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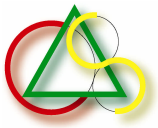


# Indoor EKF SLAM

Patric Jensfelt
Email:patric@nada.kth.se

Including work by:
Guido Zunino


 

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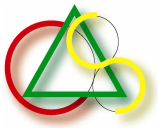

## Outline


- Line based indoor SLAM
- Using typical indoor geometric constraints
  - Right angles
  - Line = wall from floor to ceiling
- Indoor sub-maps
- Error recovery with point based SLAM


 

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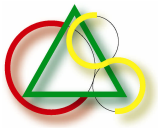

# SLAM w. lines from laser


- EKF SLAM algorithm
- SICK laser data as input
- Features: lines


 

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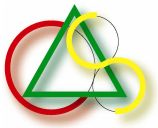
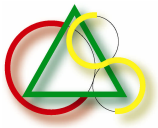


# Feature: Line


- Lines are extracted using “growing” followed by least square.
- Lines are represented as $(\rho,\alpha)$, i.e. distance and angle.
- End-points maintained outside the filter
- 0.25m and 10 points used lower limit for the line extraction



# Data association


- If (f.match(m) && f.specMatch(m))
  - f.match(m): Mahalanobis distance between feature *f* and measurement *m.*
  - f.specMatch(m): Feature specific matching. For lines it requires an overlap.
- Accept measurement-feature match iff measurement matches only one feature in the map.

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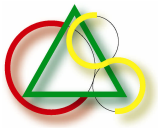

# More on implementation


- OO-framework
- Each feature-type must supply basic functions like; calc of innovation given measurement, specMatch(Measurement*), etc.
- Have tried lines, doors and points


 

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# Platform 1: Asterix

- Nomad200
- 16 sonars
- SICK PLS
- 16 infrareds
- Synchro-drive
- Camera on pan-tilt
- Linux
- Single processor PIII 450MHz

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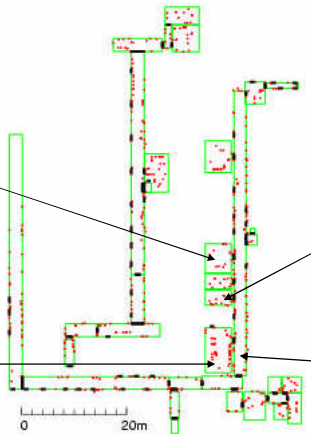
# Environment 1: CVAP/CAS building

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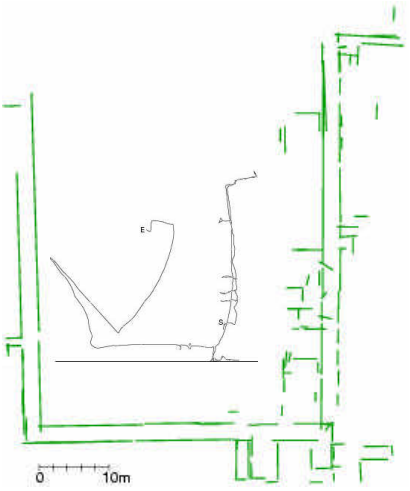
# Result at CVAP/CAS

- 388 m total distance
- 44 min (2640s)
- Robot controlled with joystick
- 127 lines

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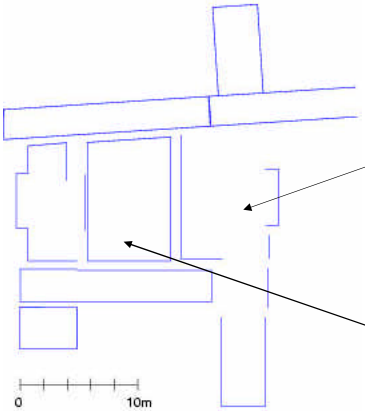
# Env. and platform 2: Atrium in main building

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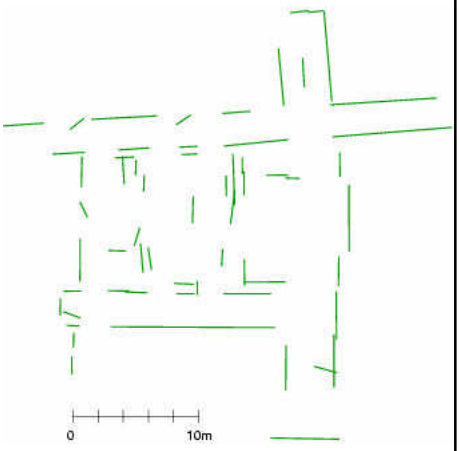
# Result in Atrium

- 165 m total distance, twice around a loop
- 22 min (1320s)
- Data collected while being a tour guide for students
- 67 lines

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# Conclusions

- Computation time only small fraction of total time for experiment. BUT full SLAM is $O(N^2)$ and at the end scans had to be skipped.
- Not so good data association
- Large odometric perturbations not handled well (thresholds!)

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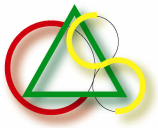

# Conclusions II


- Bad registration between laser and odometry (not a real-time OS)
- Fast rotations (+ bad registration) are problematic
- The SISO-rule applies (Shit In ) Shit Out)
- Poor end-point management of lines
- Door leafs are in the map (must be treated with care, DYNAMIC!!)
- A closed door splits the map! (end of corridor)




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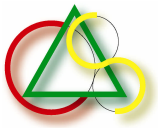
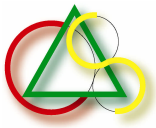


# Conclusions III


- Doors are tricky to extract consistently when the walls are thick.
- Different features require different motion strategies. Lines often extend along the path, whereas for example points don't
- Lines are rather simple in this aspect



# Lessons learned


- Make sure that your input, is good. Remember SISO.
- Make sure your environment is large enough, some problems are not visible otherwise.
- Take extra care when the robot is rotating fast or better, put SLAM in control of motion!



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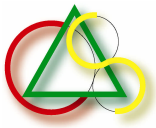

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# Platform 3: Trilobite vacuum cleaner

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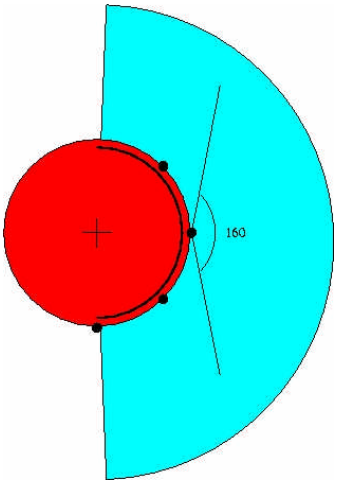
# Platform continued

- 1 sonar transmitter and 4 microphones in horizontal plane.
- Range: approx 2.5 m

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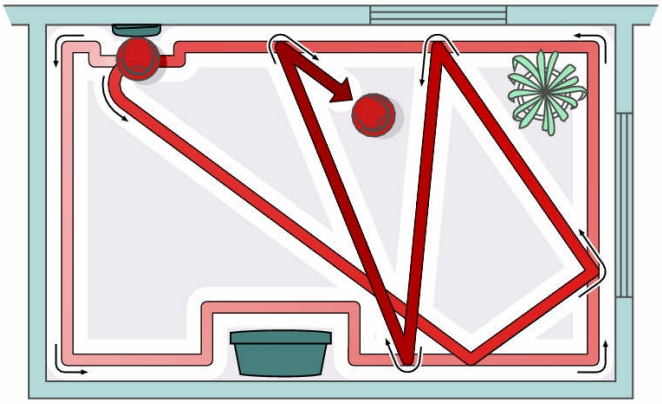
# "Mapping" strategy





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# Utilizing architectural constraints on Trilobite

- Problem:
  - Processor from "refrigerator"! (integers only)
  - Often stuff on floor along walls ) slips easily
- Idea:
  - Use architectural constraint; Walls are straight and many things indoor tend to be positioned with right angles between them.

# Algorithm

- Extract lines using Hough transform from sonar
  - First line becomes reference line
  - Lines must be long enough
- Validate extracted line against reference line
  - Must be close enough to parallel or orthogonal (with uncertainty taken into account)
- Correct the pose as if all angular error was produced in the last corner (an approximation)




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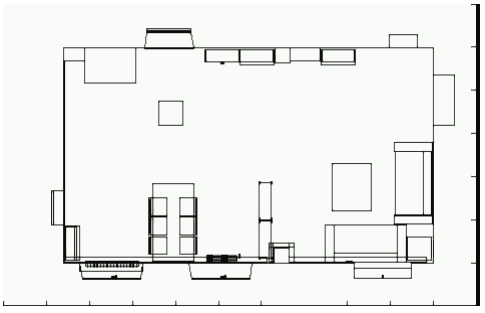
# Results



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# Clutter in sensor height!

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# SICK on pan-tilt

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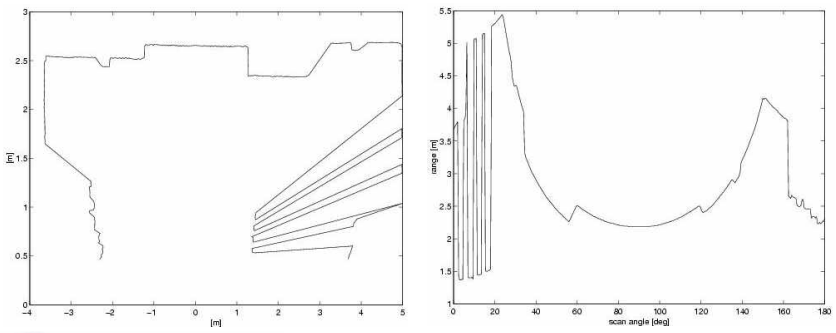
# Less clutter higher up

- Wall often easy to find at its intersection with the ceiling.




Cartesian Polar

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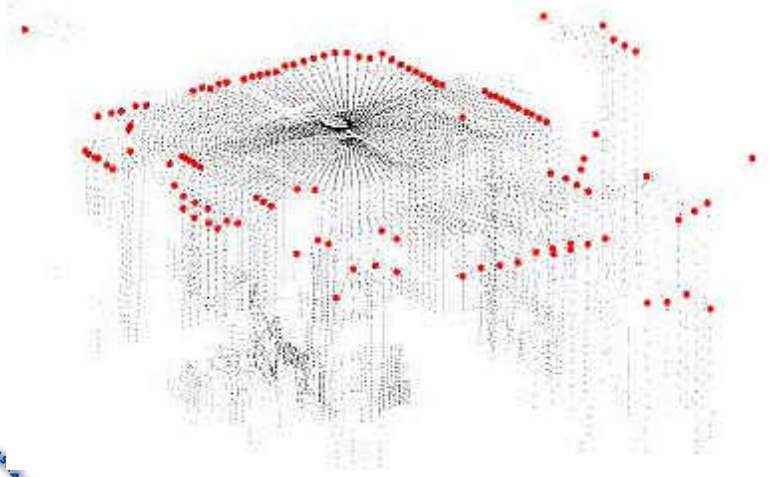
# Pan the SICK and extract intersection points



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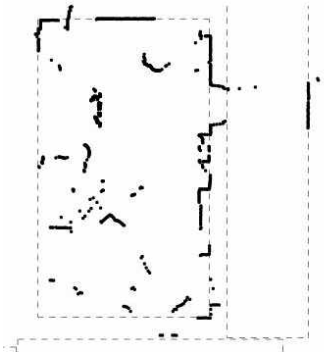
# Compare the result!



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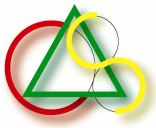

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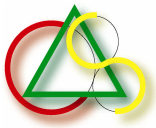

# Sub-maps


- At some point it might be necessary to split the map into several sub-maps. This typically gives:
  - Requires less memory and processing time
  - Higher local accuracy
  - Sub-optimal if not all information is used

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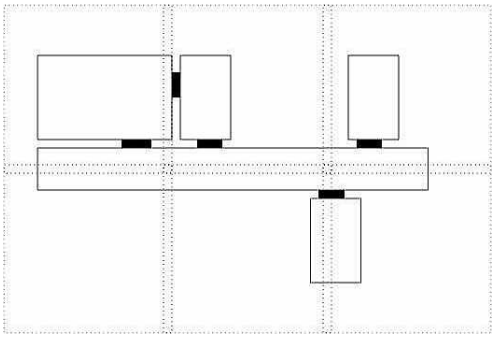
# Typical sub-map division

- Square grids
- Equal in size
- Placement not dependant on the environment



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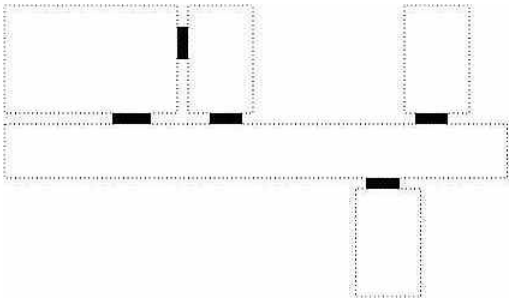
# Indoor sub-maps

- Rooms give natural sub-map division
- Visibility constraints between sub-maps almost given for free



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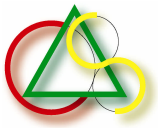

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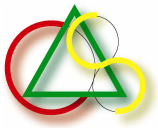
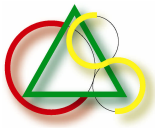


# Error recovery by Guido Zunino


- It is not a question of IF errors will occur, rather WHEN they will occur.
- Must be able to recover from them
- Examples:
  - Large un-modeled odometric perturbations, common when passing e.g. thresholds
  - Erroneous data associations
  - Linearization errors (map slippage)



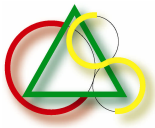
# Simple error recovery strategy


- Detection:
  - No matching measurement when they where expected ) error might have occurred
  - Allow only M iterations with matches that where expected but did not occur
- Recovery:
  - Store copies of old verified maps
  - Re-localize in last verified map







# Recovery scheme


- Localization:
  - Match local map consisting of last detected features against last verified map ) pose estimate $x_L$ and covariance $P_L$
- Restoration:
  - Use $(x_L, P_L)$ as measurement in de-correlation and EKF update as in (Leonard & Feder 1999)
  - Continue mapping
  - Old feature matches ) map assumed verified





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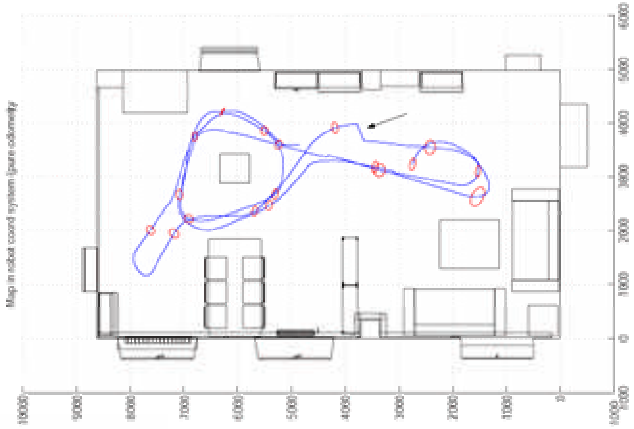
# Example with sonar point landmarks



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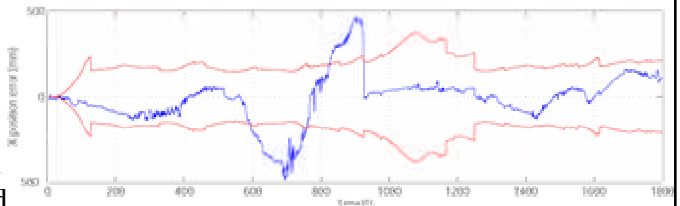
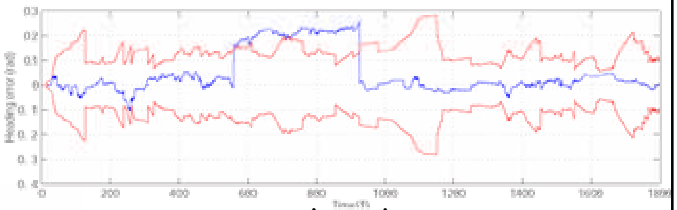
# Error vs. 2σ bounds

Errors estimated using laser based tracker running in parallel



x-position



orientation

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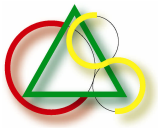

# Conclusions


- Robust although very simple
- Examples of failure situations:
  - Erroneous matching delaying detection
  - Un-modeled occlusions causing failure to detect feature ) unnecessary recovery and loss of accuracy