Self-localization of (Autonomous) Mobile Systems

Soccer Robots, Mobility Assistants and Remote Cameras

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Safe and Secure Cognitive Systems
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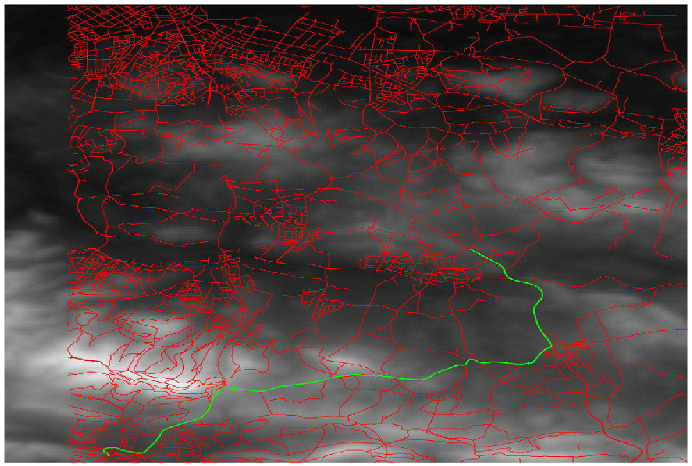
Overview

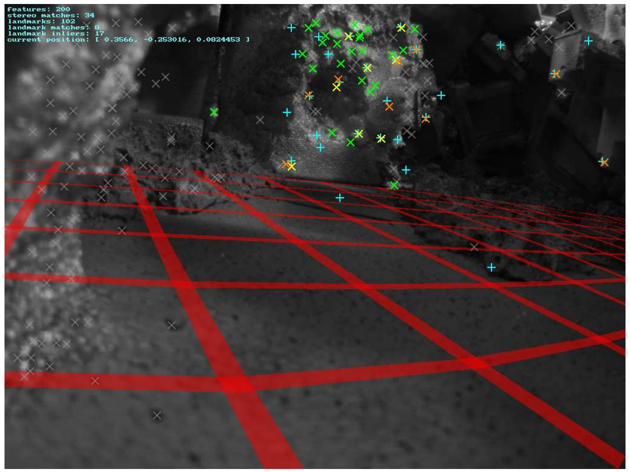
Soccer Robots

Mobility Assistants in Indoor Environments

Outdoor Localization without GPS

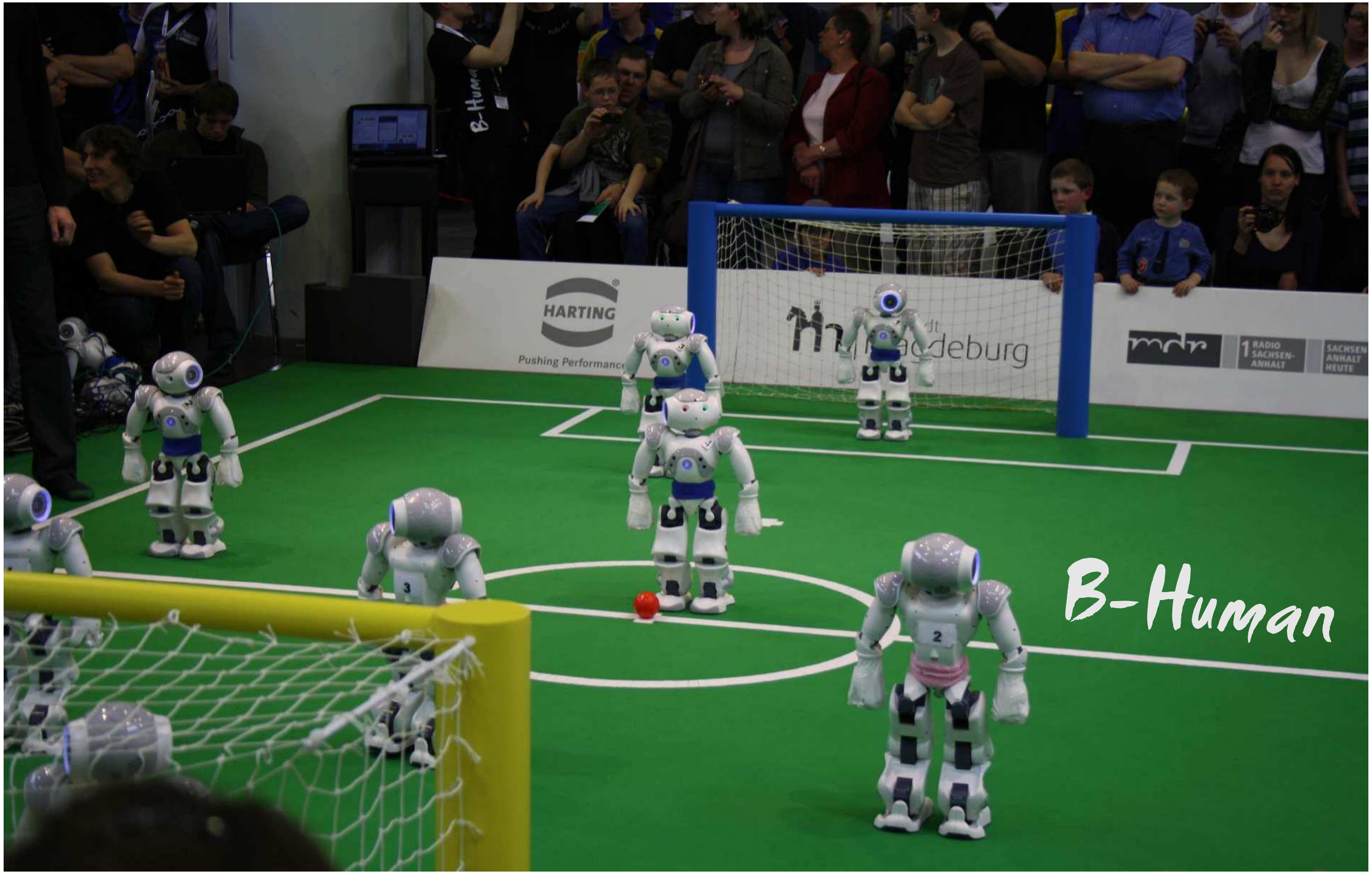


Visual SLAM



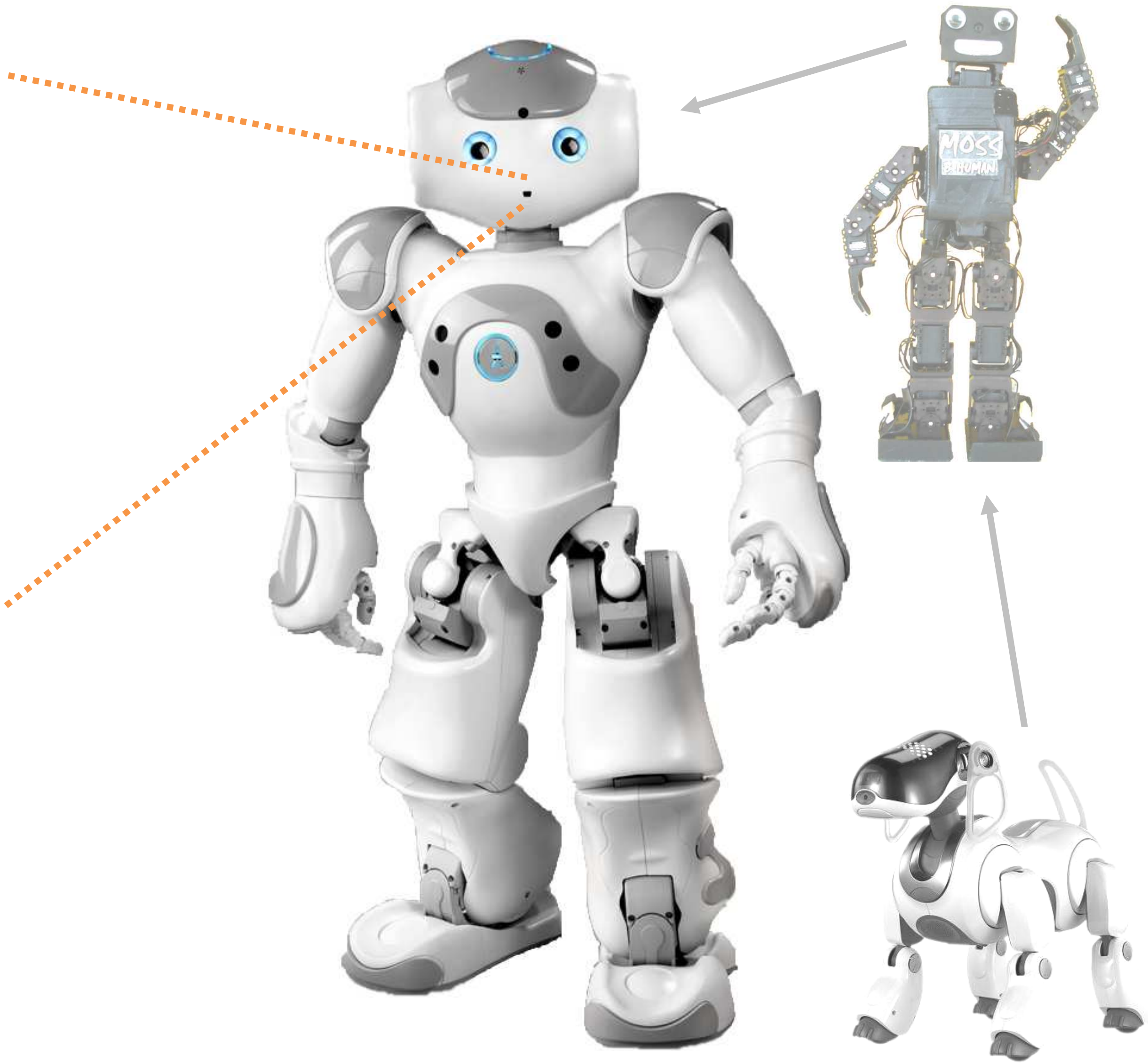
RoboCup Standard Platform League

Safe and Secure Cognitive Systems



RoboCup Standard Platform League

Safe and Secure Cognitive Systems

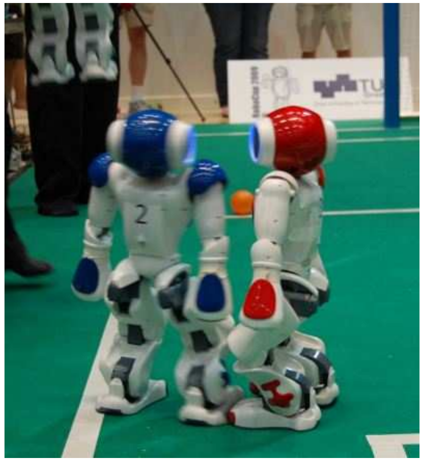


320 x 240 pixel @ 30fps

500 MHz processor

Gyroscopes + accelerometers

External Sources of Uncertainty



Blocks

Fouls

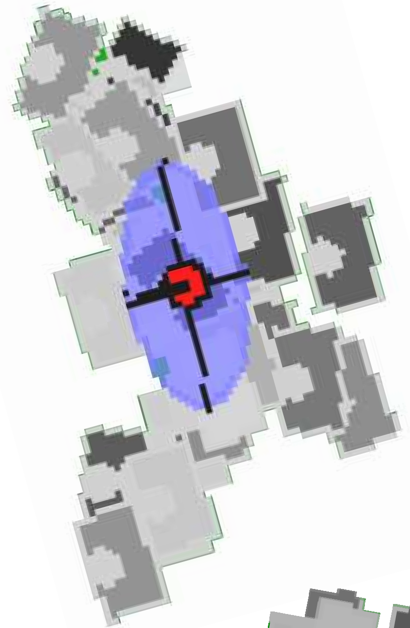
Referees

Spectators

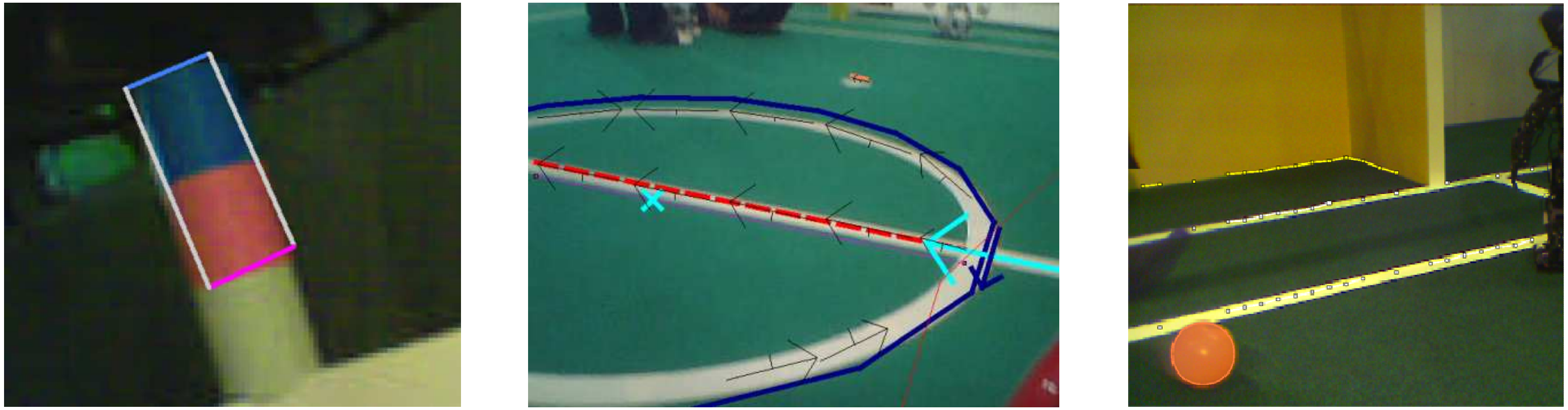
- Other actors introduce uncertainty
  - RoboCup soccer is an adversarial environment
- Permanent external state changes demand efficiency
- Self-localization is necessary for success

Monte-Carlo Localization

- Textbook particle filter implementation
  - "Probabilistic Robotics" (Thrun, Burgard, Fox)
  - Sensor Resetting
  - Augmented-MCL approach
  - 100 particles
  - X_t = Position and rotation in 2D
- Advantages
  - Represents multimodal probability distributions
  - Efficient handling of the *"Kidnapped Robot Problem"*
  - States can contain discrete elements
- De-facto standard in some RoboCup leagues
  - Often combined with (Extended /Unscented) Kalman Filter
- Contributions
  - Robust sensor models
  - Efficient pose extraction algorithm

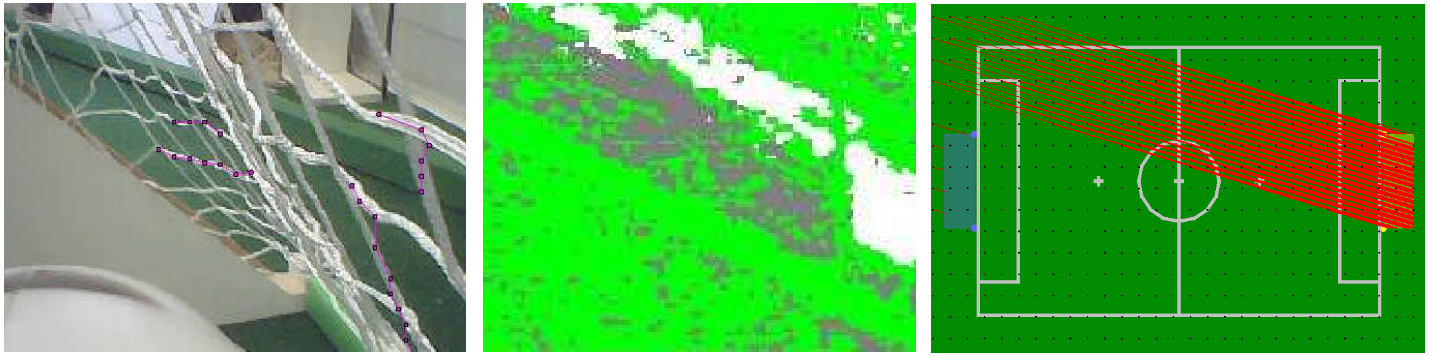


Sensor Models



Unique cues ◄- -► Ambiguous cues

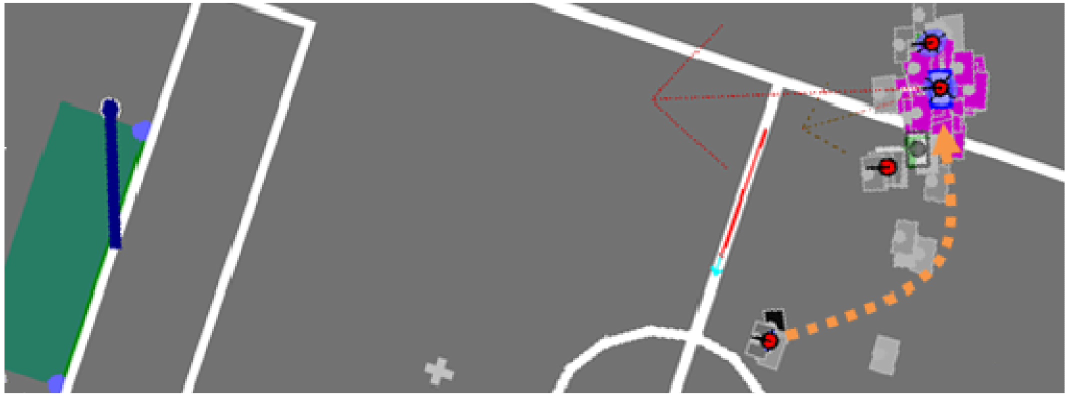
State-based sensor model to compensate limited vision



Tim Laue, Thijs Jeffry de Haas, Armin Burchardt, Colin Graf, Thomas Röfer, Alexander Härtl and Andrik Rieskamp:
Efficient and Reliable Sensor Models for Humanoid Soccer Robot Self-Localization.
In Changjiu Zhou, Enrico Pagello, Emanuele Menegatti, Sven Behnke and Thomas Röfer (editors): Proceedings of the Fourth Workshop on Humanoid Soccer Robots in conjunction with the 2009 IEEE-RAS International Conference on Humanoid Robots, S. 22 – 29, Paris, Frankreich, 2009.

Pose Extraction

- Not handled by MCL
- Multimodal distributions are not trivial to handle
  - Clustering or rasterization of state space needed
- Sensor resetting reinforces multimodalities

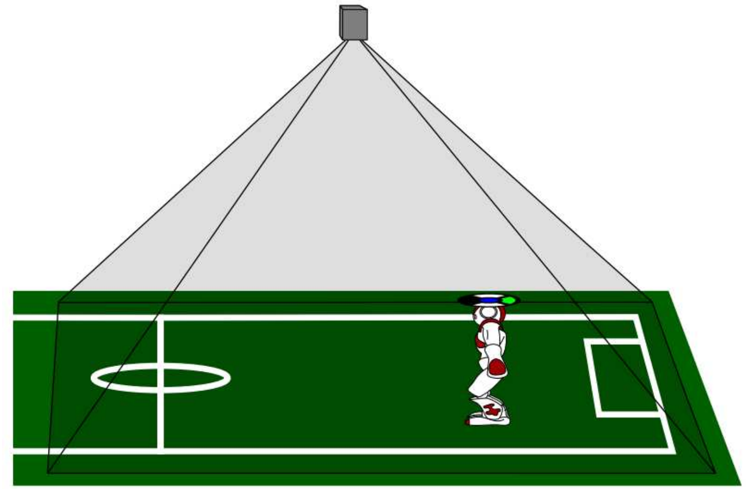


- New approach for extracting poses from multimodal distributions
  - Based on resampling ancestry of particles
  - Continuous and efficient

Tim Laue and Thomas Röfer:
Pose Extraction from Sample Sets in Robot Self-Localization - A Comparison and a Novel Approach.
In Ivan Petrović and Achim J. Lilienthal (editors): Proceedings of the 4th European Conference on Mobile Robots - ECMR'09, S. 283–288, Mlini/Dubrovnik, Kroatien, 2009.

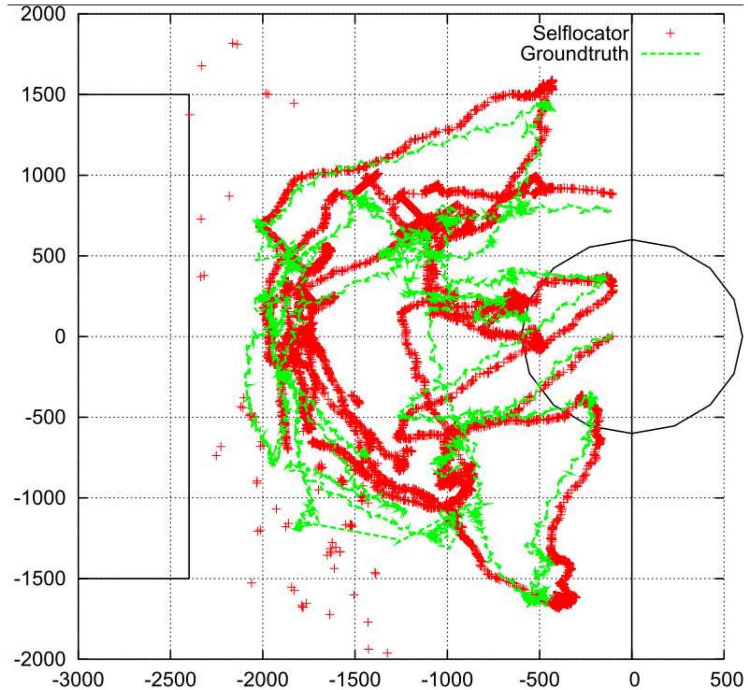
Precision

- Multiple experiments using an external tracking system



- Average error:

Walking on the field	~10 – 15cm
1 vs. 1 soccer	~20cm
2 vs. 2 soccer	~30cm



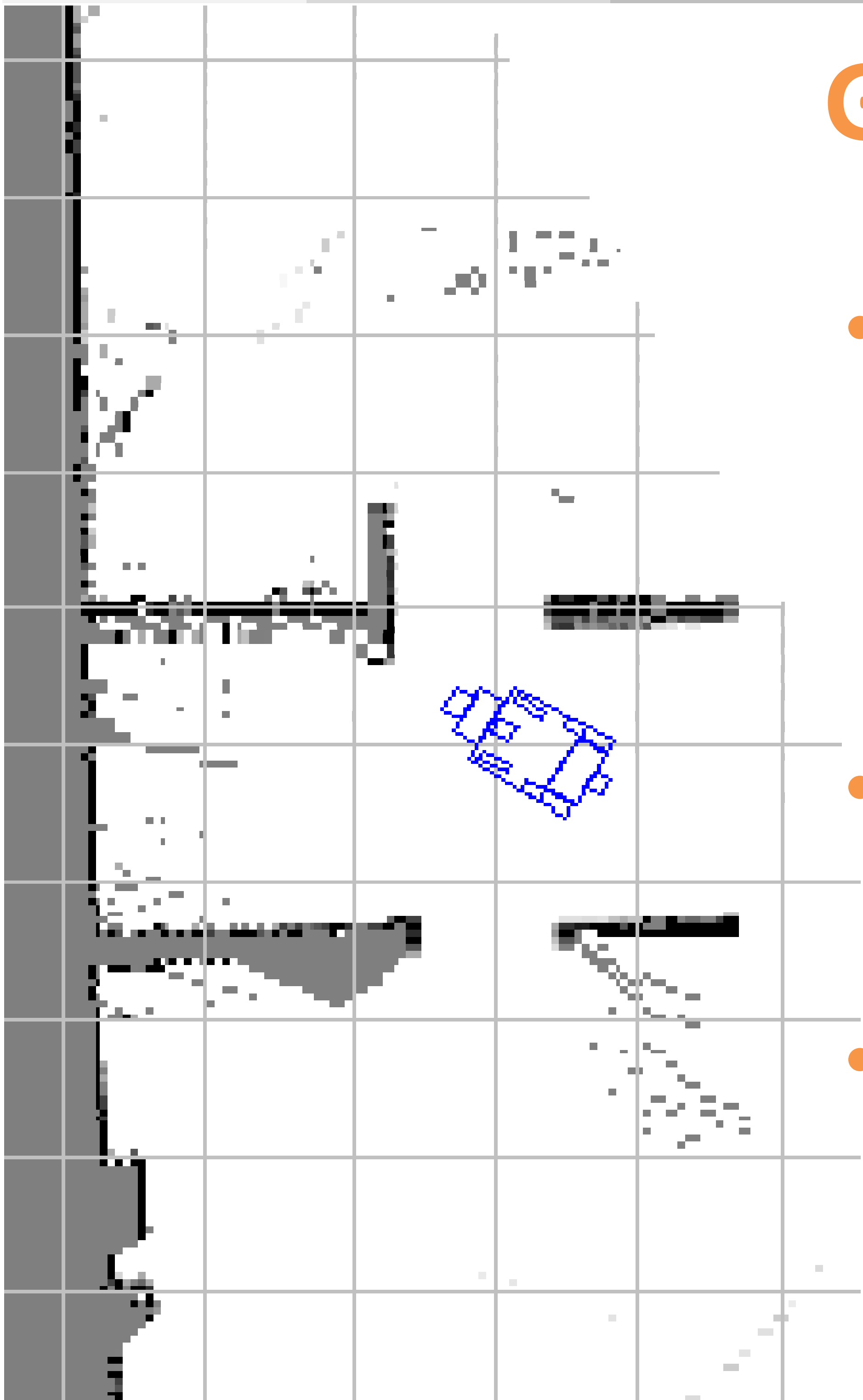
Mobility Assistants

iWalker

Rolland

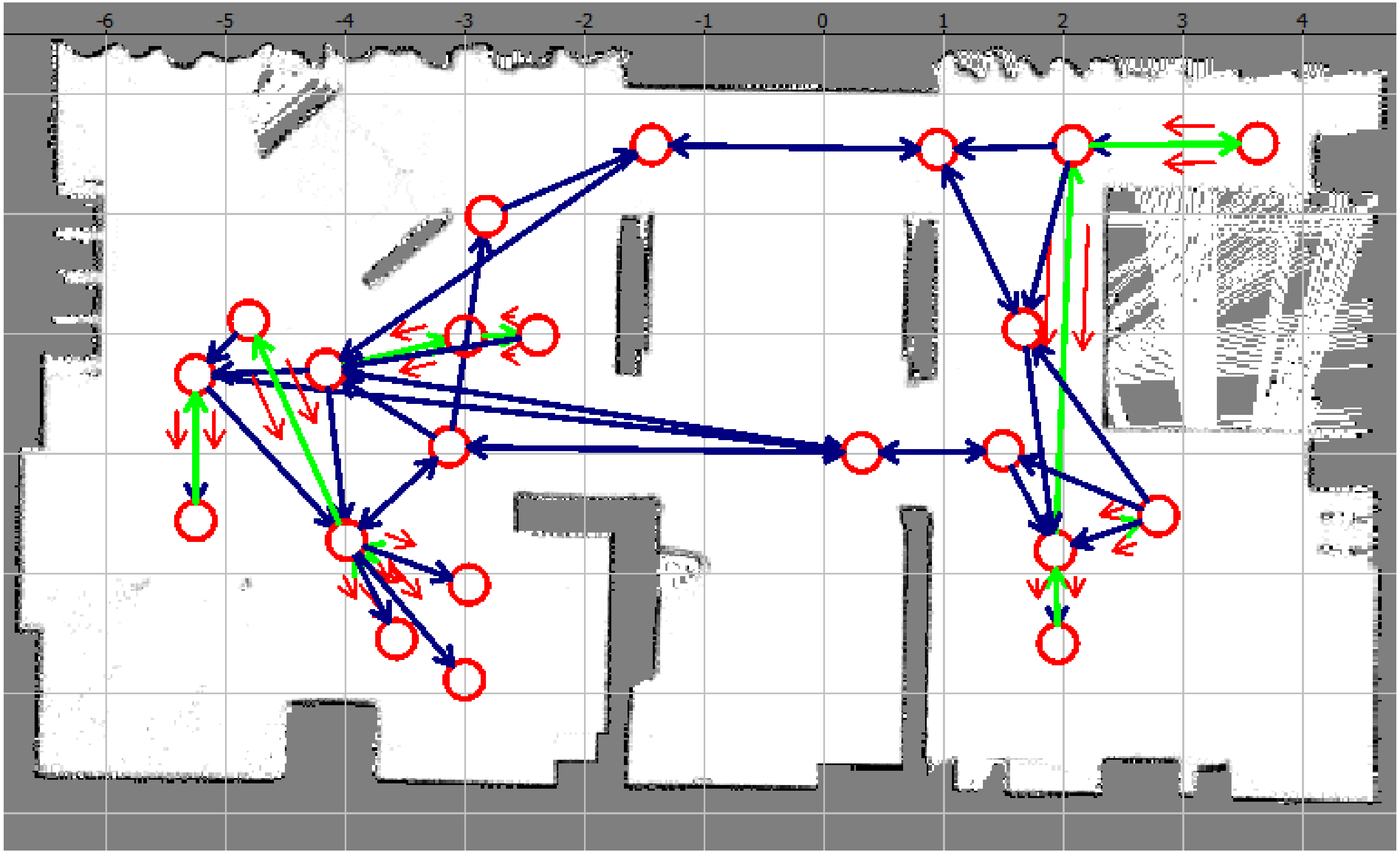
Laser range finders
(Hokuyo / Sick S300)

GMapping



- GridFastSLAM implementation
  - Universität Freiburg
    - Stachniss, Grisetti, Burgard
  - http://openslam.org/
  - Open Source
  - Applied to many environments
- Mapping for vehicles that
  - Move in 2D
  - Have one 2D laser range finder
- Extensions by us
  - Localization mode
  - Loading and saving maps
  - Win32 support

Navigation Graph



Bremen Ambient Assisted Living Lab (BAALL)

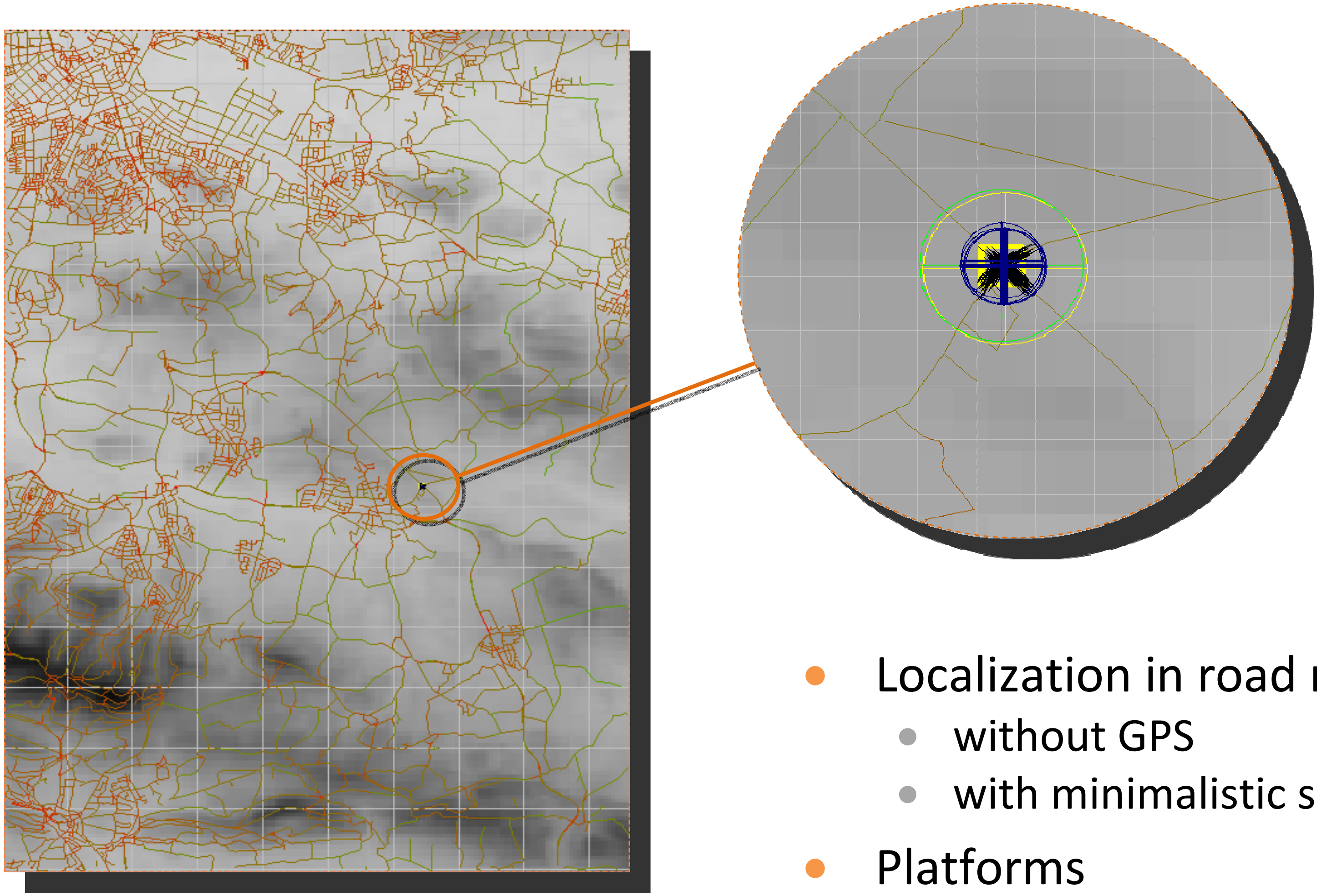
Wayfinding Assistance

Thomas Röfer, Tim Laue and Bernd Gersdorf:
iWalker - An Intelligent Walker providing Services for the Elderly.
In Technically Assisted Rehabilitation 2009, Berlin, 2009.

Autonomous Navigation

CeBIT 2009

Outdoor Navigation

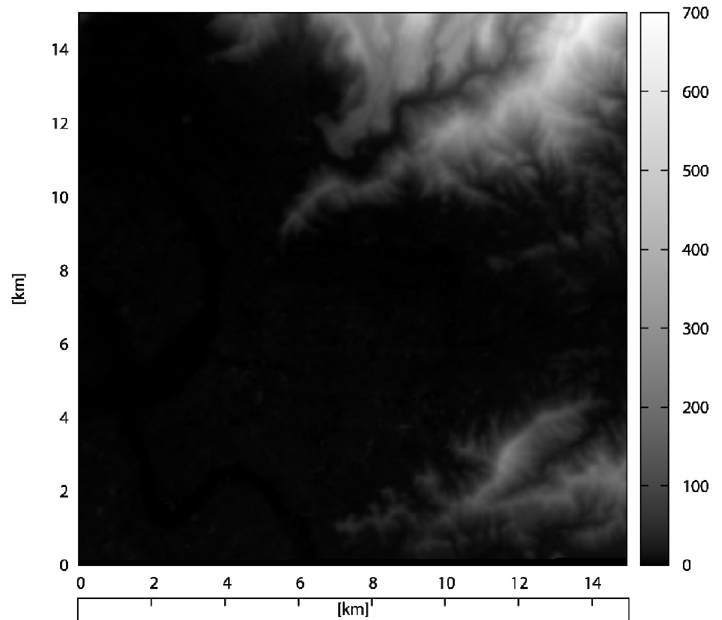


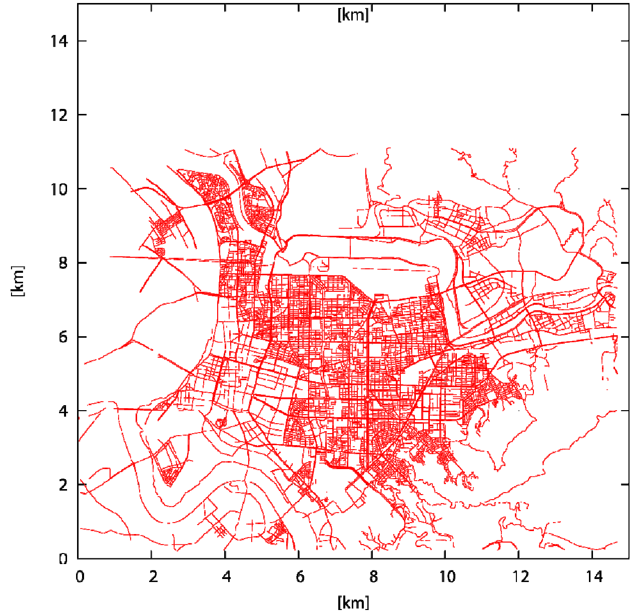
Christian Mandel und Tim Laue:
Particle Filter-based Position Estimation in Road Networks using Digital Elevation Models.
In Proceedings of the 2010 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Taipei, Taiwan, 2010.

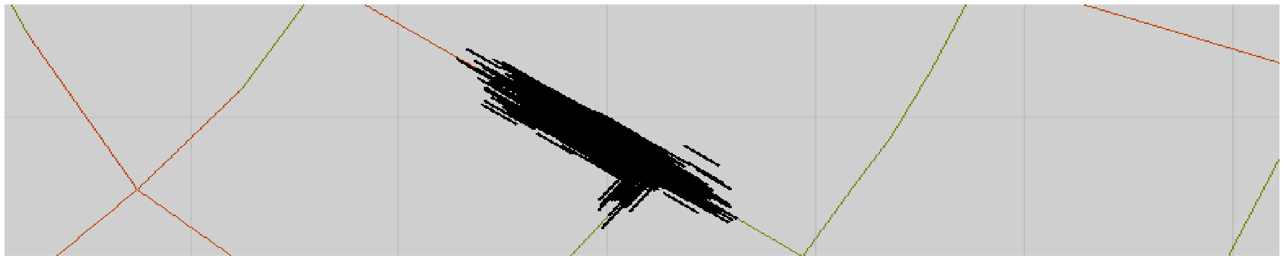
- Localization in road networks
  - without GPS
  - with minimalistic sensor equipment
- Platforms
  - Rolland
  - Bicycle

Monte-Carlo Localization

- Same implementation as for soccer robots
- Sensor model
  - Barometer + digital elevation map
    - Shuttle Radar Topography Mission
  - Compass
- Motion model
  - Odometry
  - Along OpenStreetMap model

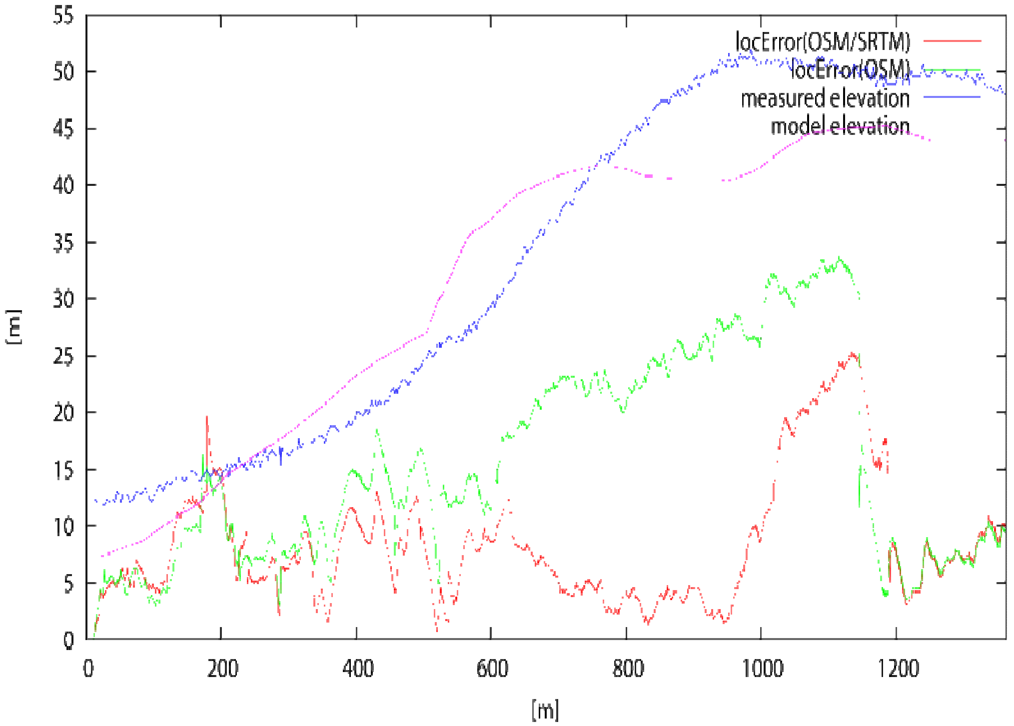


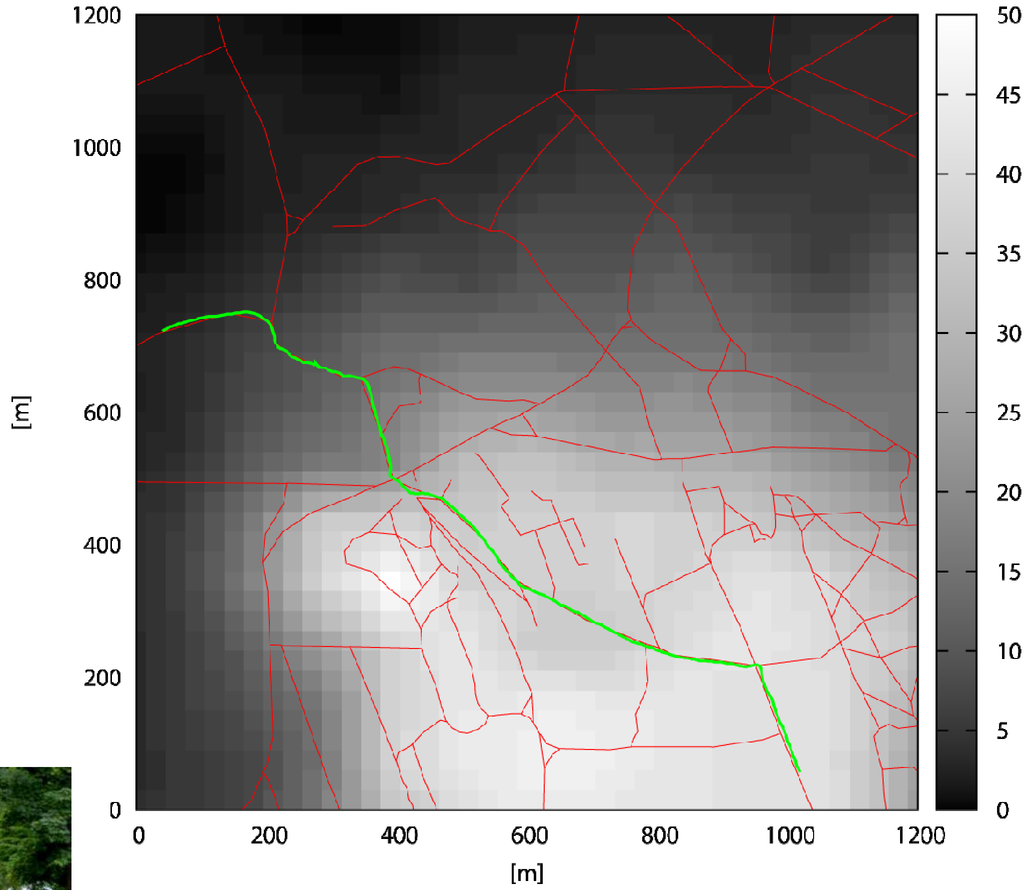




Safe and Secure Cognitive Systems

Experiments

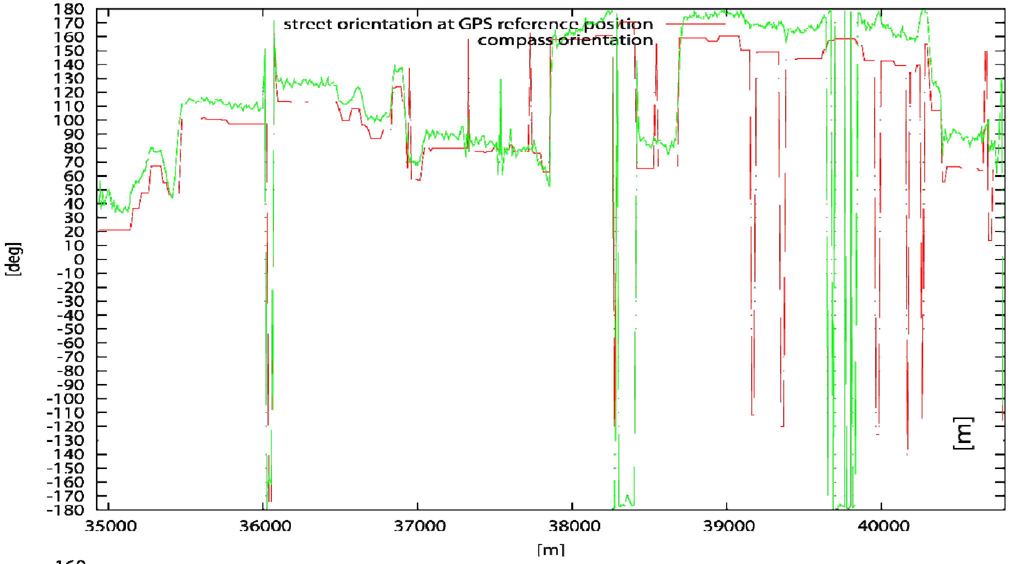


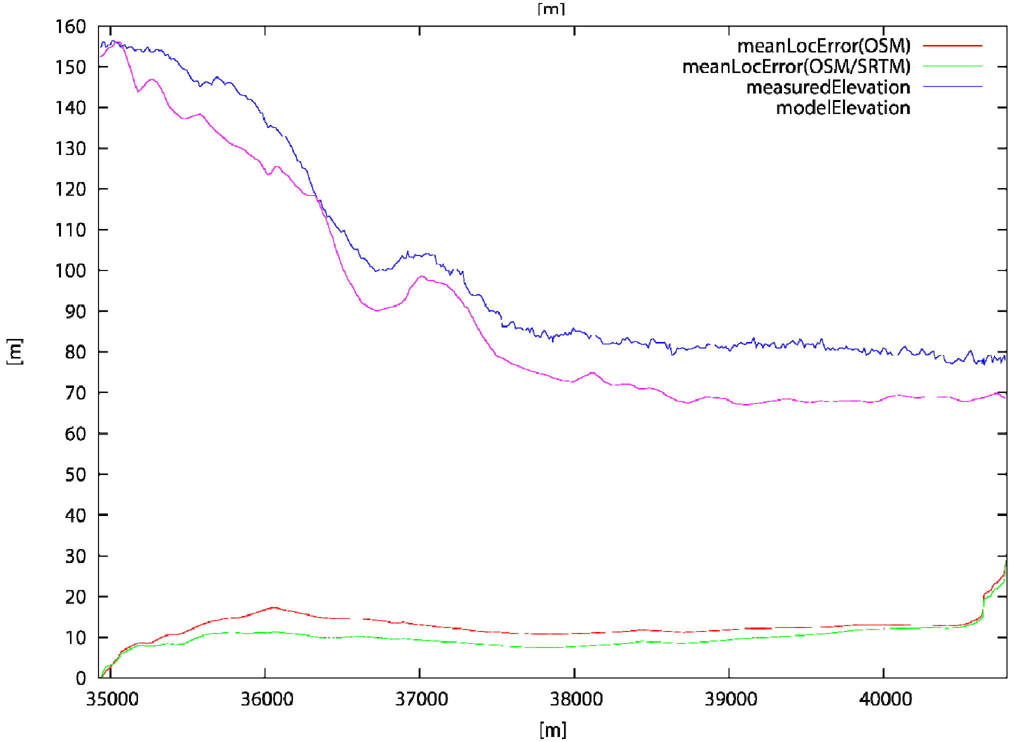


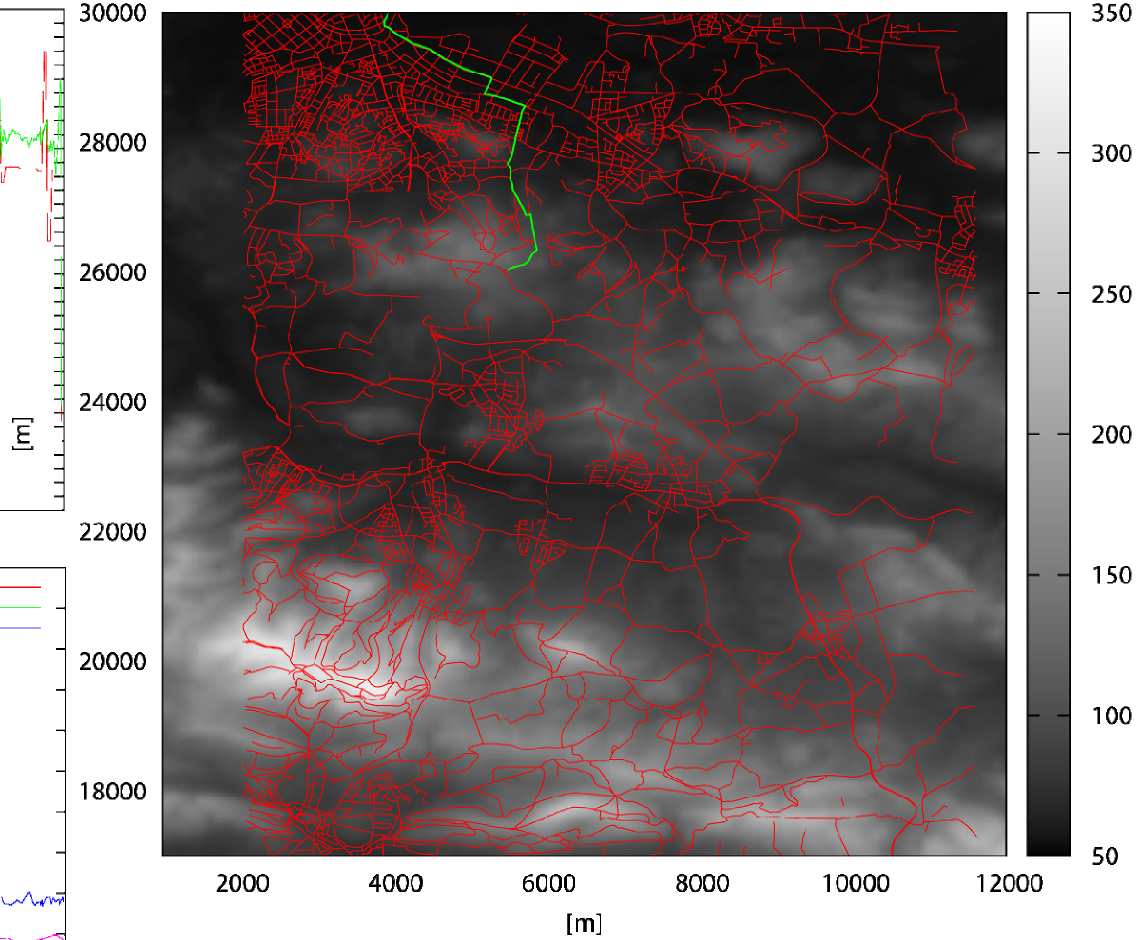
location: Worpswede, Germany

length: 1364m

Experiments



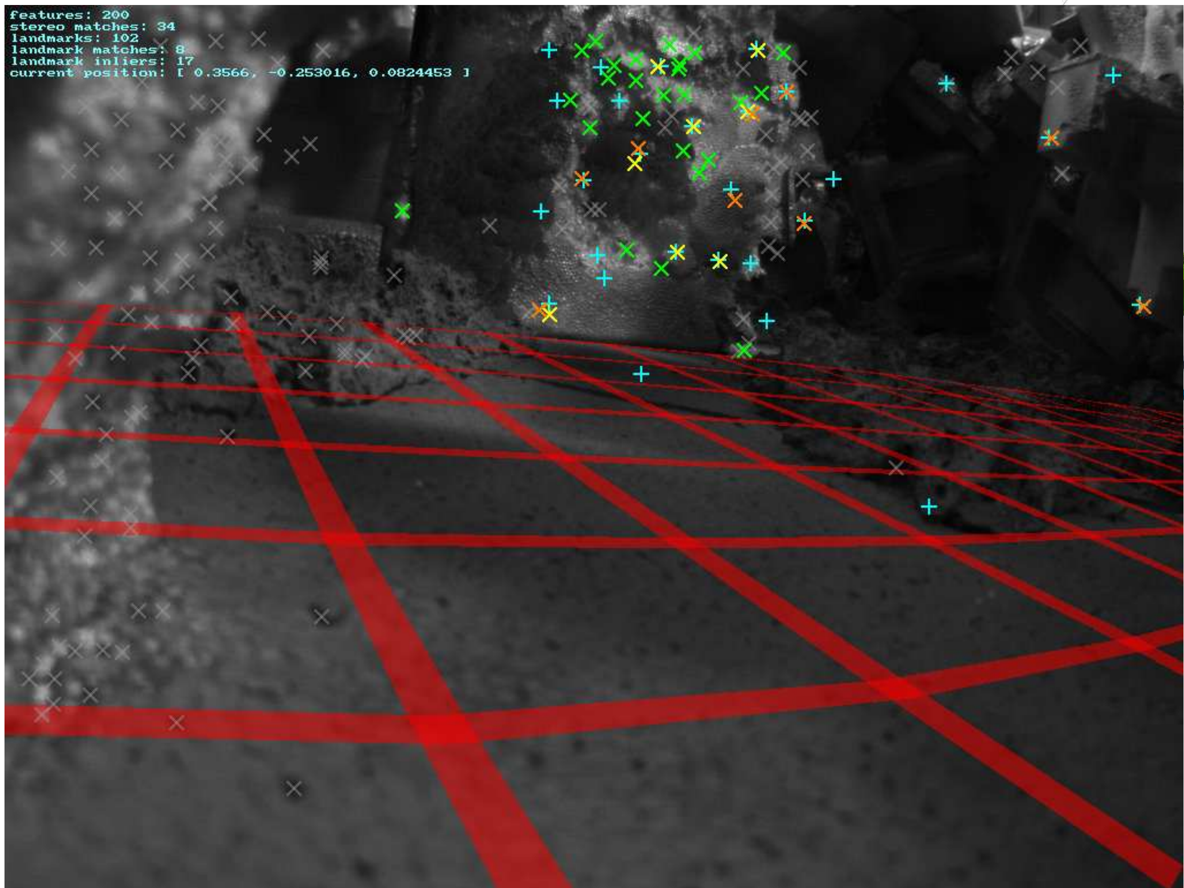


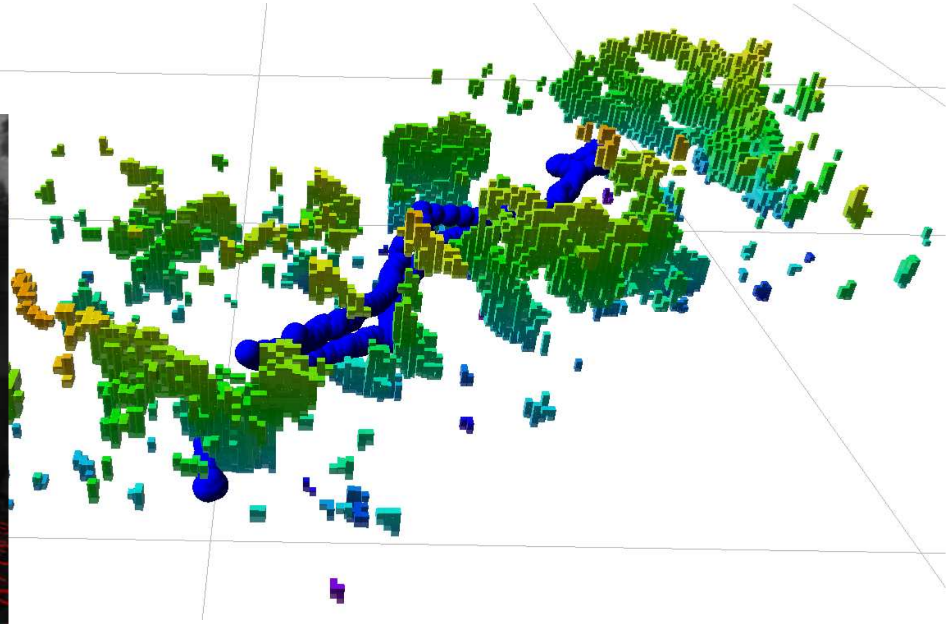


location: Osnabrück, Germany

length: 5875 m

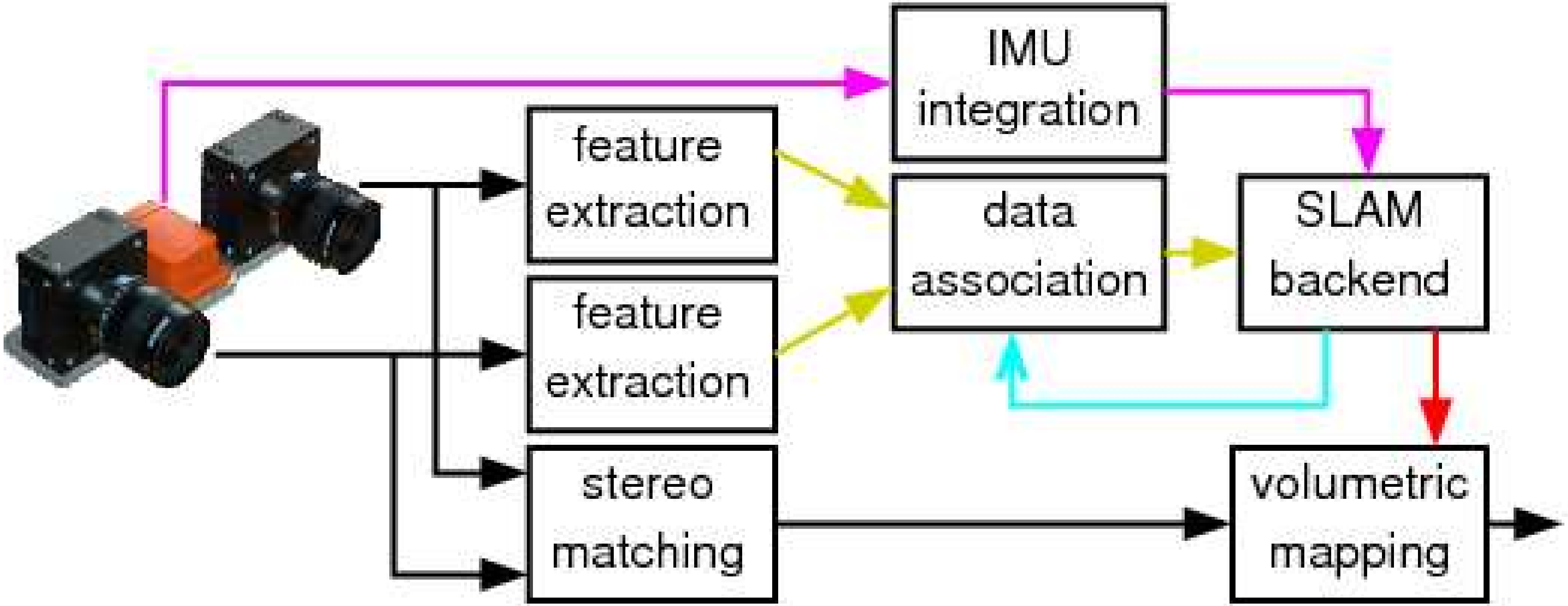
Experiences in Building a Visual SLAM System from Open Source Components





Christoph Hertzberg, René Wagner, Oliver Birbach, Tobias Hammer, Udo Frese:
Experiences in Building a Visual SLAM System from Open Source Components.
In Proceedings of the International Conference on Robotics and Automation (ICRA), Shanghai, China, 2011.

Overview / Architecture

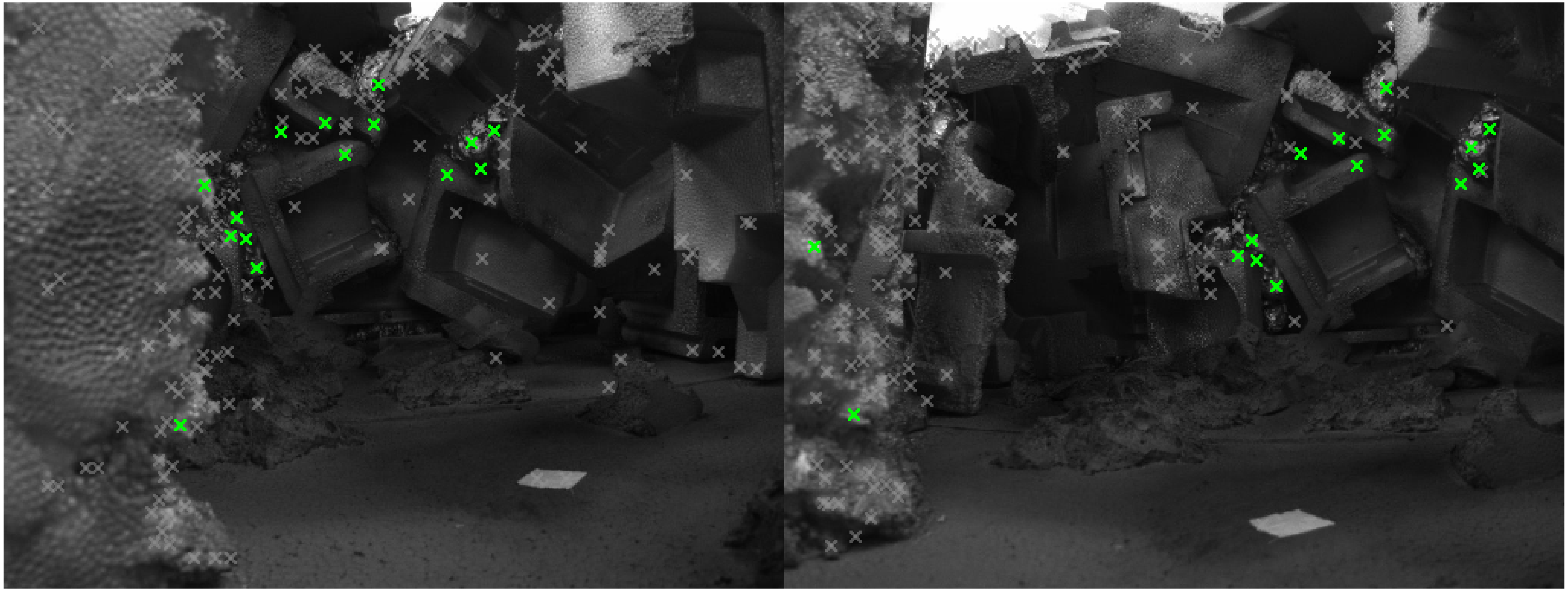


Feature Extraction

- Look for keypoints in each image
- Signature is computed for each keypoint
  - Should be similar for reasonable changes in perspective/lightning
  - But different for different keypoints
- We evaluated detectors/descriptors
  - SURF/SURF is good compromise regarding speed and reliability

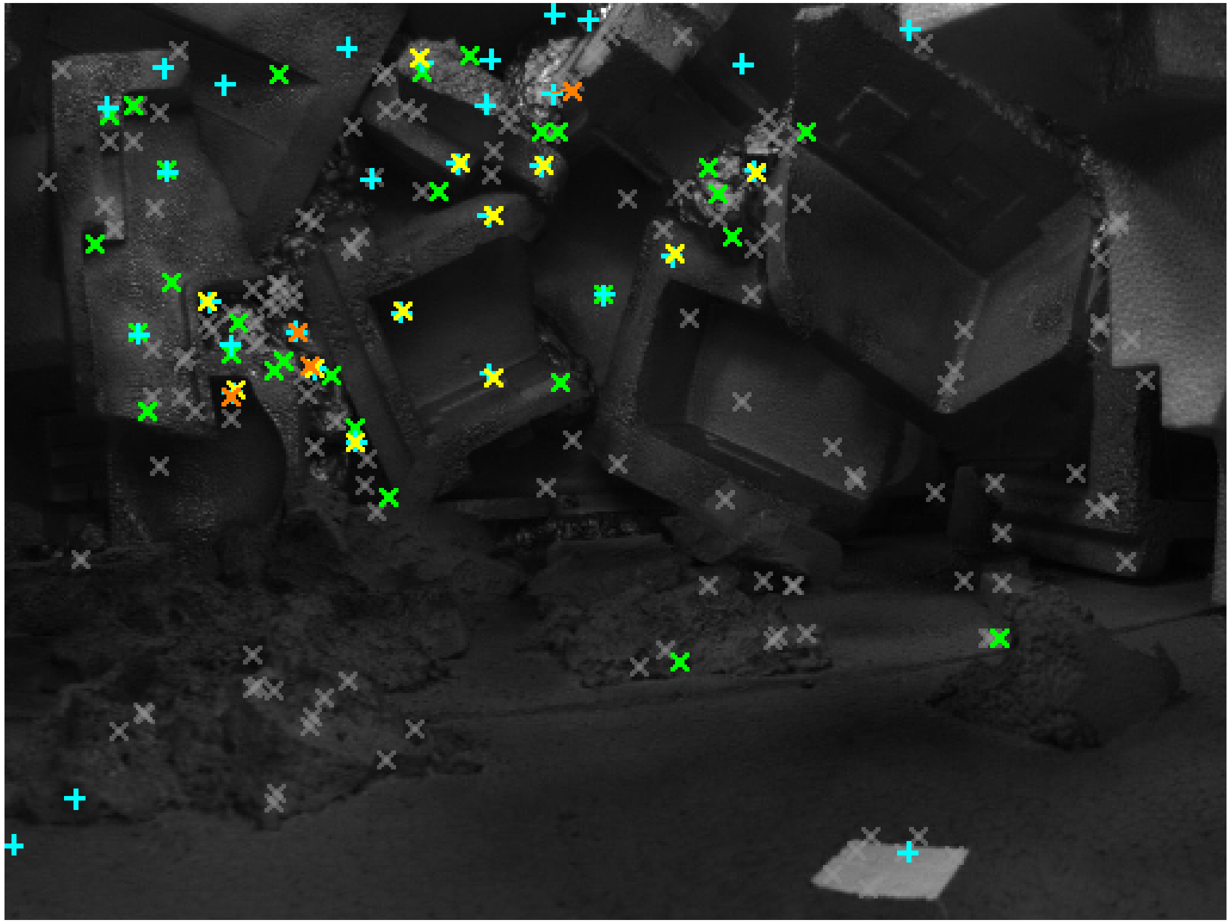
Data Association (Stereo)

- For every keypoint in left image search nearest neighbor in right image
- Consistend match iff left point is also nearest neighbor of right point
- Still many outliers, so additional epipolarity check
  - Calculate corresponding 3D point



Data Association (Global)

- Same approach for new features versus map features
- Keypoints found in map add new constraint for feature
  - Additional check for outliers
- Keypoints not found are registered as new feature
- Too few features, so additional monocular measurements



Data Association (Summary)

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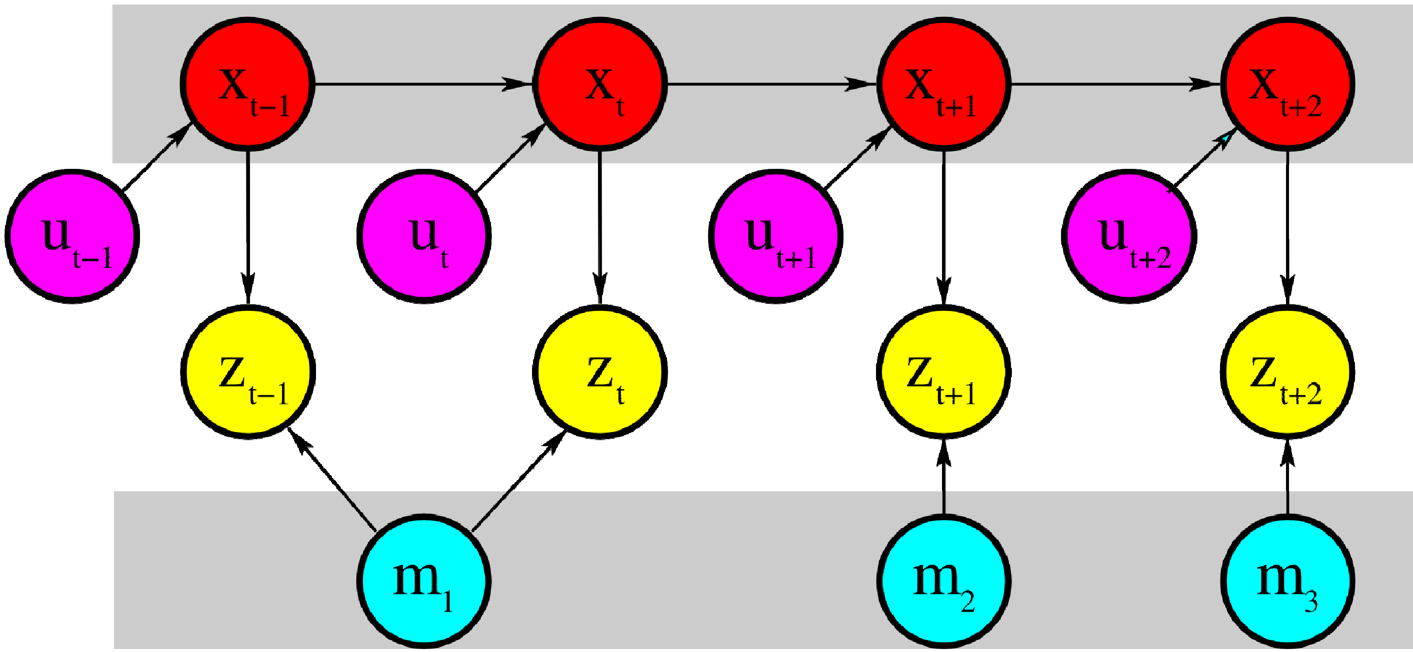
- Method sufficiently robust with enough matches between consecutive frames
- Method is not capable of loop-closing
- Runtime of nearest-neighbor search is negligible (<2ms)

IMU-Integration

- IMU Measurements can compensate short periods w/o feature detection
- Also give information about orientation



IMU-Integration II

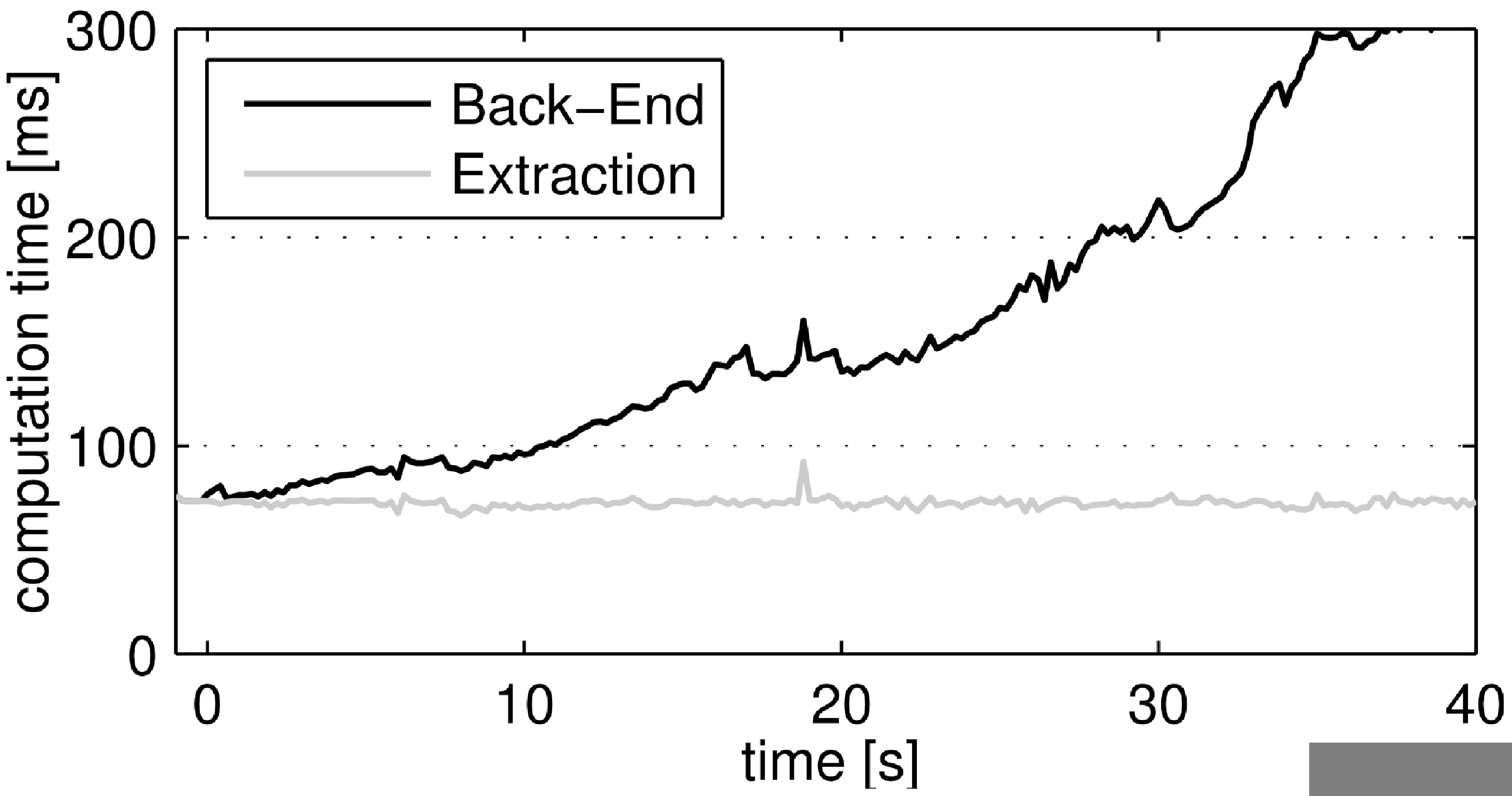
- Frequency of IMU data is too high
- Integrate IMU data between two image frames into single measurement
  - Accumulate data in gravitation-less space
- Apply rotated, accumulated data and subtract gravity

SLAM-Back-End

- After each camera frame optimize poses and landmarks by Least-Squares optimizer *SLoM*
- Textbook Sparse Gauss-Newton method
- States are handled as *manifolds*
  - *More details in Udo's talk tomorrow*

System Performance

- System runs about 30 seconds @5Hz
- Afterwards frames are dropped and system loses stability, eventually



Dense Mapping

- Extract local dense map from stereo pair using OpenCV's Blockmatcher
- Register to global map with optimized poses from SLAM result using OctoMap