Local Navigation of Autonomous Robots

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- Homing
- Panorama and interest points
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  - Simulation
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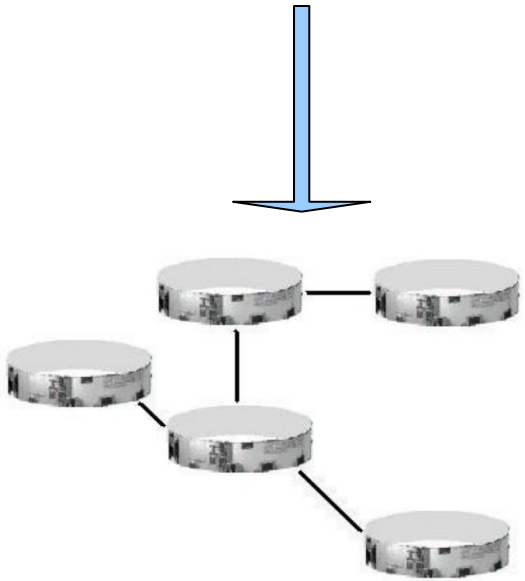
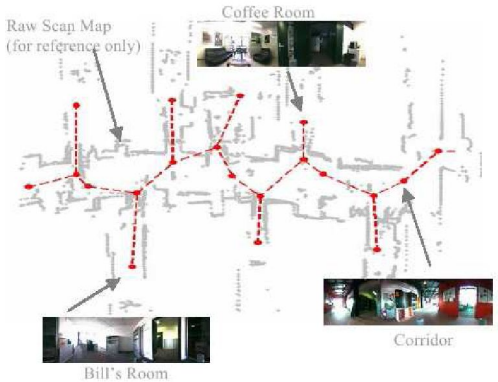
- Bachelor: GNG

Global Localization Method

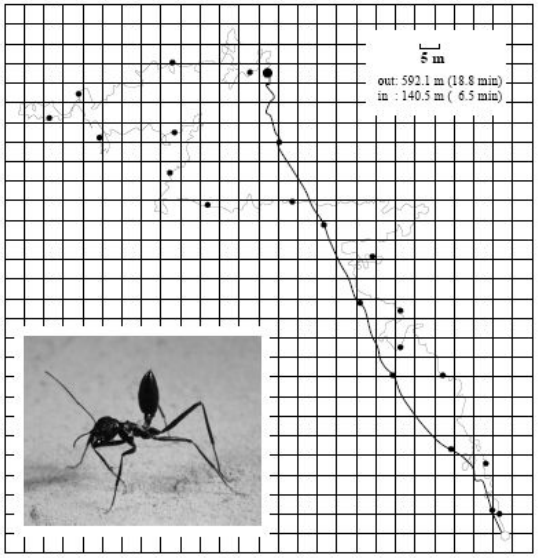
- Based on Ramisa (2006)
- Query panorama compared to all map panoramas
- Maximum number of inliers determines current location (room)
- Problem: ambiguity
- Solution: go to location of panorama origin



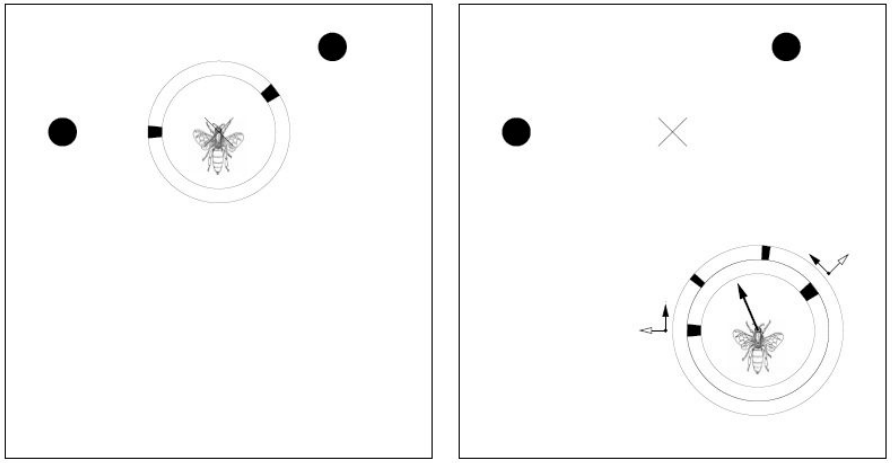


Homing

- Homing based on insect navigation
- Two types
  - *Associative*: store 'all' locations
  - *Local*: store only home



Lambrinos et al. (1998, 2000)
based on Wehner (1987)

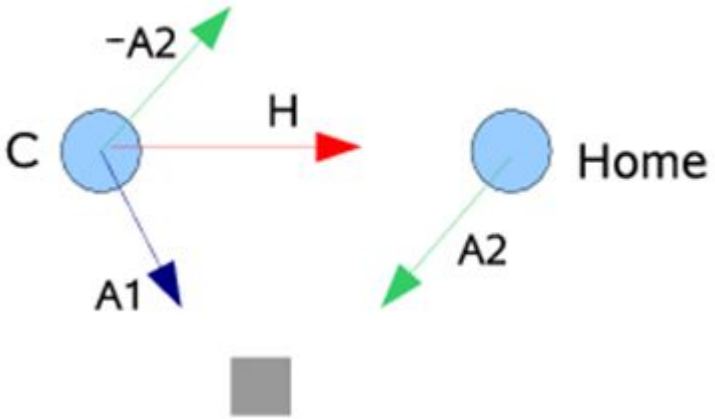


Snapshot model, Cartwright & Collet (1983)

Average Landmark Vector

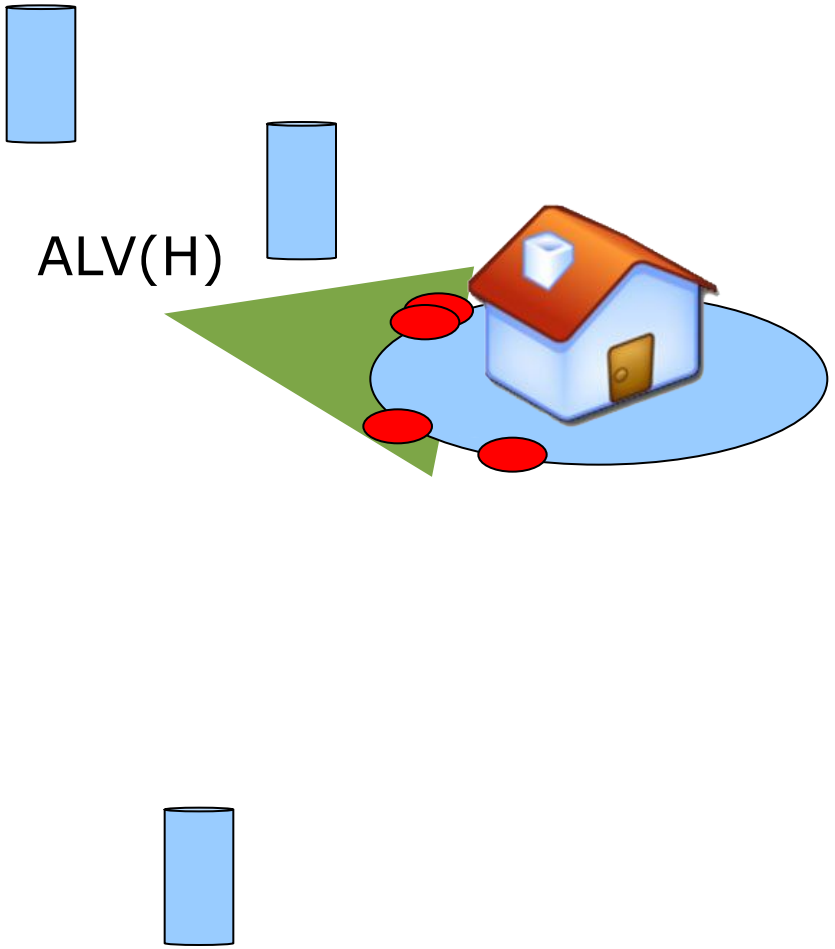
$$ALV(F, \vec{x}) = \frac{1}{n} \sum_{i=0}^{n} \vec{F}_i - \vec{x}$$

$$\text{homing}(F, \vec{x}, \vec{d}) = ALV(F, \vec{x}) - ALV(F, \vec{d})$$



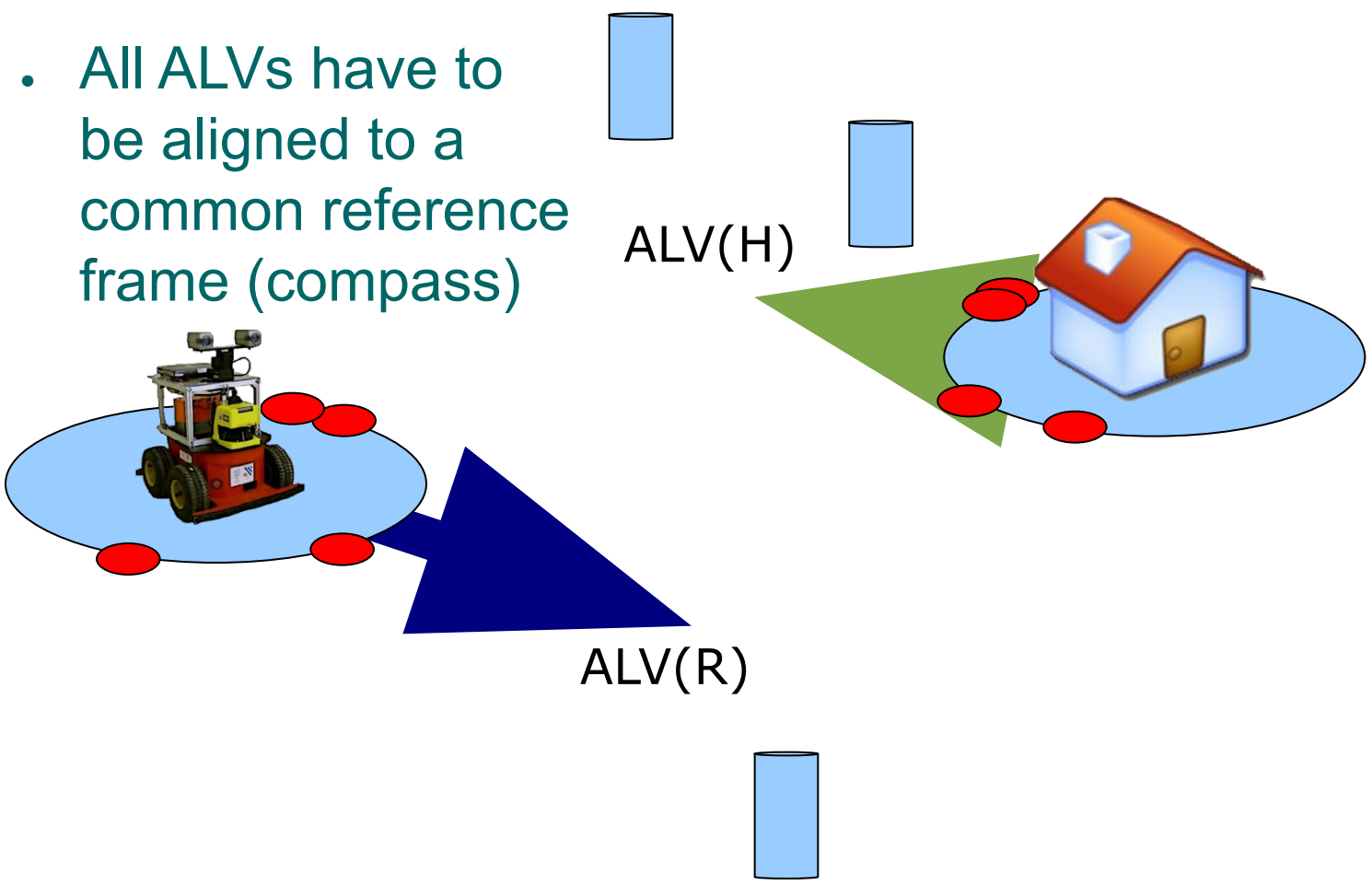
ALV Homing

- Average position of landmarks viewed from the home position



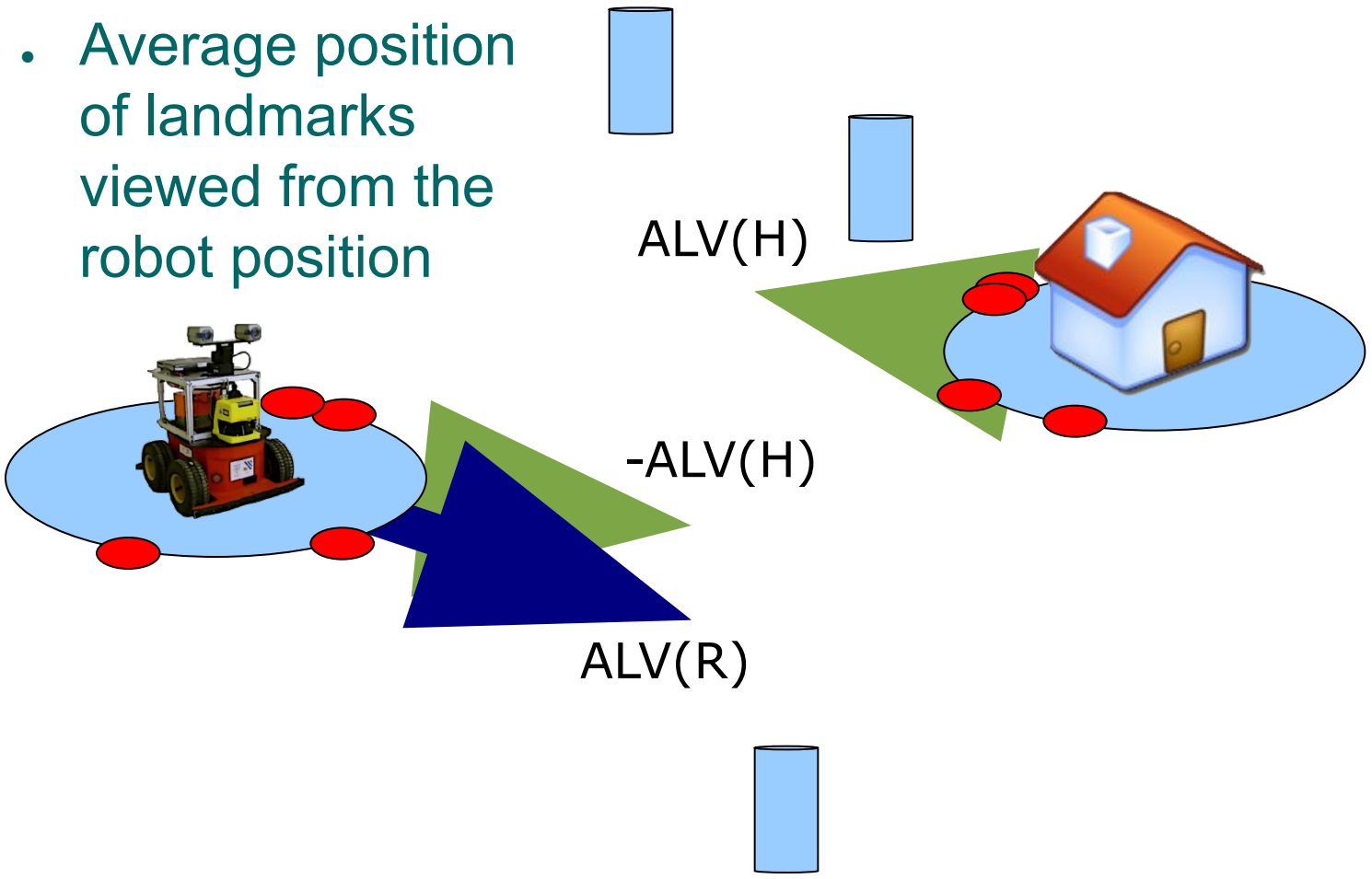
ALV Homing

- All ALVs have to be aligned to a common reference frame (compass)



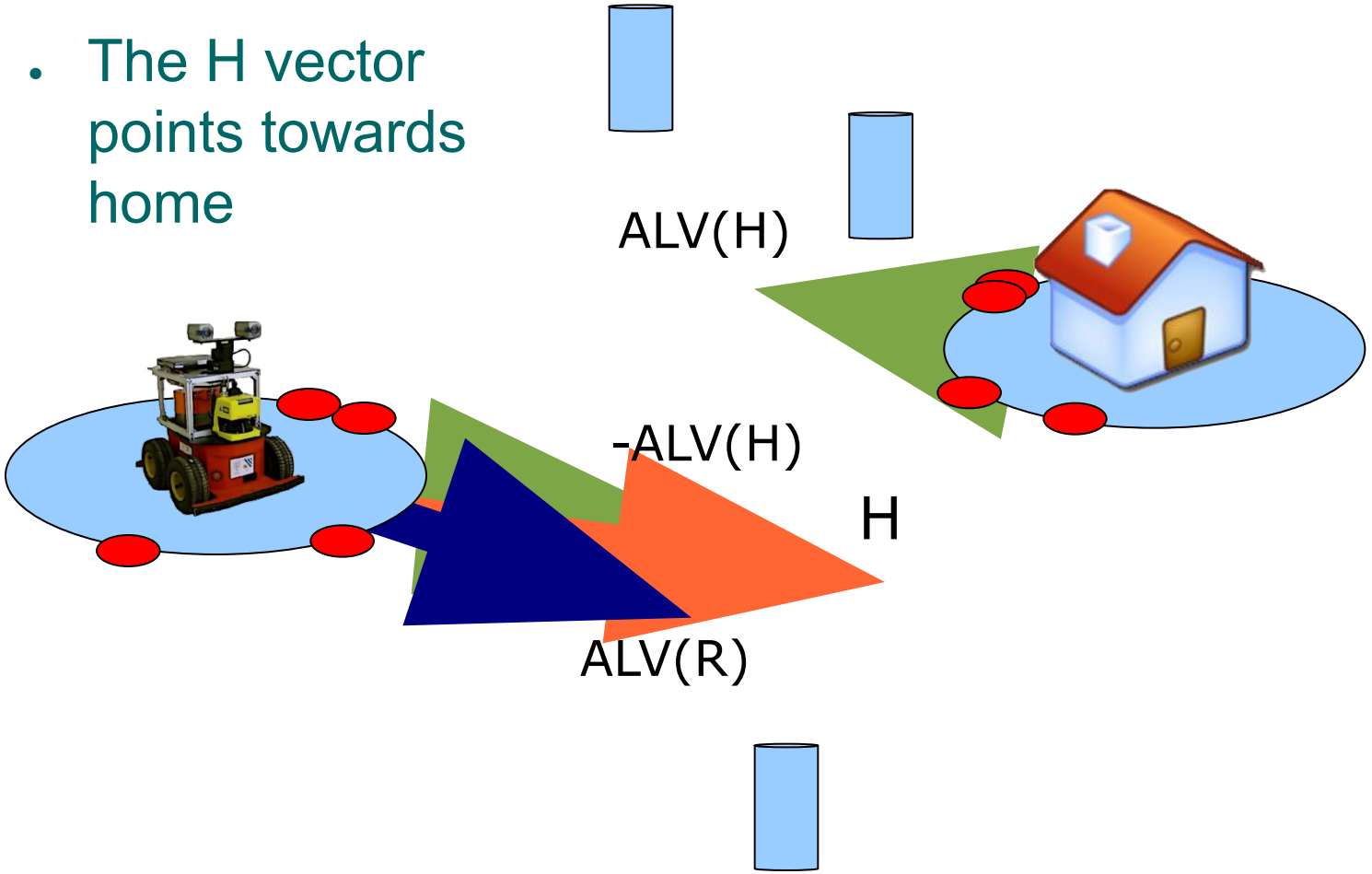
ALV Homing

- Average position of landmarks viewed from the robot position



ALV Homing

- The H vector points towards home



ALV Homing

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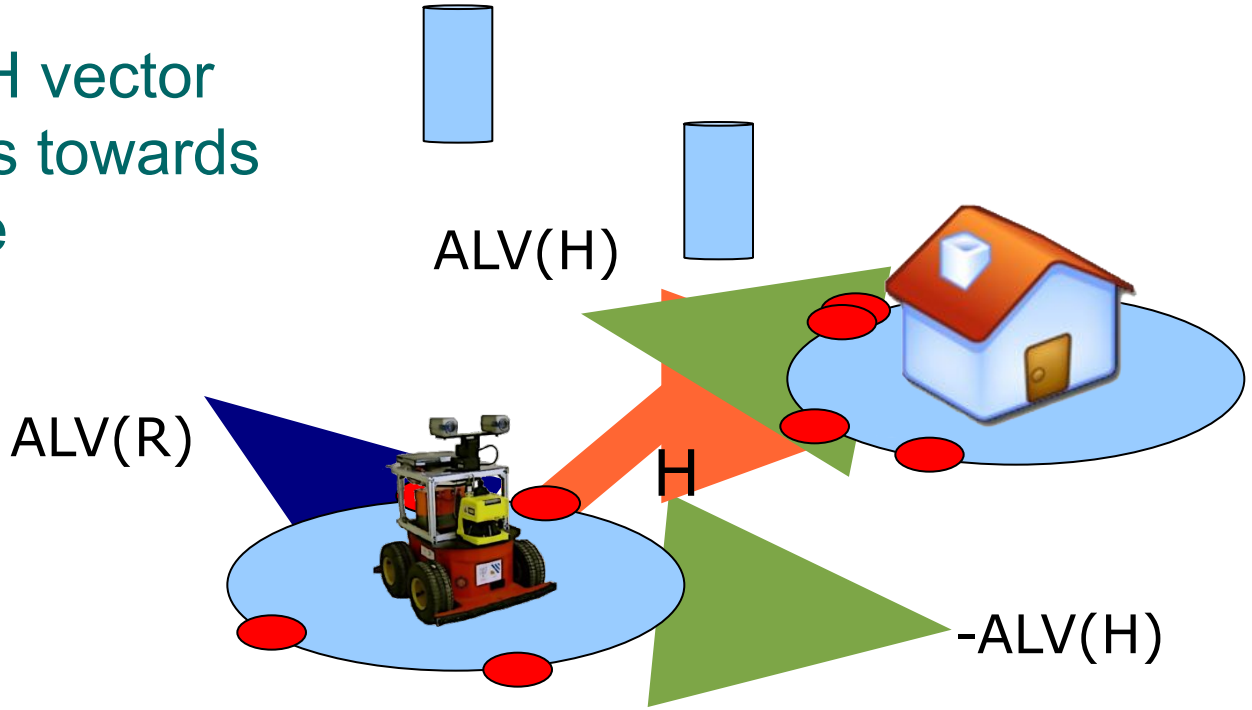
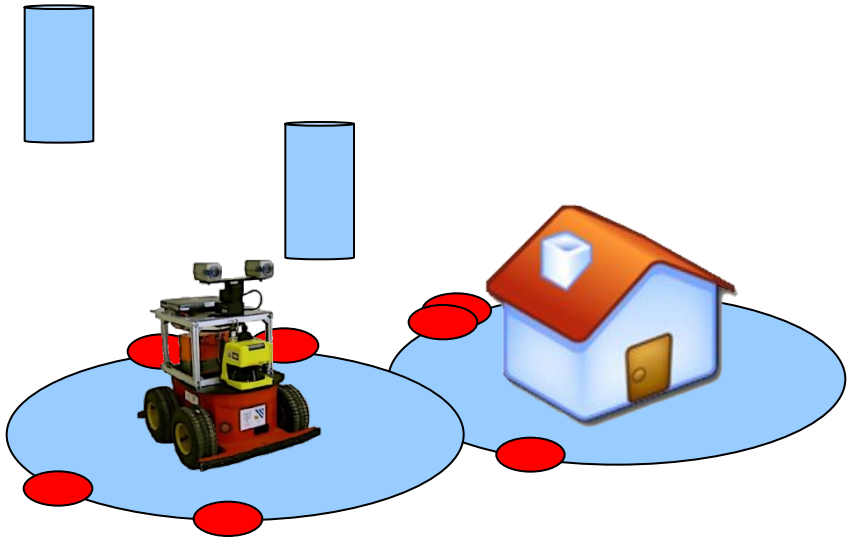


- By iteratively repeating this procedure the robot returns home

ALV Homing

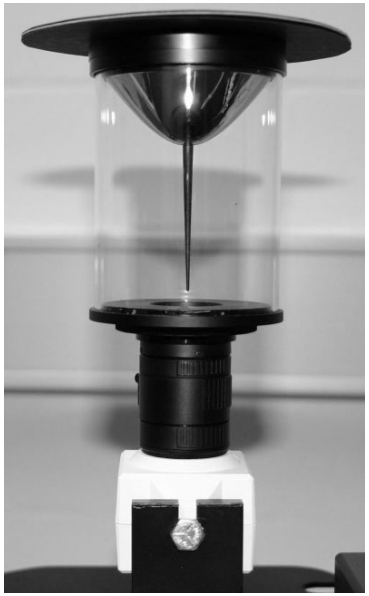
- The H vector points towards home



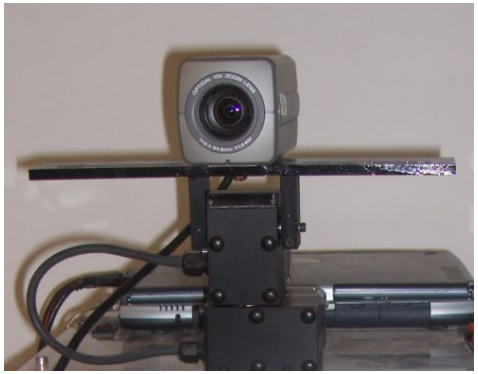
- By iteratively repeating this procedure the robot returns home

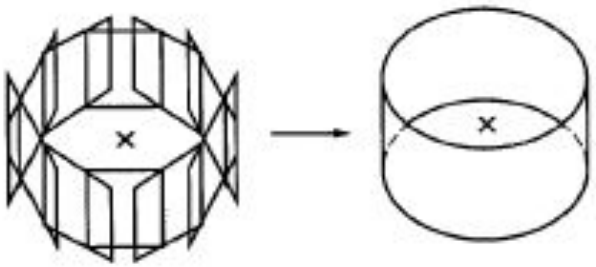
Panorama

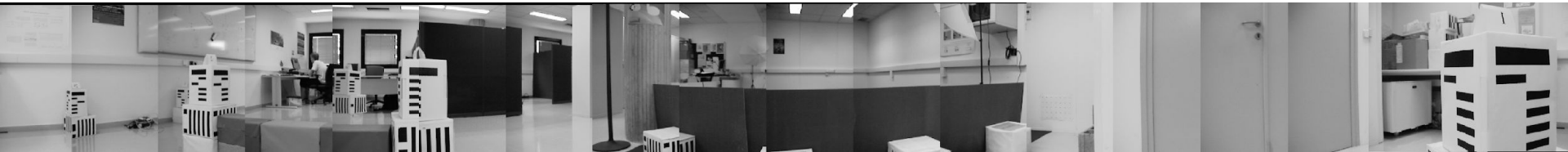
Normally used:



But we used:







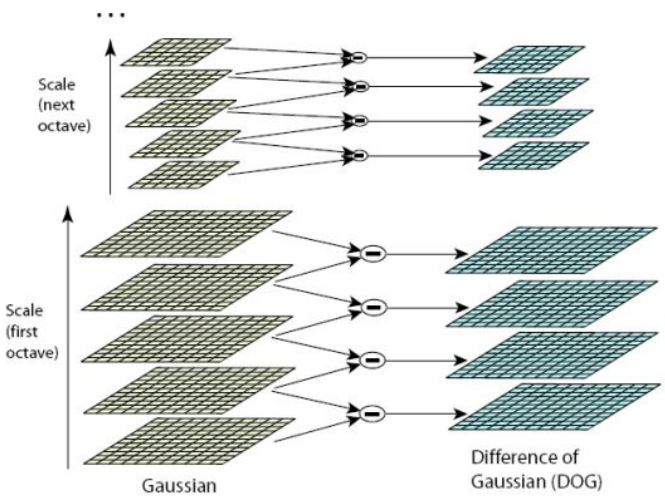
Interest Points

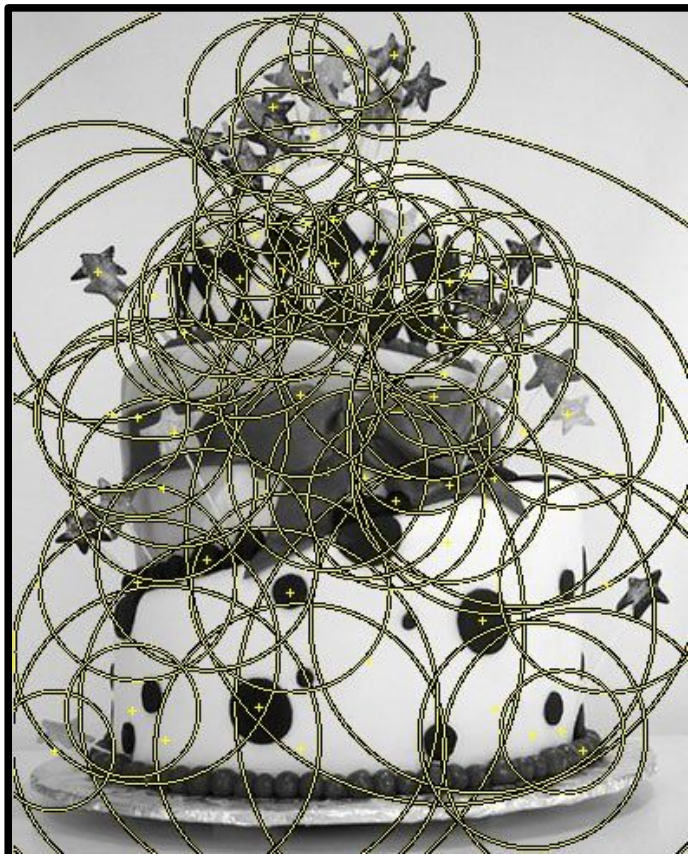
- Visual features instead of landmarks
- Robustness required to
  - Position change
  - Orientation
  - (relative) size

Difference Of Gaussian

- Difference of Guassian (DoG) (Lowe, 1999, 2004)

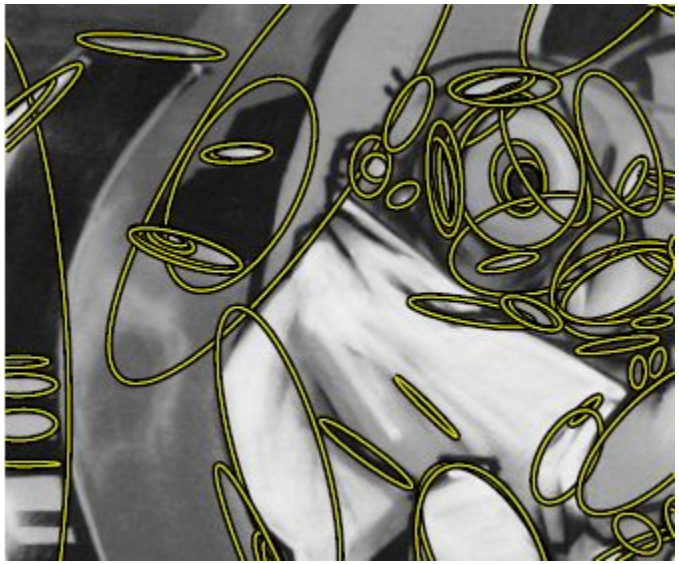
- Scale-Covariant region detector
- Detects blobs and corners





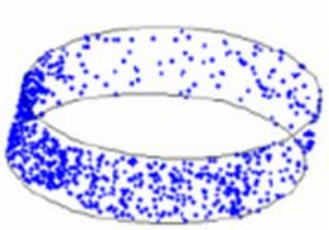
MSER

- Maximally Stable Extremal Regions
- *Extremal regions:* regions with higher/lower intensity than pixels at border
- *Maximally stable:* when intensity changes region still there
- Relatively fast

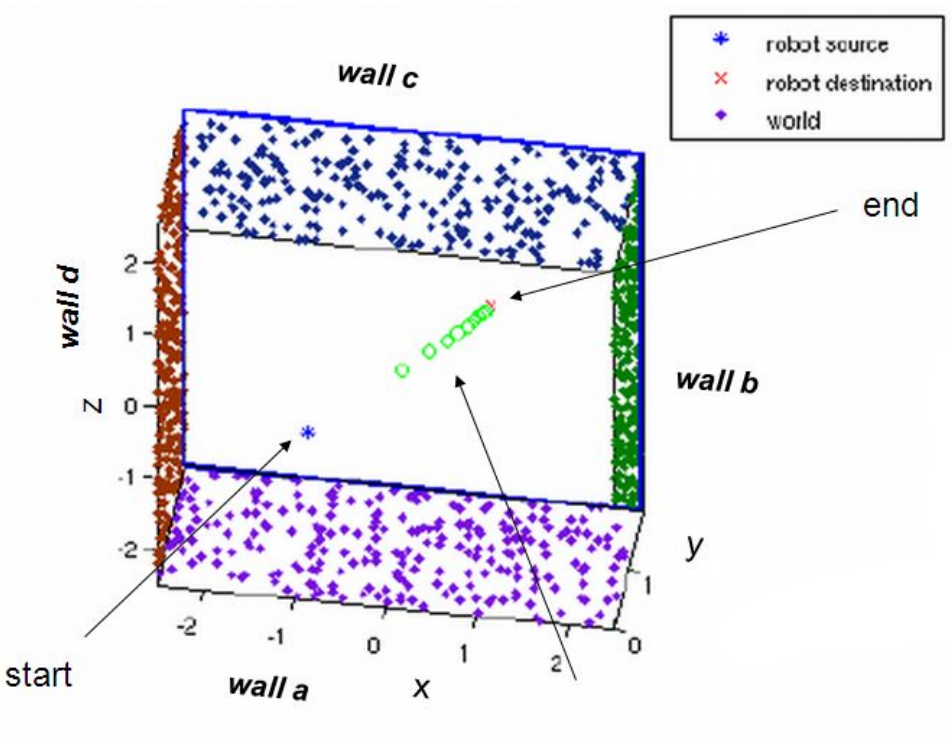


Simulation

- Simulation as first test robustness
- Parameters:
  - Room size
  - Noise
  - # features
  - Remove/add random features (occlusions)
  - 'White' walls



Cylindrical projection

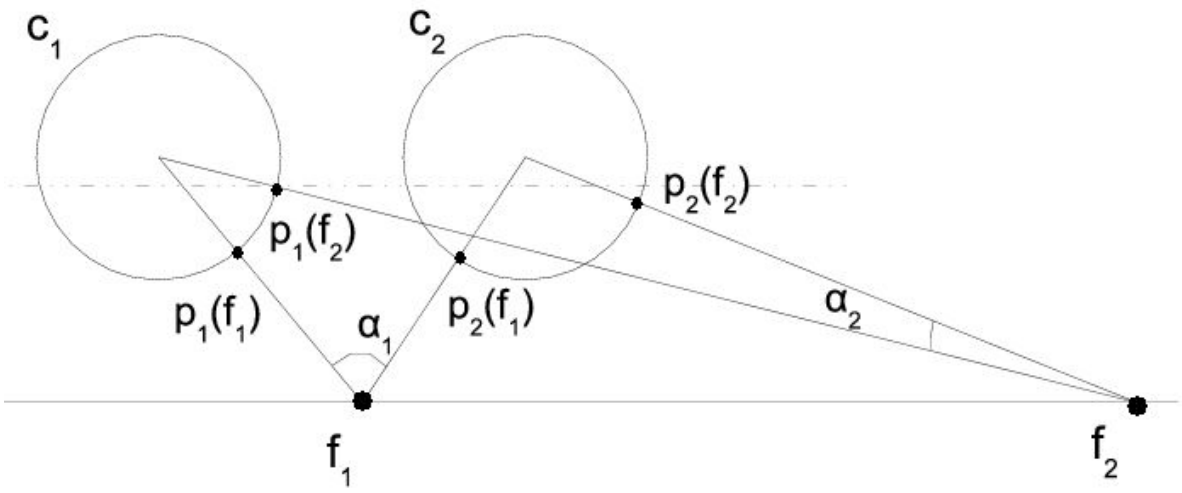


Simulation Results

Parameter	Average Success rate
Removing 50%	85%
<= 1 mm noise (std.dev.)	90%
To 0,05 m noise (std.dev.)	5%
500 or more features	100%
20 features	50%-80%

Projected features closer to each other

☐ Long room problem



Real world experiments

- Three rooms used
- Robot
- Panorama

IIIA Robot laboratory

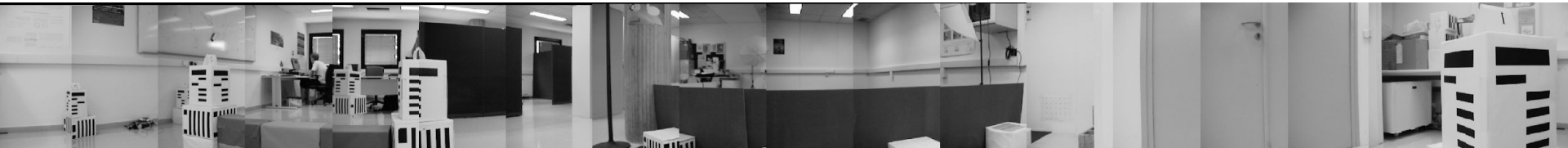
Pioneer 2AT

Experiments

- Constant orientation
- Matrix of panoramas in different rooms
  - To verify the ALV homing method
- Only home direction compared
- 2 types of features detectors:
  - DoG
  - MSER
- In order to Compare: Landmarks

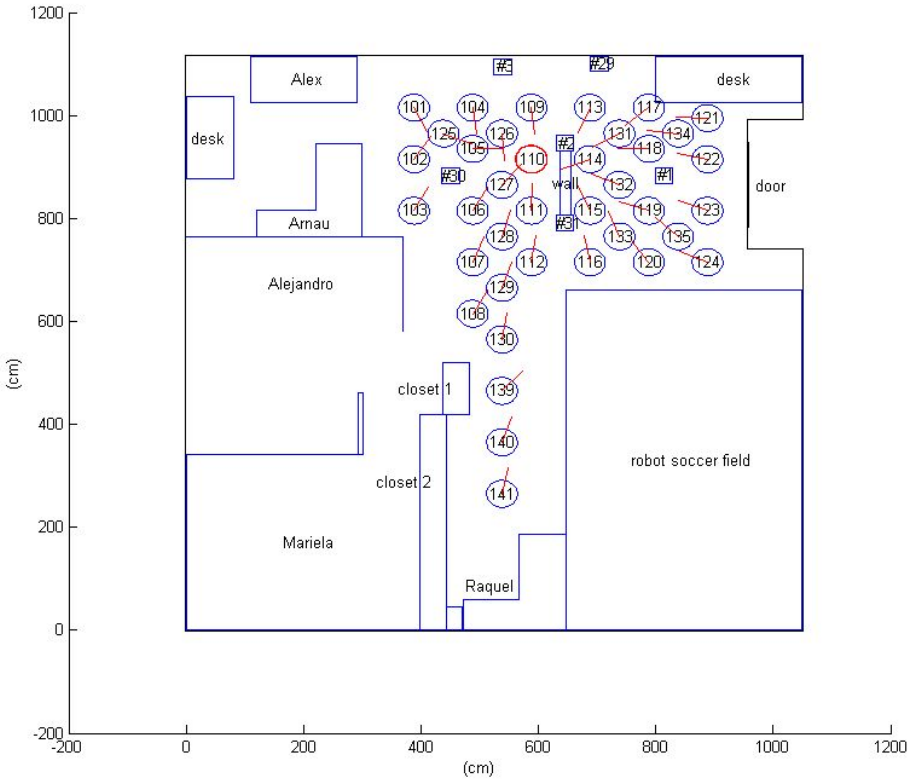
Landmarks

- To compare the method with DoG and MSER
- Binary code:
  - Bar at left: 0
  - Bar at right: 1
  - ☐ 32 combinations



Results: Robot laboratory

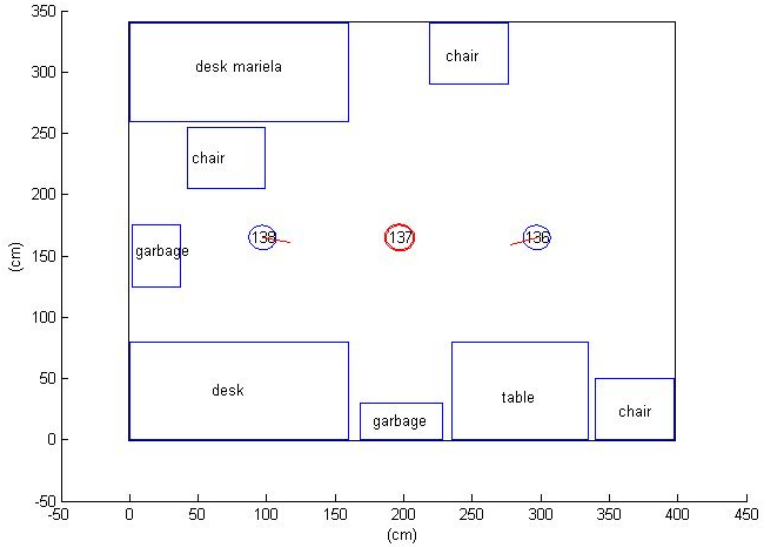
- Size: 10.5 m x 11.2 m
- 38 panoramas
- Best: MSER (in map)



	DoG	MSER	Landmarks
Mean Error	35.60º	27.84º	14.88º
Median Error	22.85º	16.03º	10.17º
Std Dev	36.67º	35.51º	14.86º
Best home	117	117	110

Results: Square room MSER

- Size: 4.0 m x 3.4 m
- 3 panoramas
- MSER (in map)



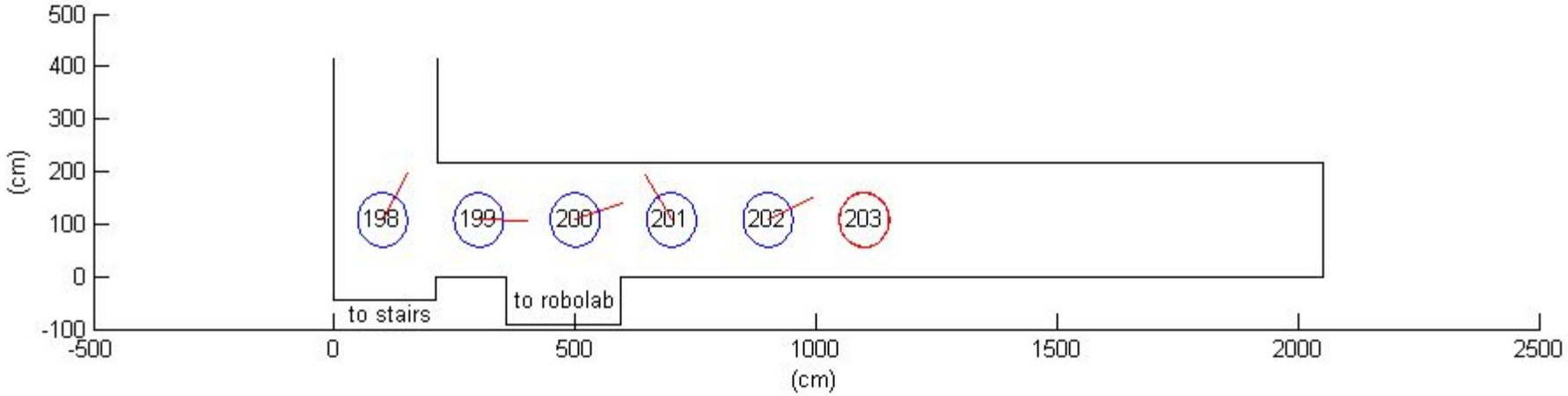
	DoG	MSER
Mean Error	13.78º	9.65º
Median Error	12.00º	12.03º
Std Dev	11.31º	7.84º
Best home	138	138

Results: Corridor

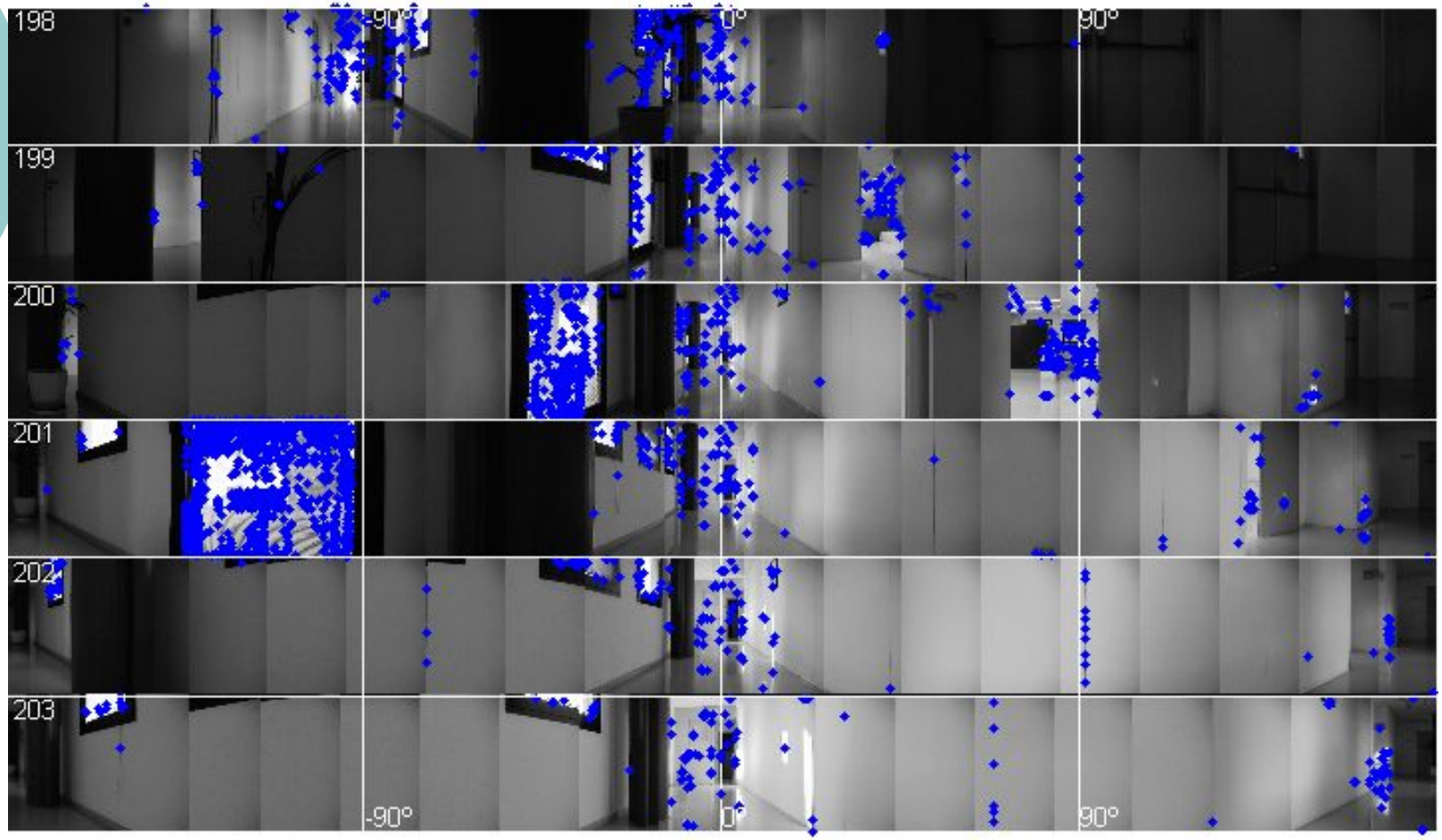
- Size: 2.5 m x 22.5 m
- 6 panoramas

- MSER (in map)

	DoG	MSER
Mean Error	56.26º	52.67º
Median Error	44.58º	35.71º
Std Dev	43.64º	44.90º
Best home	203	200



Results: Corridor

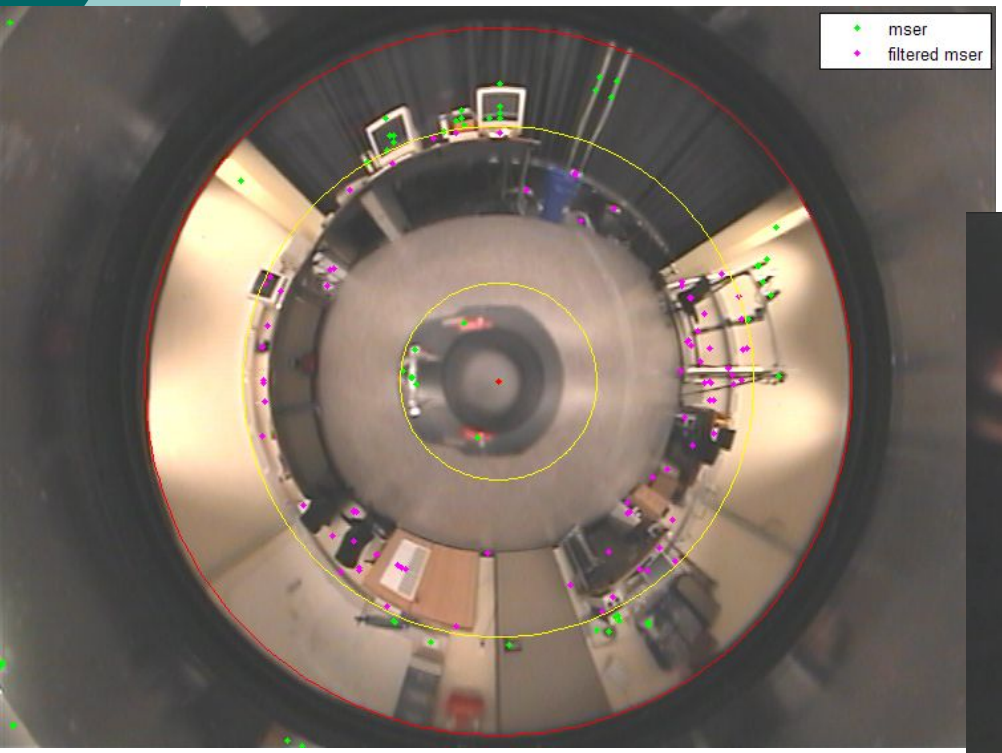


Improvements

- Using lower half of the panorama:
  - Contains closer objects
    ☐ more square (?)
  - Only significant better result in the *Robot laboratory*

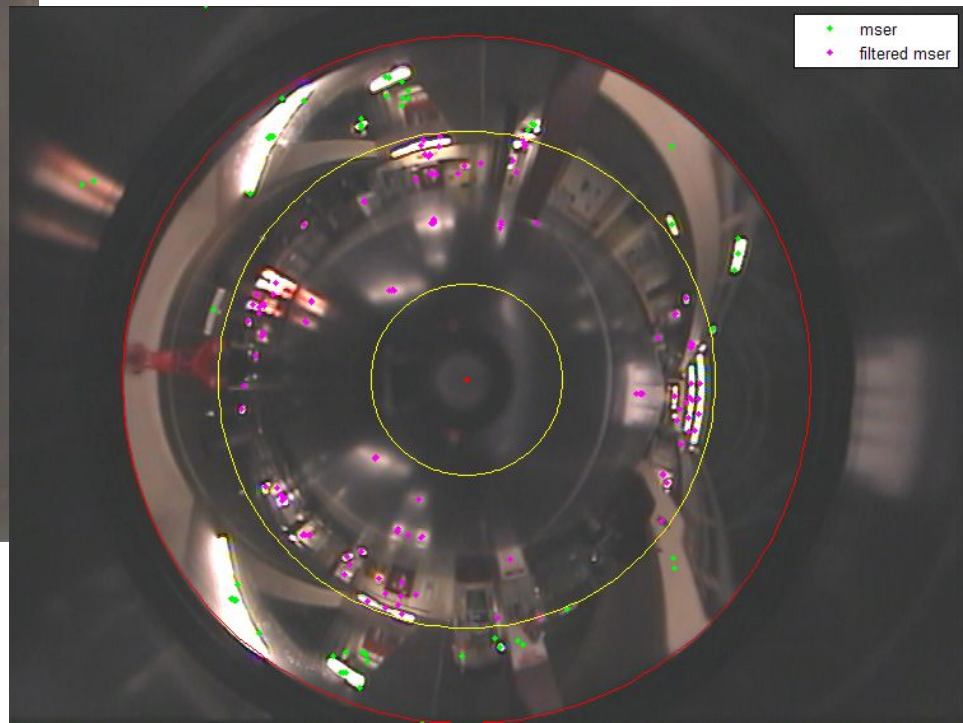
Vardy's Image database

Bielefeld University



Robot laboratory (10x17)

Main hall (10x21)

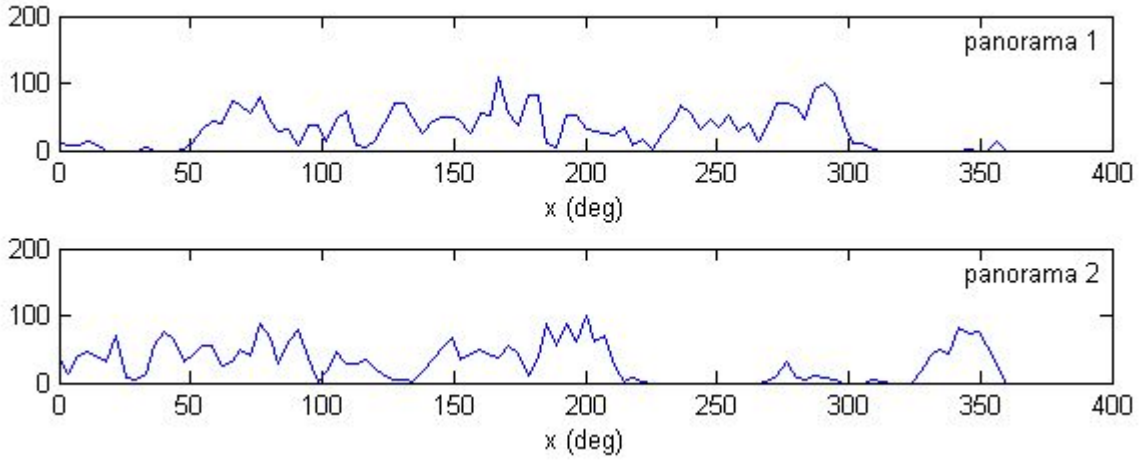


Alignment

- Compass
- Odometry
- Franz et al. (1998): estimate by shifting panorama
- Use feature detectors

Alignment

- Histogram of features



Overall real world results

- MSER outperformed DoG
- No relation found between distance and error
- Camera to parabolic mirror delivers good results
- Rooms:
  - Worst result in corridor

Conclusions

- When robot has several hypotheses
  - Homing can be used to return to most likely position
  - If this is the correct hypothesis ☐ success
  - Otherwise, retry

Main conclusion:

ambiguity problem in localization method 'solved'

Conclusions

- ALV homing:
  - Simple, fast, robust and low in memory requirements
  - But requires orientation
  - Local navigation
- Can make use of different camera's
- Robustness also thanks to feature detectors
  - *Advantage:* no (artificial) landmarks

Future work

- Navigation experiments
- Alignment method
- Panoramas
  - Use parabolic mirror ☐ faster
- Cover larger distances
  - Smith et al. (2006): waypoints
  - Solution to ‘long room problem’
- Improvement of the ALV homing method:
  - Depth, e.g. stereo

Growing Neural Gas

- Bachelor project: navigation
- Growing Neural Gas
  - Comparable to Kohonen network
  - Nodes can be added/removed
- Different sensors:
  - Camera (hsv)
  - Sonar
  - Odometry
- Parameter optimalization method
- Better than baseline (random)

Publications

- Goldhoorn, A., Ramisa, A., Toledo, R. & de Mántaras, R. L. (submitted), Combining Invariant Features and the ALV Homing Method for Autonomous Robot Navigation Based on Panoramas.
- Goldhoorn, A. (2008) Solving ambiguity in global localization of autonomous robots. Master's thesis, University of Groningen.
- Goldhoorn, A., Ramisa, A., de Mántaras, R. L. & Toledo, R. (2007a), Robot homing simulations using the average landmark vector method, Technical Report RR-IIIA-2007-03, IIIA-CSIC, Bellaterra.
- Goldhoorn, A., Ramisa, A., de Mántaras, R. L. & Toledo, R. (2007b), Using the average landmark vector method for robot homing, in '19th International Conference of the ACIA', Vol. 163 of *Frontiers in Artificial Intelligence and Applications*, IOS Press, pp. 331-338.
- Goldhoorn, A., Eldering, H.K., Stadman H. (2006), Implementation of a Simultaneous Localization and Mapping system using Growing Neural Gas. Bachelor’s thesis, University of Groningen.

Questions