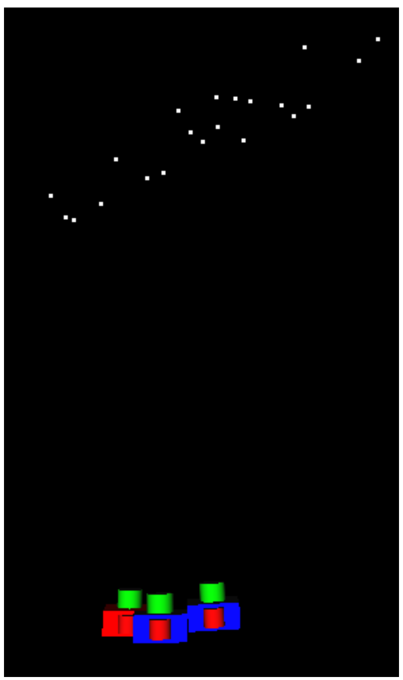


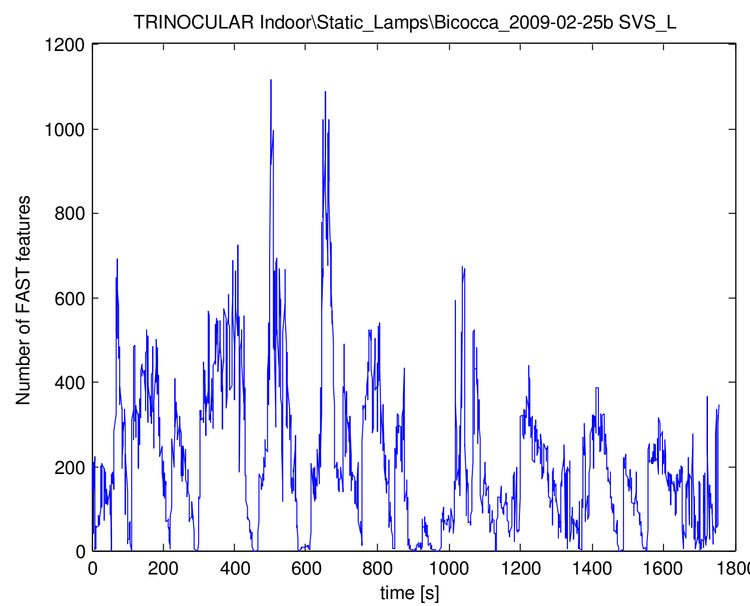


- Data density and quality verified running visual SLAM
- Typical issues that a SLAM algorithm must address in real life:
  - Dark images
  - Blurred images
  - Indoor areas with poor texture

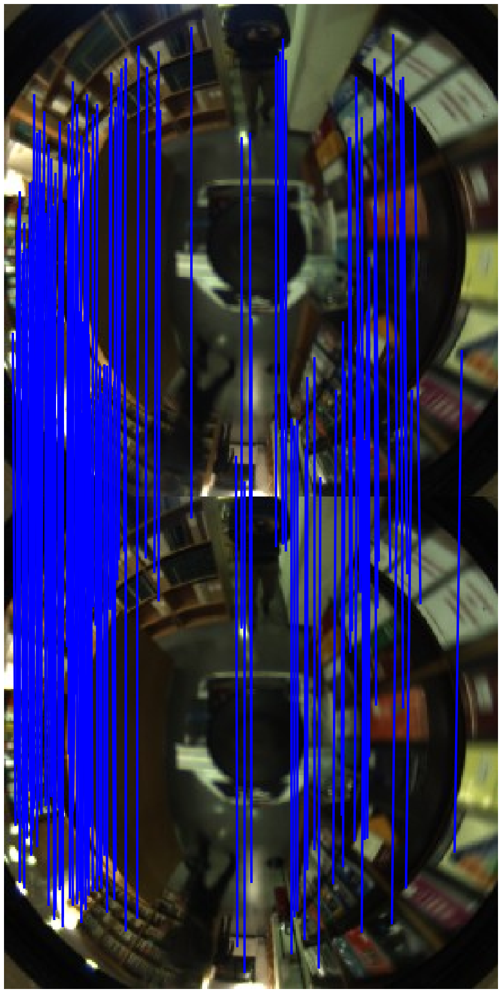
Validation: Trinocular Vision

- Calibration and data quality verified by 3D reconstruction
- Feature density

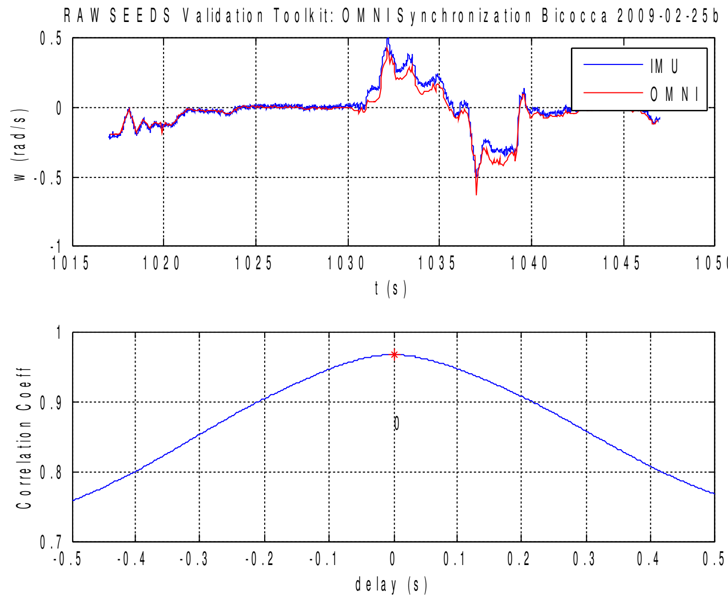




Validation: Panoramic Vision



- FAST feature extraction and matching
- Synchronization



Ground Truth Collection

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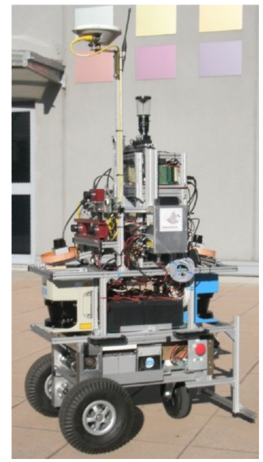
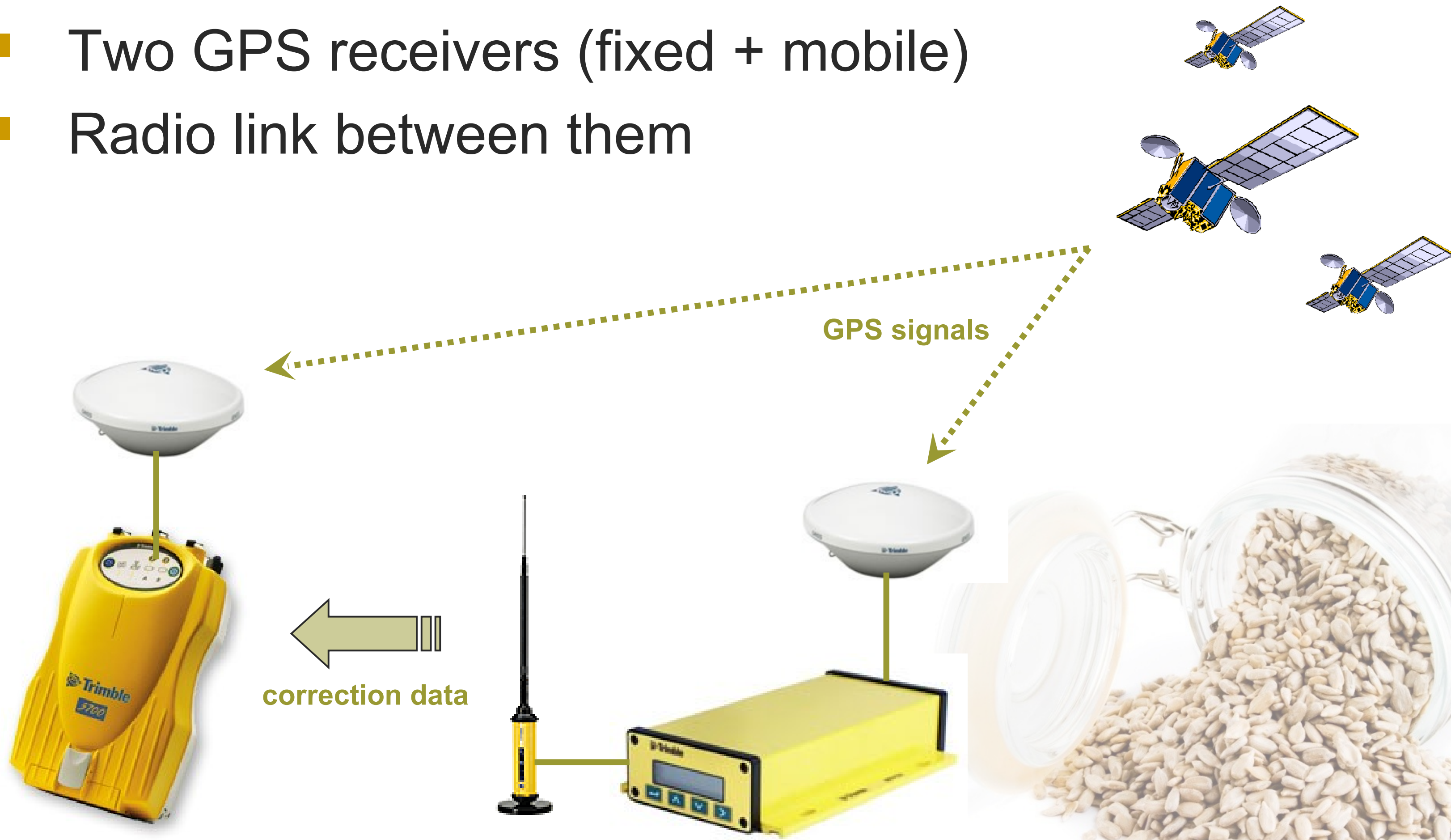
Ground Truth Setup

- GT Collection Systems
  - Outdoor: RTK (Real Time Kinematic) GPS
  - Indoor: vision-based (*GT-vision*) and LRF-based (*GT-laser*)



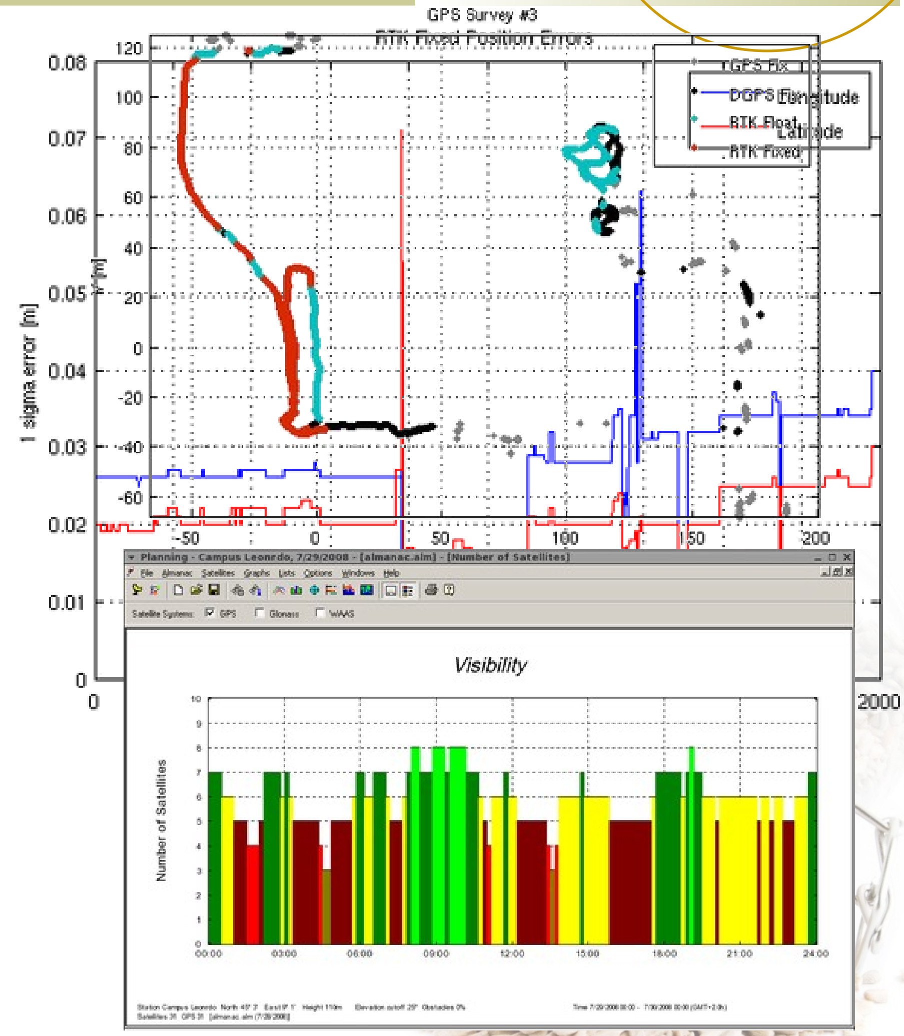
Outdoor GT: RTK GPS

- Two GPS receivers (fixed + mobile)
- Radio link between them



RTK GPS for Robotics

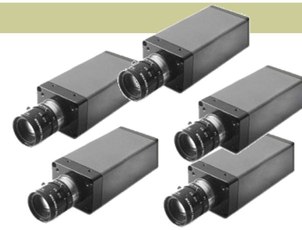
- Advantages:
  - absence of drift
  - position data available over large areas
  - easy setup... to a point
  - high positioning precision
- Drawbacks:
  - does not operate indoors
  - costly hardware
  - extremely sensible to obstacles
  - performance varies widely over time and space



Setup: Vision GT

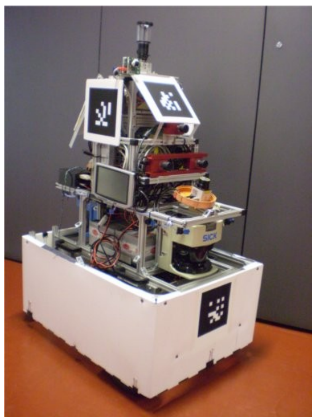
GigE switch

5 cameras
(GigE Vision)



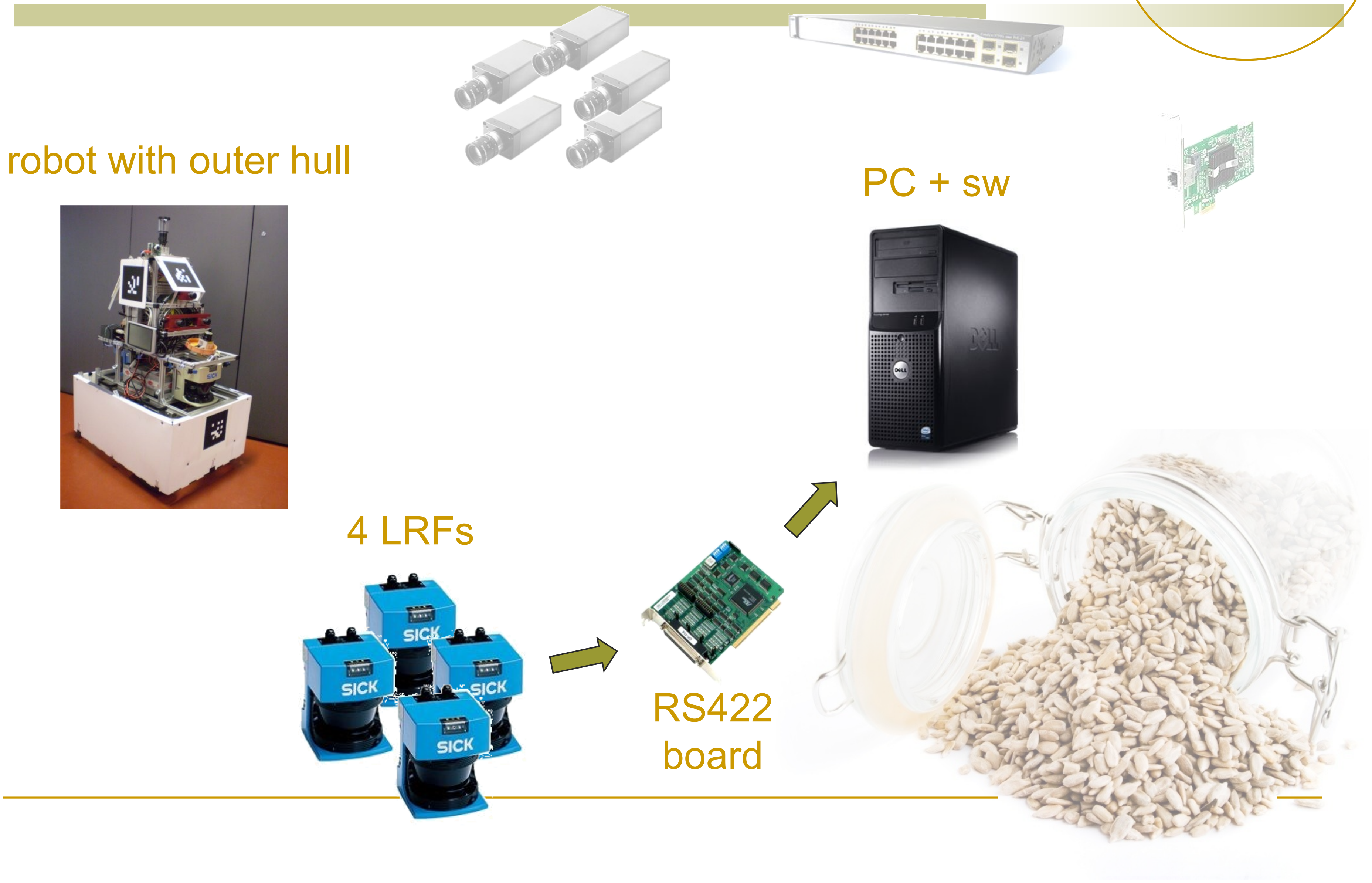
NIC

PC + sw

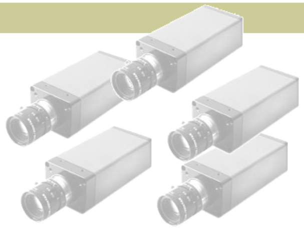


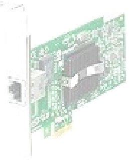
robot with visual tags

Setup: Laser GT

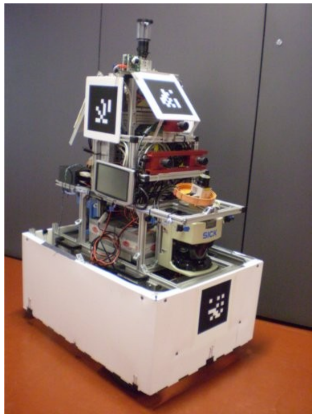


Setup: GT Synchronization





PC + sw +
PTP slave

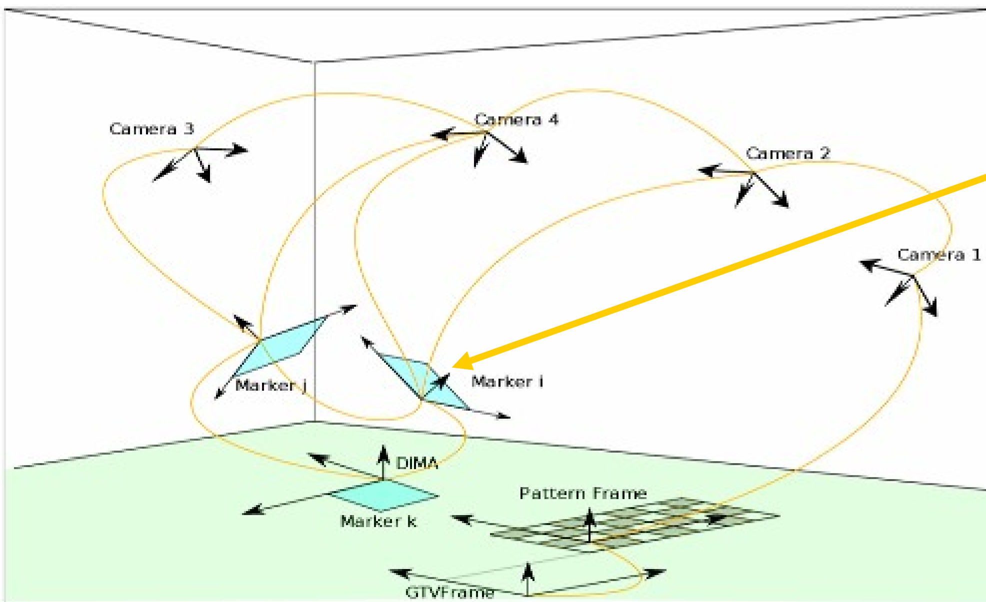


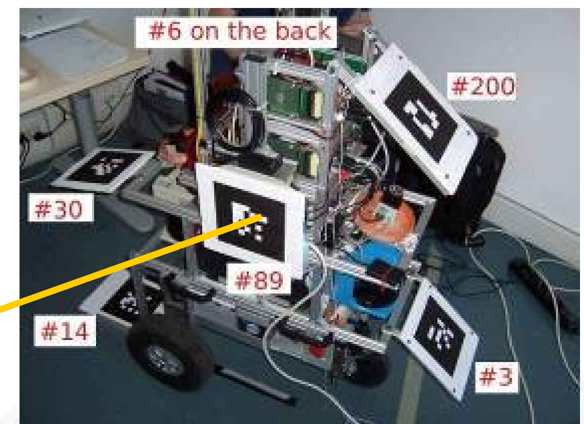
robot with
wireless router
+
PTP master

wireless NIC

Vision GT System

- Use a camera network to localize the robot
  - Good: Independent sensor
  - Bad: Requires (painful) setup/calibration
  - Doubt: Might not be accurate enough

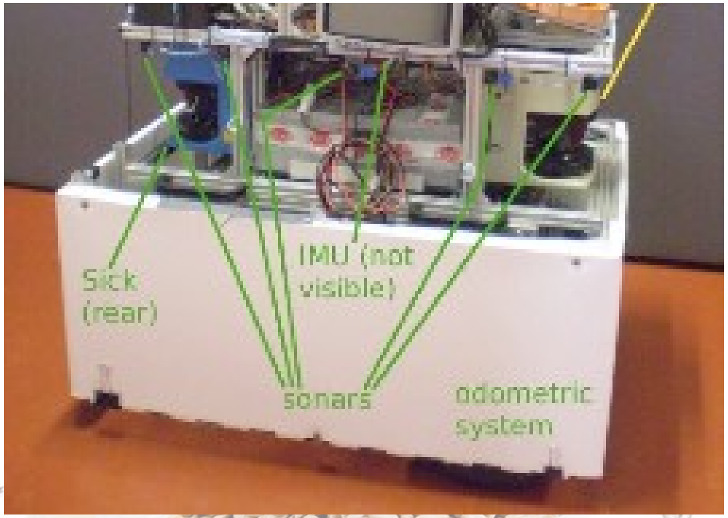




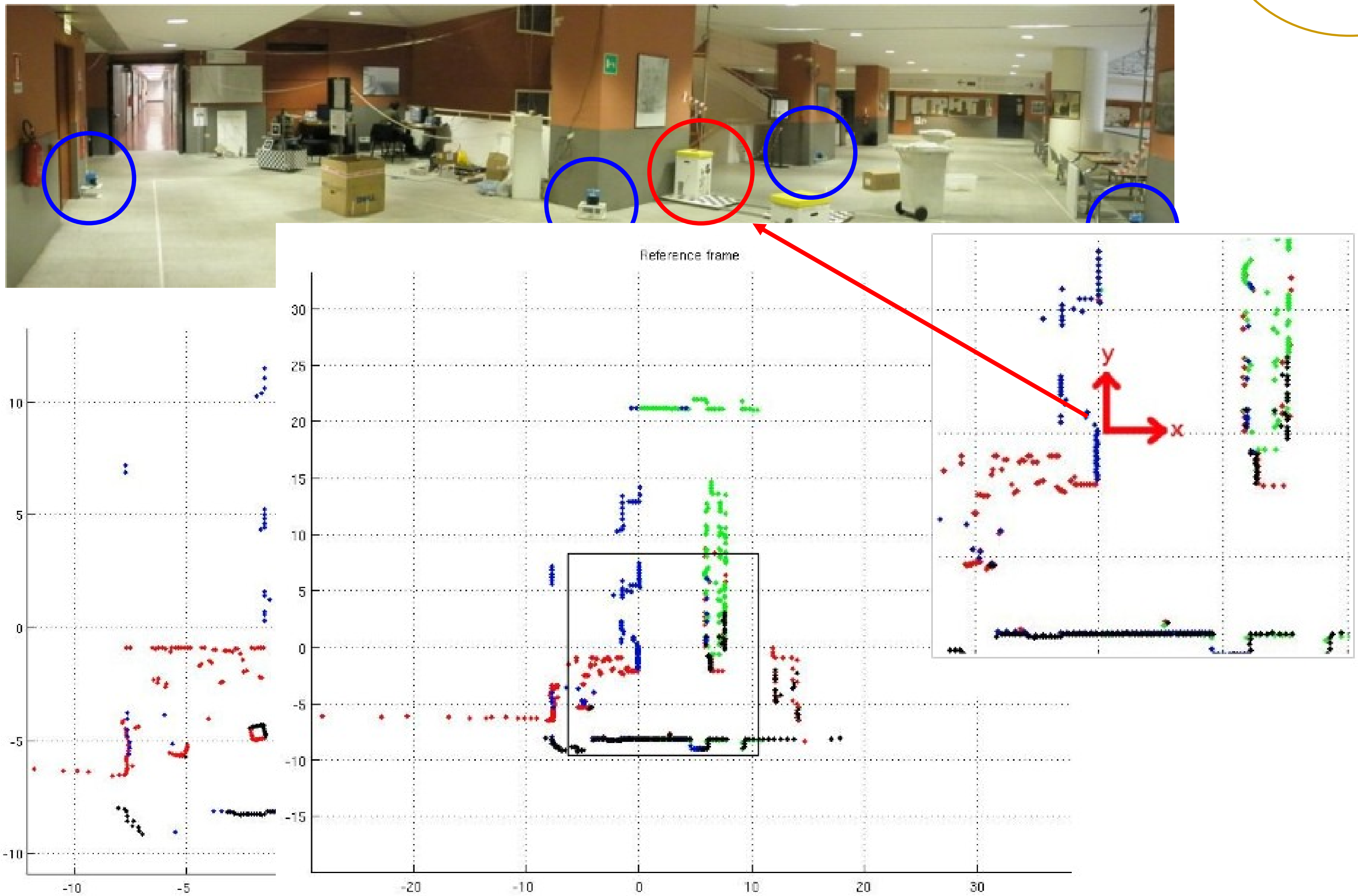
Required ~0.1 m accuracy

Laser GT System

- We developed another (offboard) poseGT system;
  - based on 4 sick laser-scanners;
  - area covered approximately as for Vision GT;
  - calibration (scan alignment) with ICP;
  - the robot model is a rectangle in the scans (the gown);
  - robot localization with ICP in the overall scan;

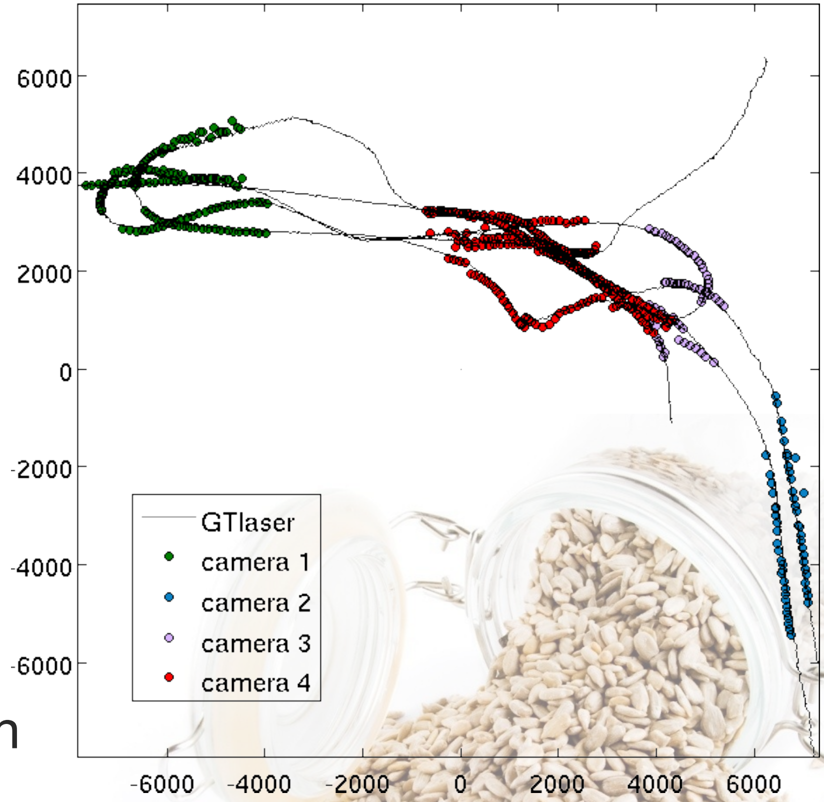


GT Systems Alignment



GT Accuracy

- Vision GT
  - 112 ± 90mm in position
  - -0.8 ± 2.16 degs in orientation
- Laser GT
  - 20 ± 11mm in position
  - 0.15 ± 1.56 degs in orientation
- Overall Accuracy
  - 19 ± 11mm in position
  - -0.12 ± 1.56 degs in orientation



Benchmark Problems and Solutions

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Benchmark Problems (BPs)

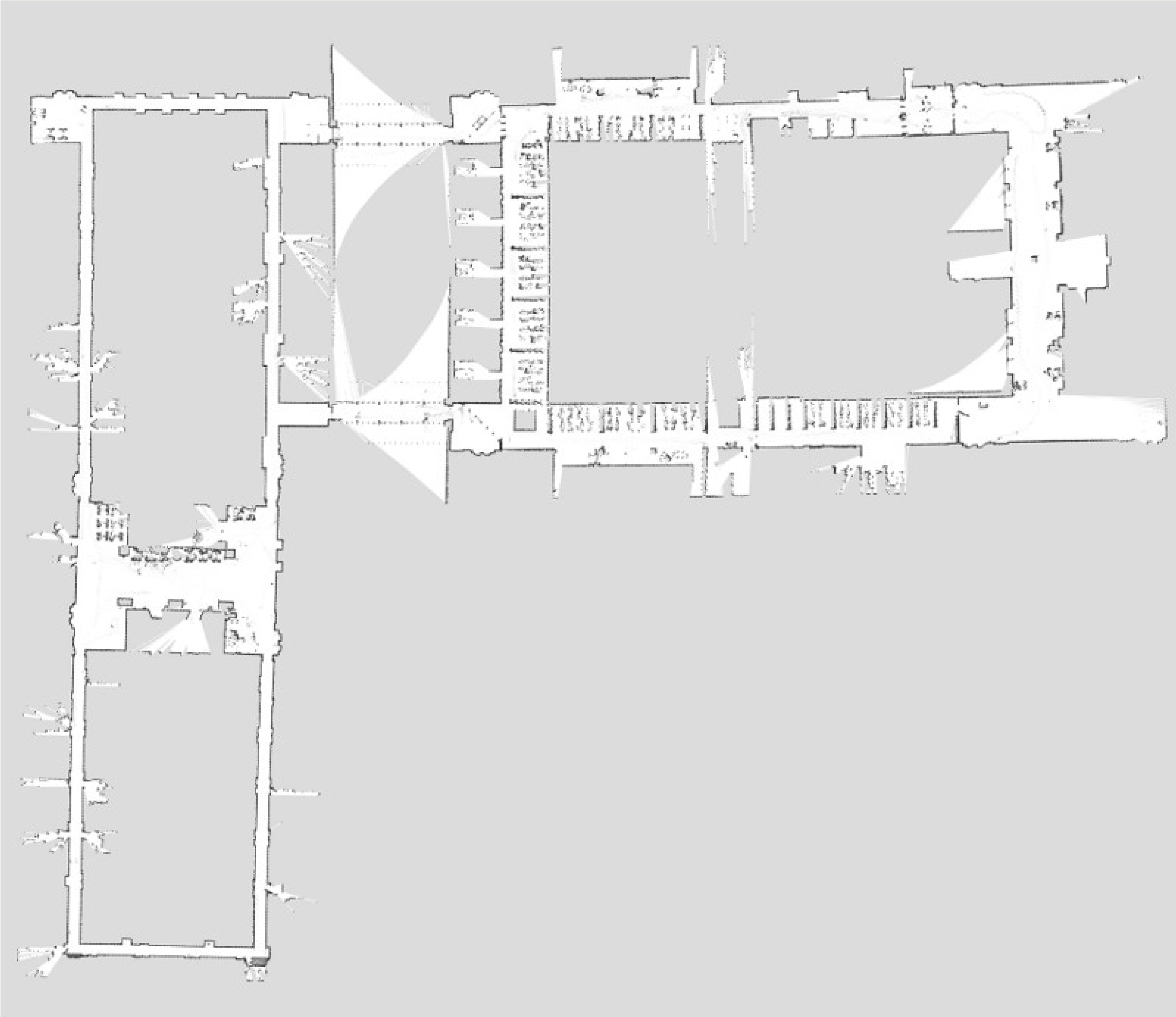
- BPs are the union of:
  - the description of a task;
  - a dataset, as the input for the execution of the task;
  - a set of rating methodologies (metrics), for the evaluation of the results of the task execution.
- RAWSEEDS Metrics
  - ME (Mapping Error)
  - ATE (Absolute Trajectory Error)
  - REC (Rough Estimate of Complexity)
  - SLE (Self-Localization Error)
  - RPE (Relative Pose Error)

	PROBLEM	SENSOR DATA
Laser SLAM	perform a map building activity with SLAM (online)	laser, IMU and odometry from a dataset
Monocular SLAM	perform a map building activity with SLAM (online)	single camera, IMU and odometry from a dataset
Stereo SLAM	perform a map building activity with SLAM (online)	stereo camera, IMU and odometry froma a dataset
Trinocular SLAM	perform a map building activity with SLAM (online)	trinocular IMU and odometry from a dataset
Omnidirectional vision SLAM	perform a map building activity with SLAM (online)	omnidirectional vision, IMU and odometry from a dataset
Sonar SLAM	perform a map building activity with SLAM (online)	sonar sensors, IMU and odometry from a dataset
Multisensor SLAM	perform a map building activity with SLAM (online)	streams from more than one sensor, for a dataset

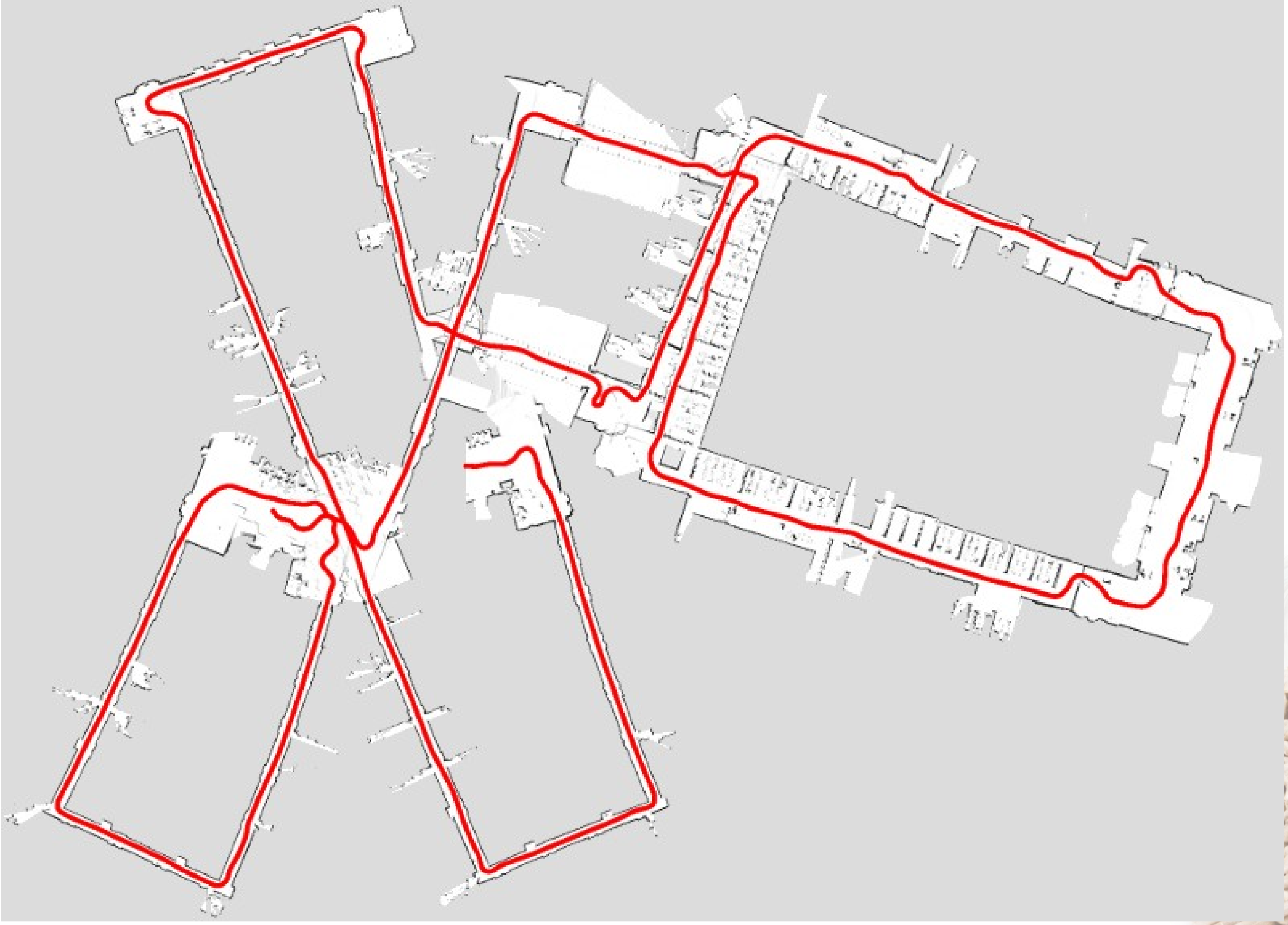
Benchmark Solutions (BSs)

- Generation of ready to use solutions for the RAWSEEDS BPs, using the following algorithms
  - Laser Based
    - Scan-matching [ALUFR]
    - Rao-Blackwellized Particle Filters [ALUFR]
    - Graph-based SLAM [ALUFR]
  - Vision Based
    - Monocular and Stereo SLAM[UNIZAR]
    - Trinocular SLAM [UNIMIB + POLIMI]
- User supplied solutions are foreseen through RAWSEEDS website

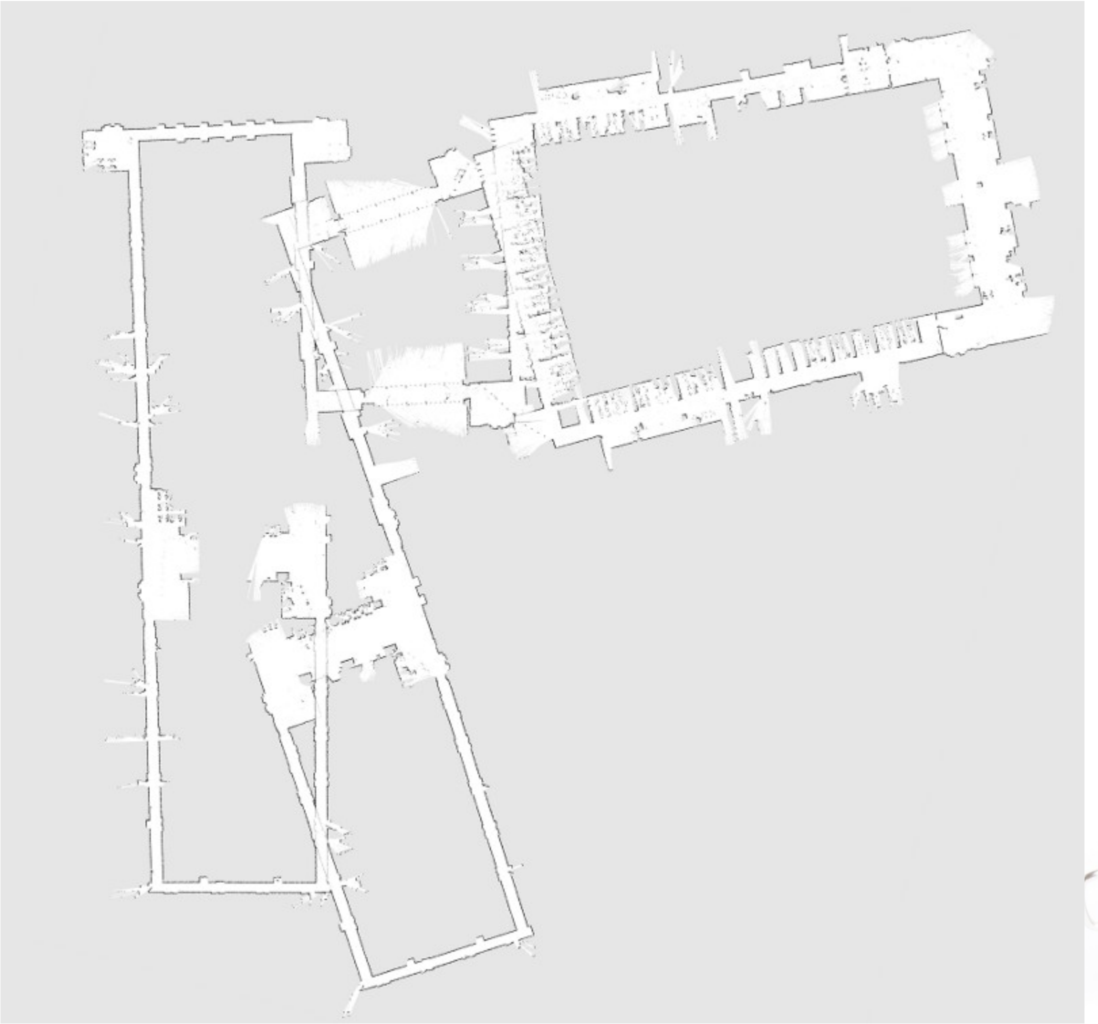
Laser-based SLAM Indoor (target)



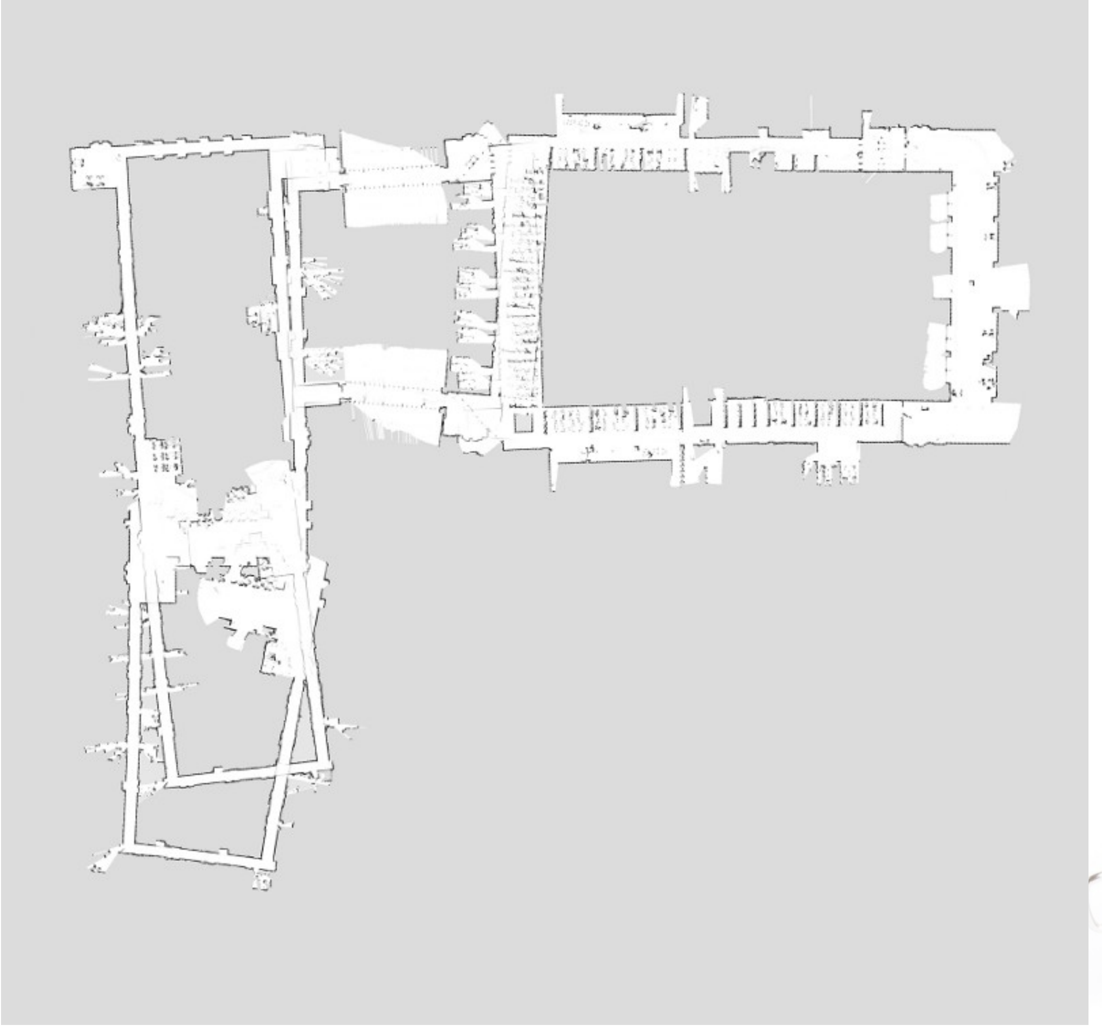
Laser-based SLAM Indoor (input)



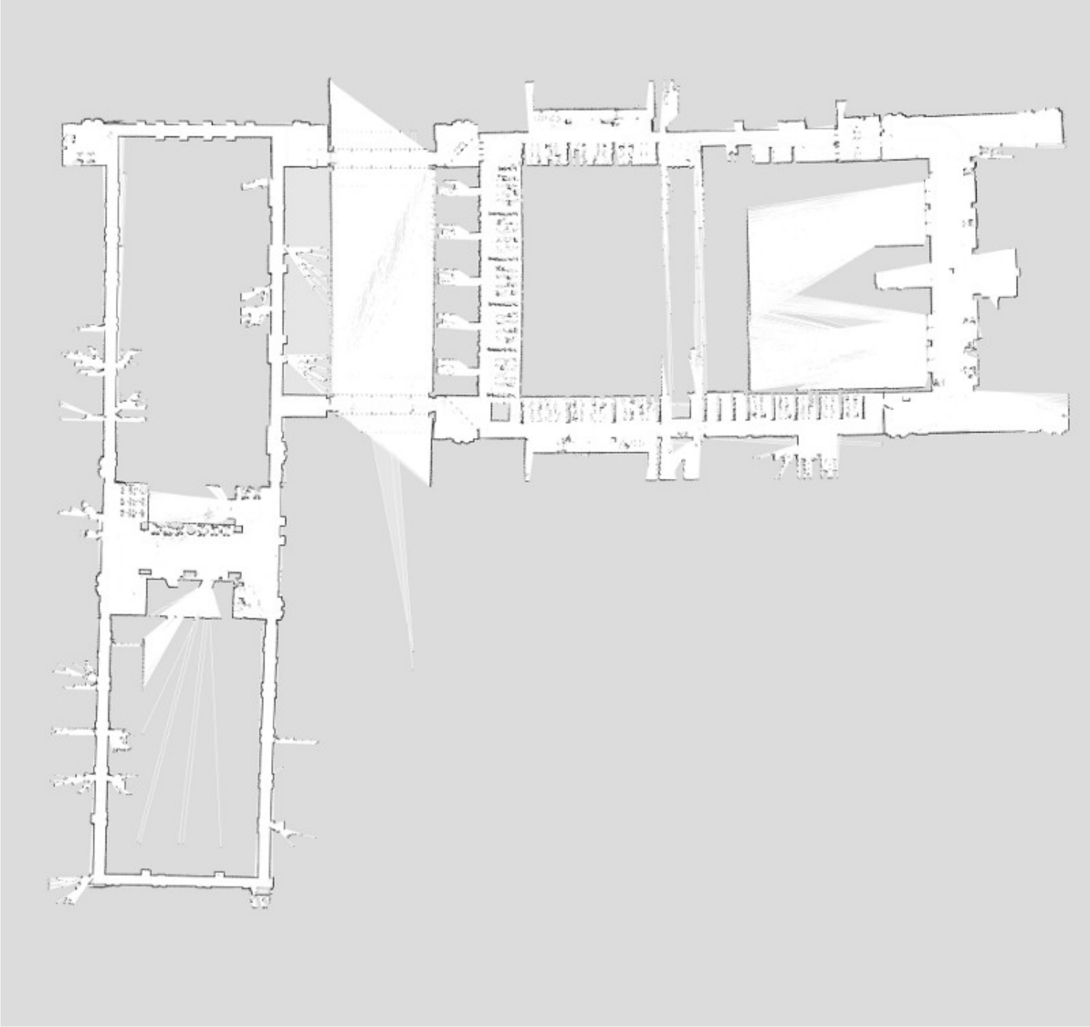
Laser-based SLAM Indoor (vasco)



Laser-based SLAM Indoor (rb-pf)

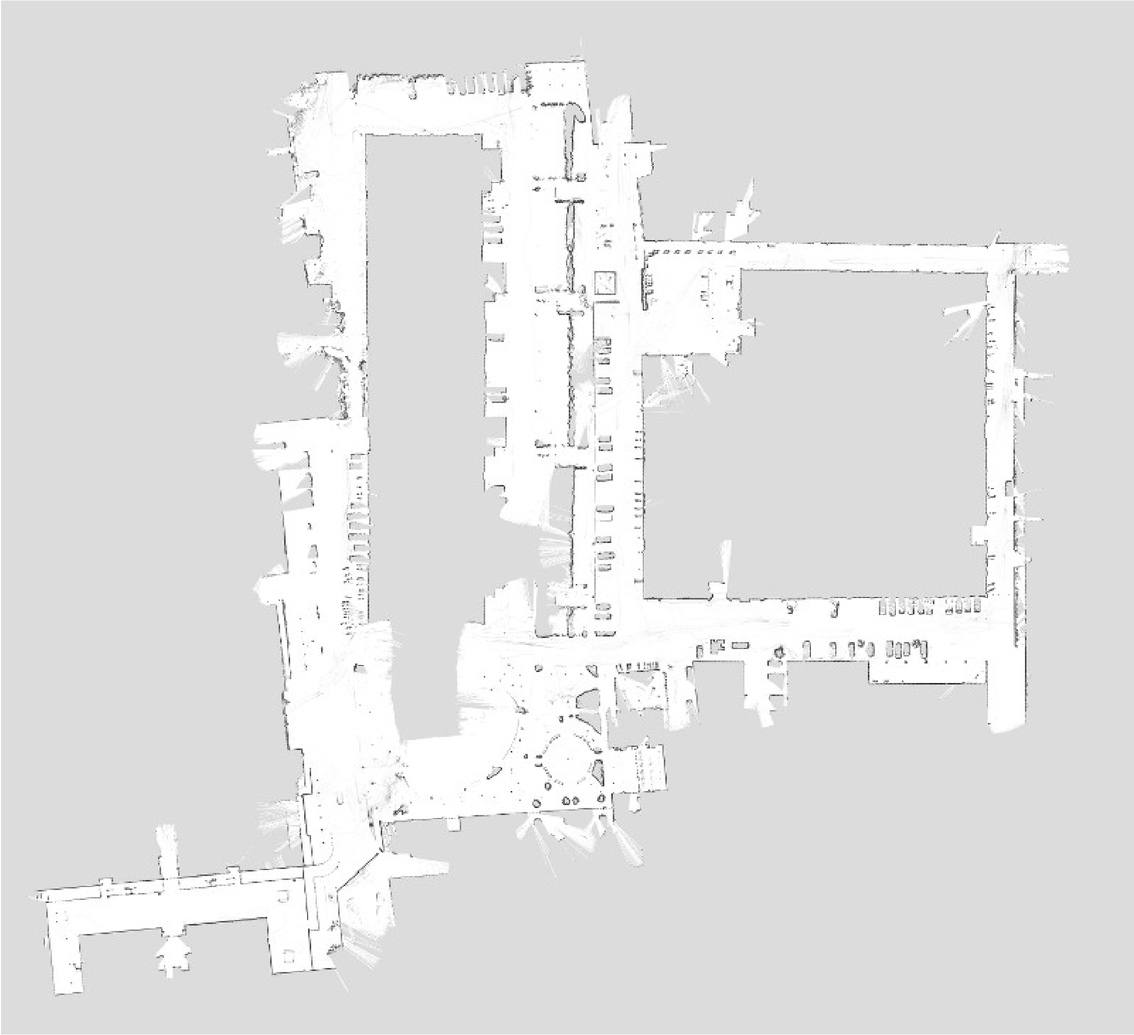


Laser-based SLAM Indoor (graph)



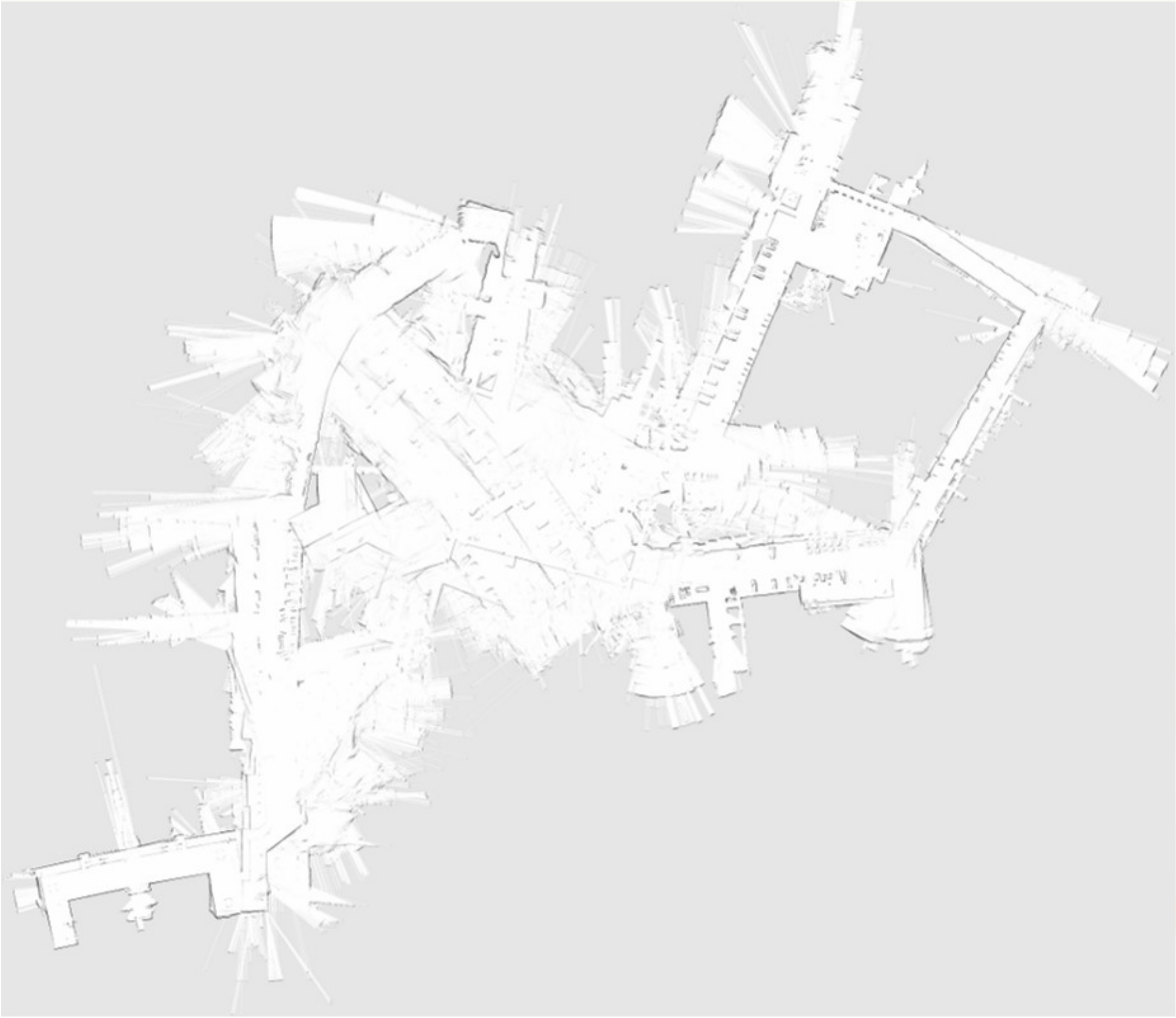
graph-mapper

Laser-based SLAM Outdoor (target)

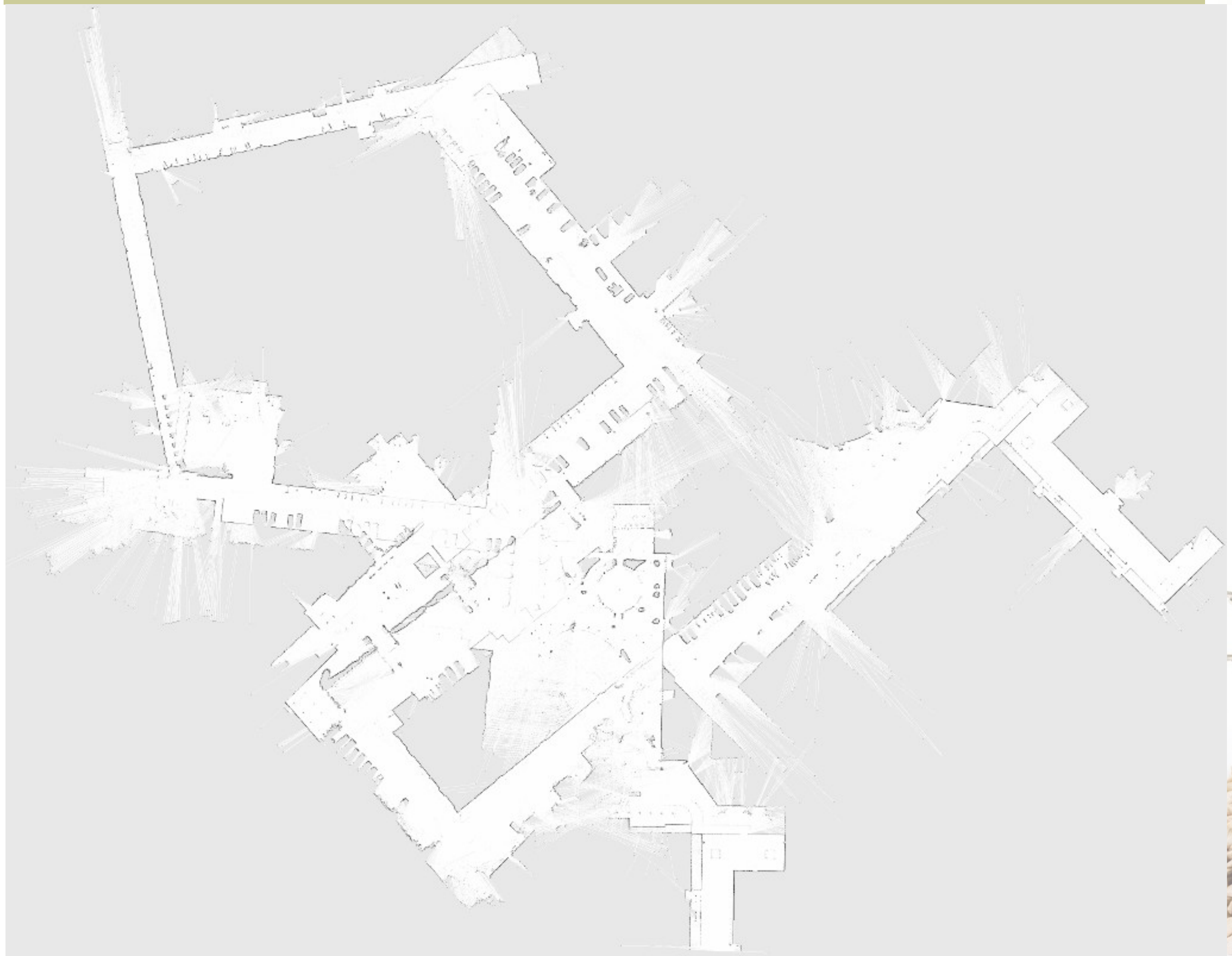


Laser-based SLAM Indoor (input)

Laser-based SLAM Indoor (scan)



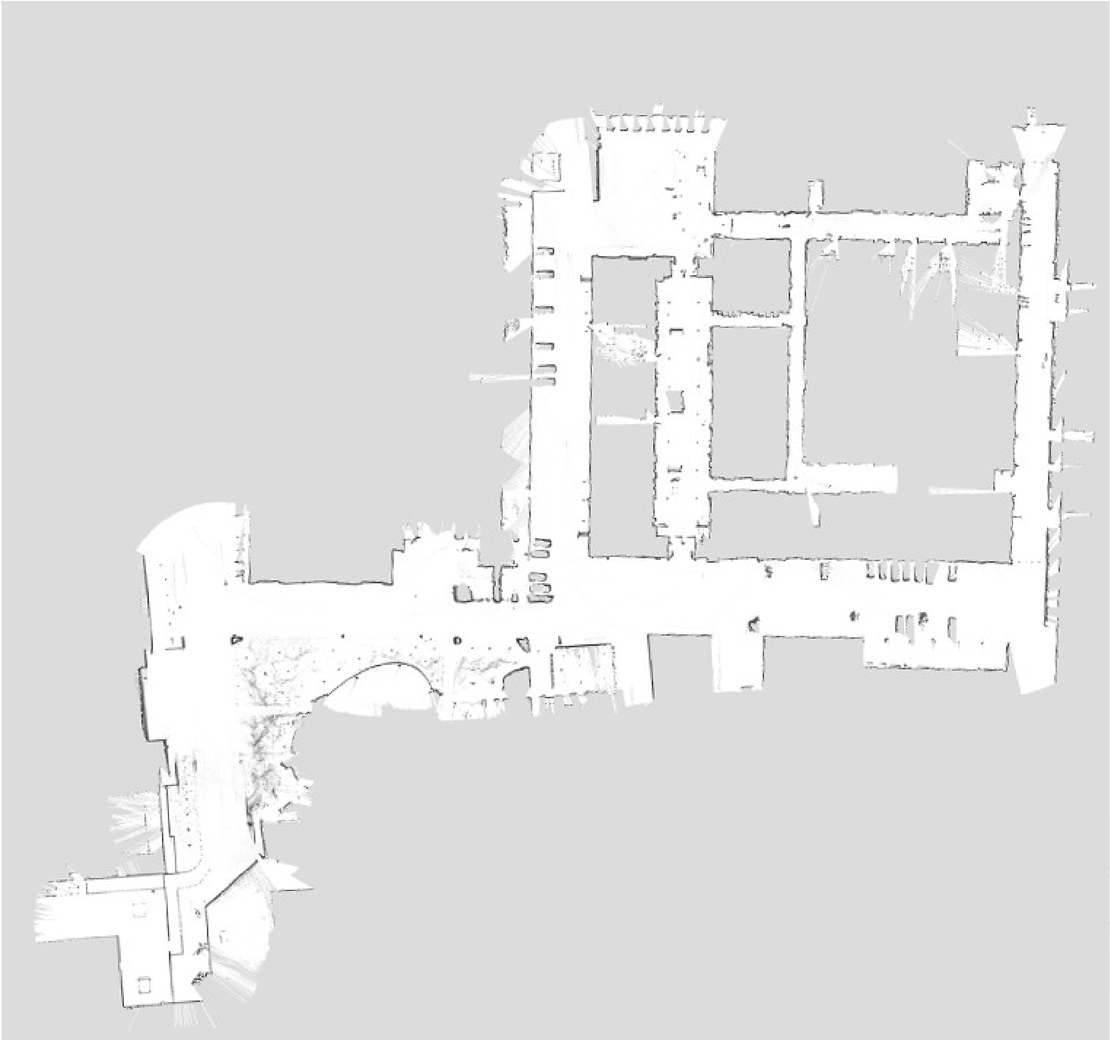
Laser-based SLAM Indoor (rb pf)



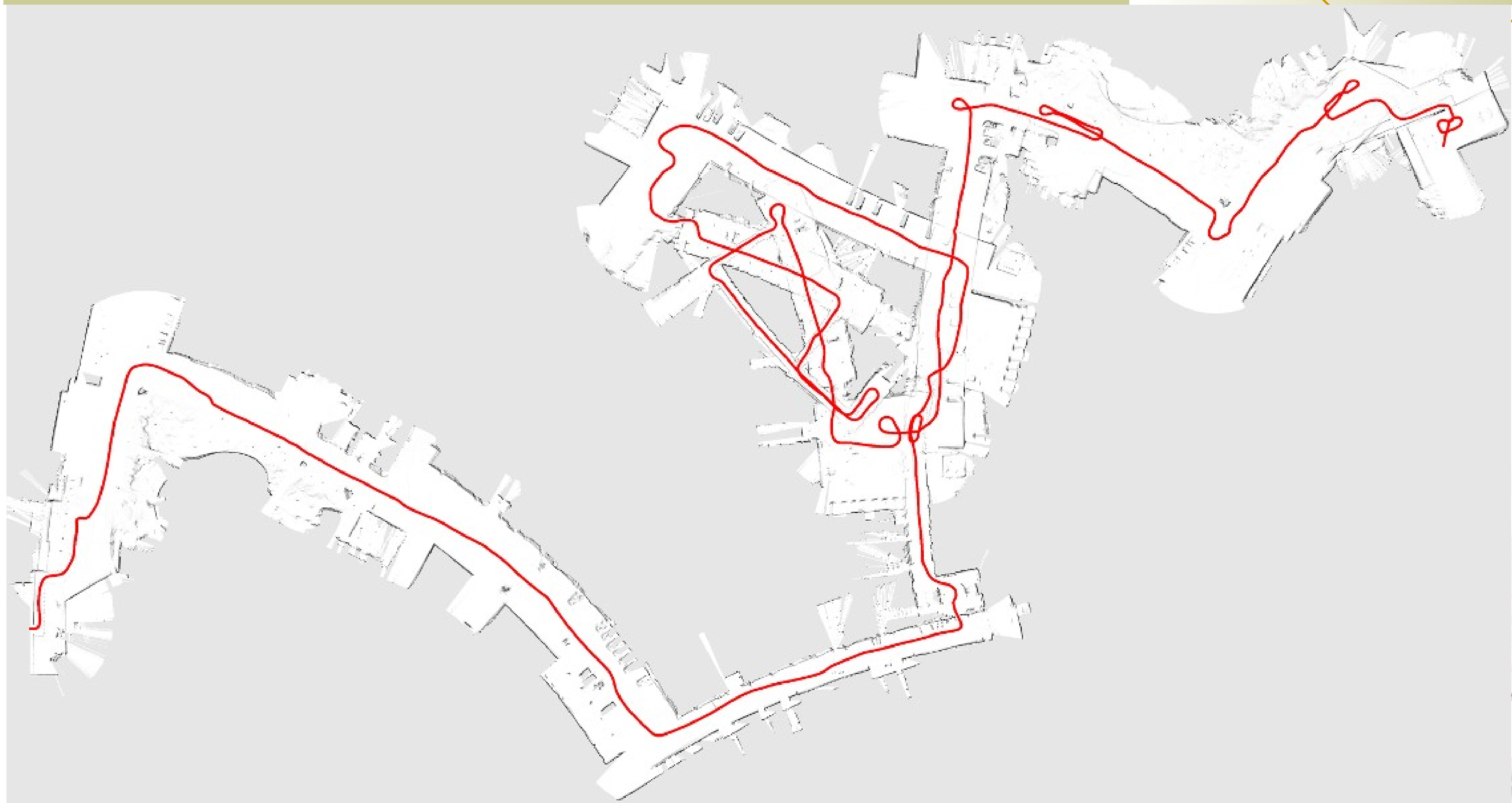
Laser-based SLAM Indoor (graph)

graph-slam

Laser-based SLAM Mixed (target)

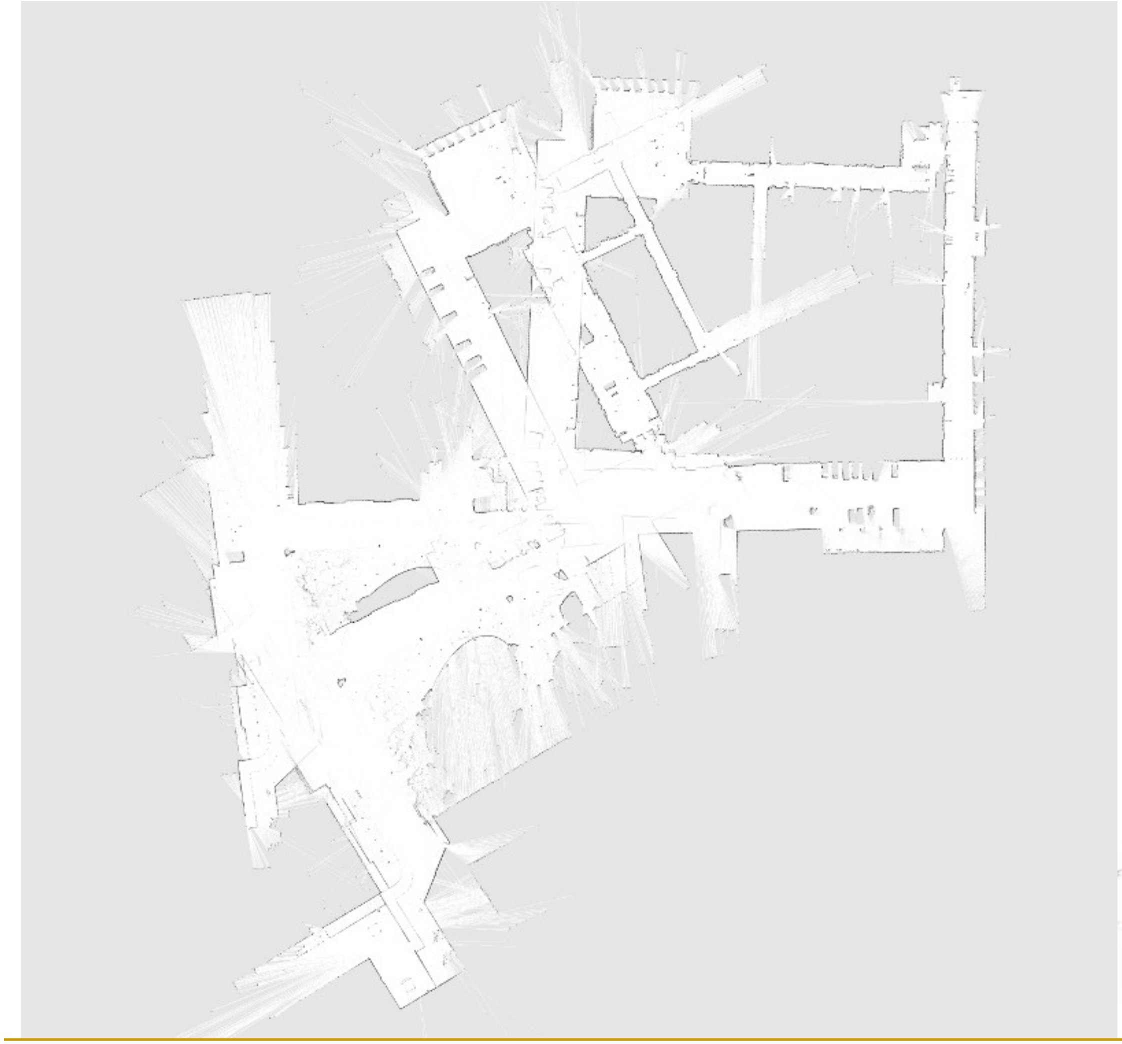


Laser-based SLAM Mixed (input)

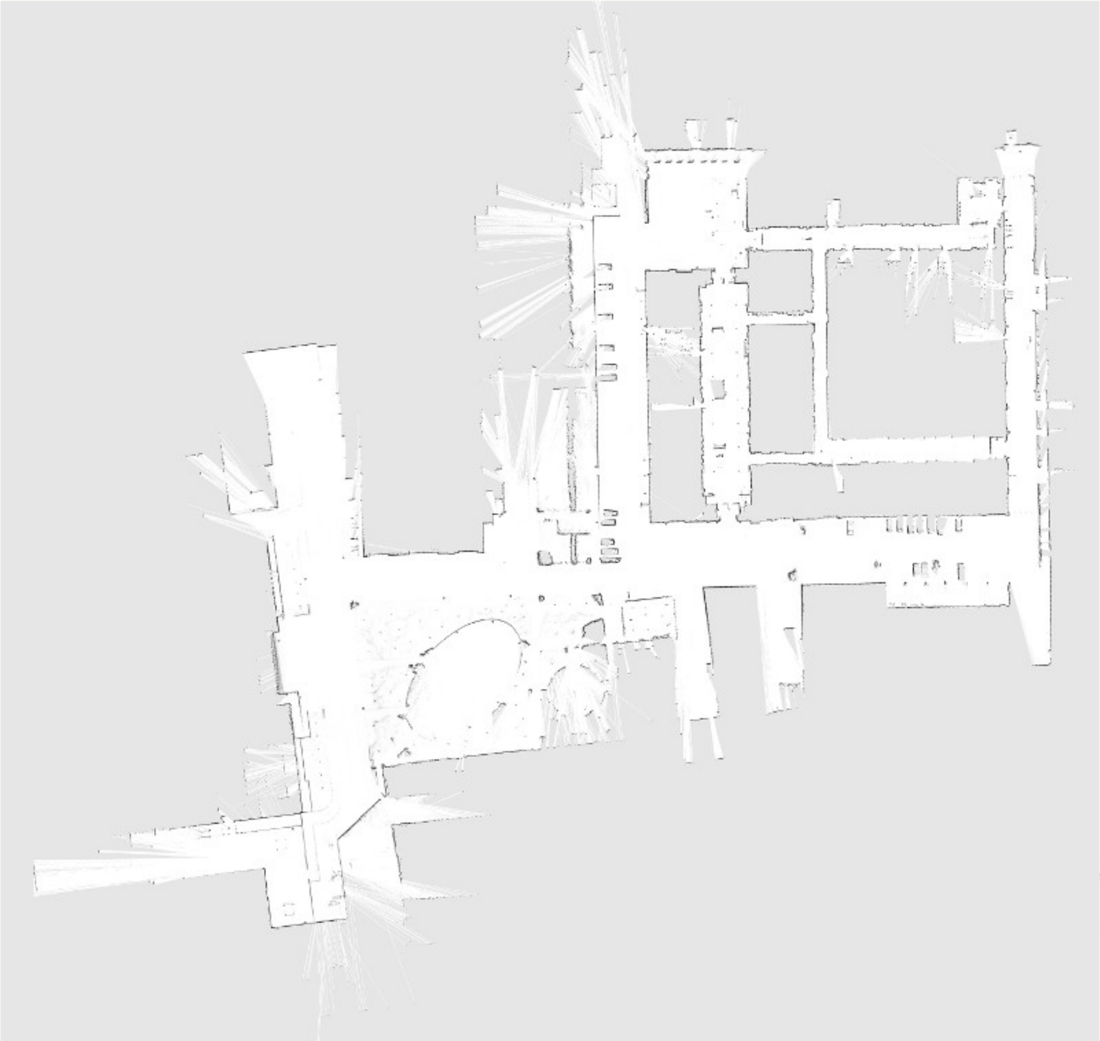


Laser-based SLAM Mixed (scan)

Laser-based SLAM Mixed (rb-pf)



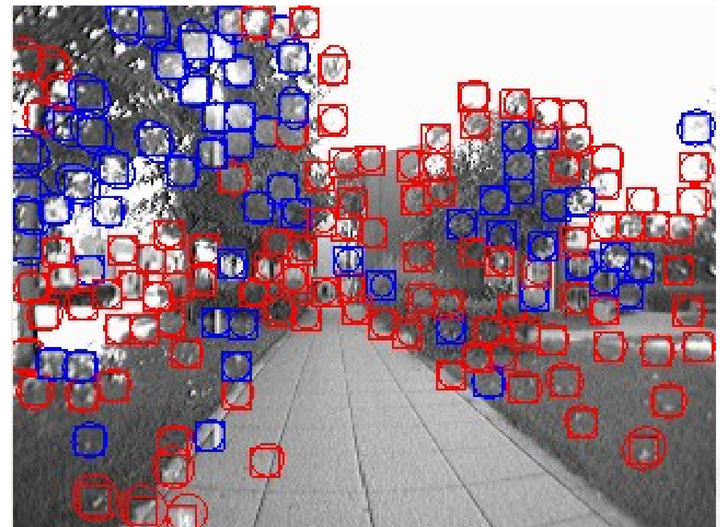
Laser-based SLAM Mixed (graph)



graph-slam

Monocular SLAM: Images used

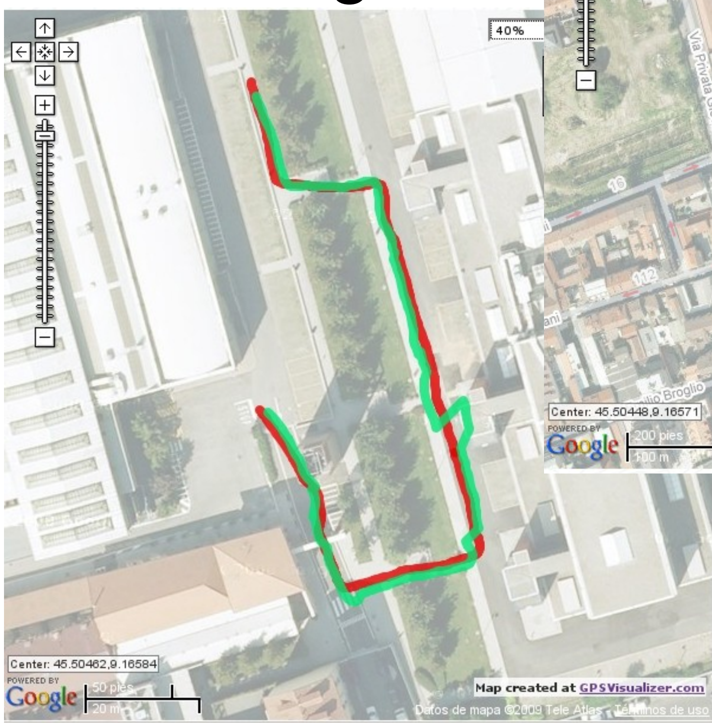
RAWSEEDS Outdoor Datasets



High number of image features per frame (~100)

Monocular SLAM Results

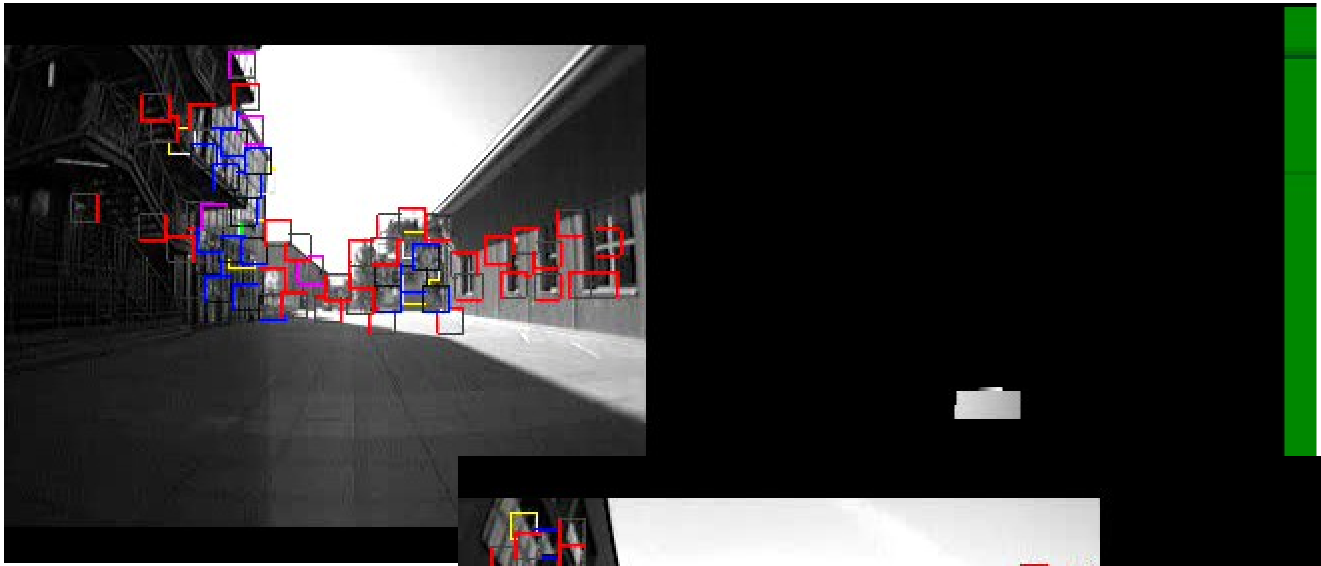
153 metres trajectory; 5400 images

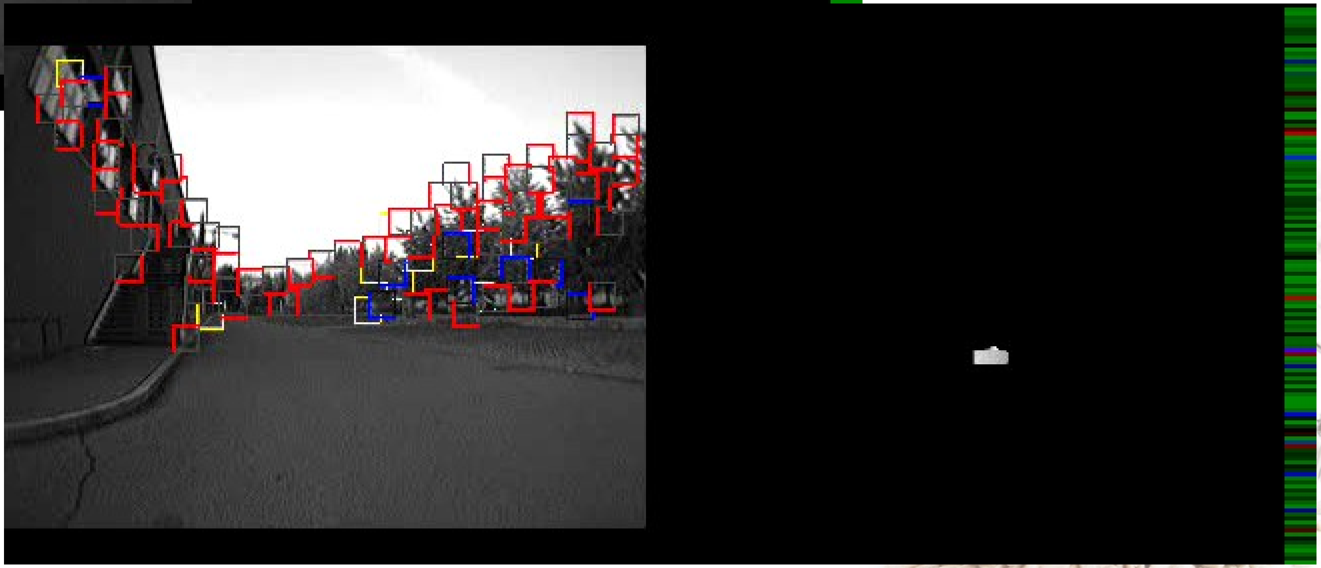


650 metres trajectory; 24180 images

- Low error (~1% of the trajectory)
- Longest trajectories ever using filtering-based visual estimation
- Near real-time processing (~1 second per frame)
- Efficient spurious search based on RANSAC

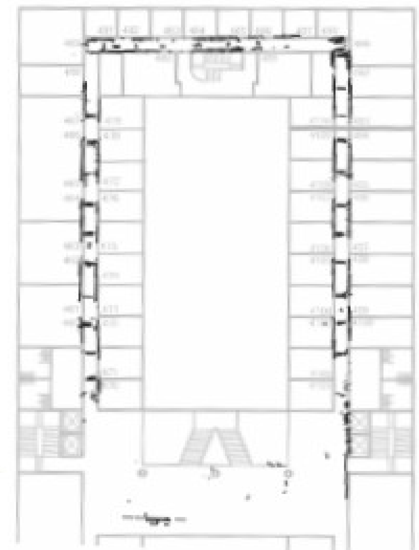
MonoSLAM: Results

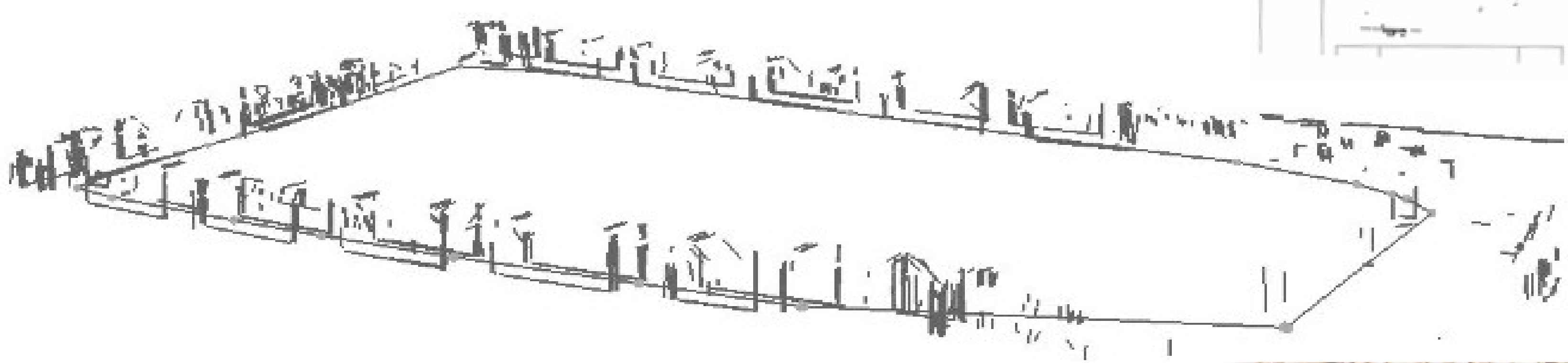




Trinocular SLAM

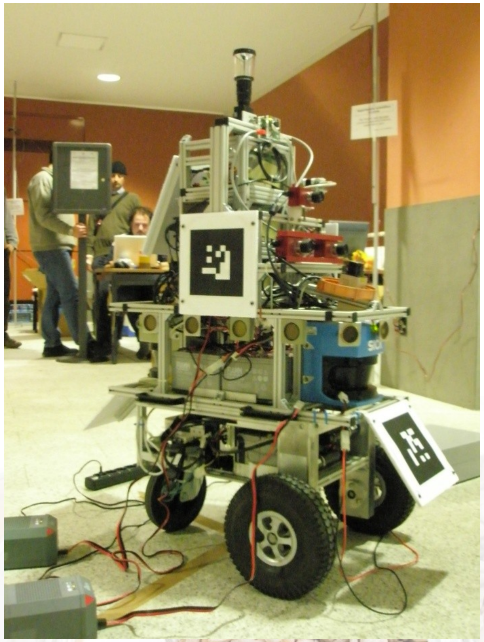
- 3D segments extracted from trinocular images are directly used as features.
- Hierarchical approach with sub-maps
  - Local maps constructed by EKF and arranged in a global graph.
  - Global consistency achieved by graph-optimization.





Conclusions & Discussion

- The RAWSEEDS benchmarking toolkit soon available!
  - Multisensorial datasets with ground truth
  - Well defined benchmarks with metrics
  - Off-the shell solutions to compare with



www.rawseeds.org

- What's after RAWSEEDS?
  - More solutions ... are expected!
  - More problems ... are welkome!
  - More datasets ...
    - One platform is there, but collection has a costs!
    - What about other platforms (automotive, aerial, underwater)
  - After perception we should benchmark decisions ...