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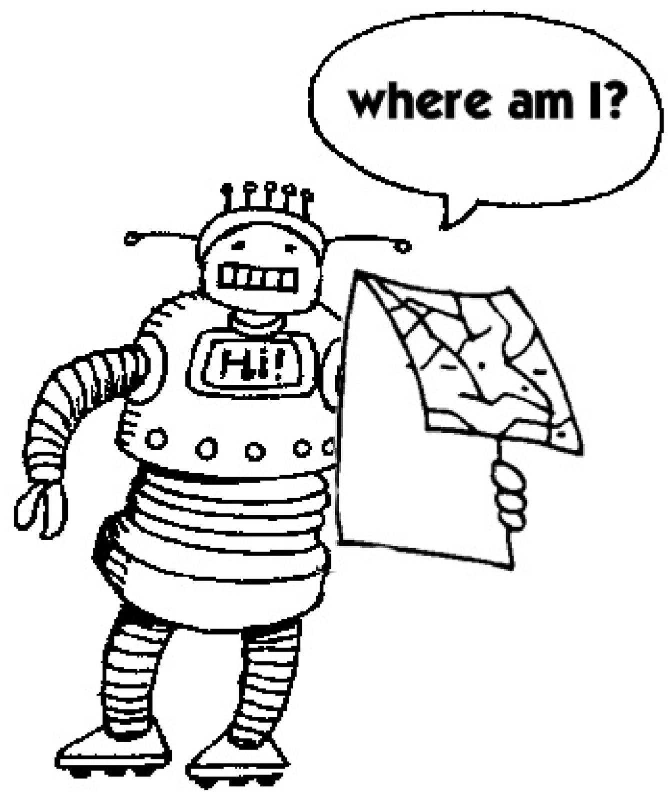
I am a PhD student at the University of Amsterdam in the Intelligent Autonomous Systems group. I spend most of my time working at TNO as part of my research agreement.
My doctoral supervisor is prof. F.C.A. Groen. My daily supervisor at TNO is Judith Dijk.
My research is on large scale SLAM and 3D reconstruction. My main research interest are robotics and autonomous systems.

UNIVERSITY OF AMSTERDAM

Omnivideo Delayed State SLAM

PhD. Research :: 10/2007 - 10/2011

I. Introduction



SLAM stands for Simultaneous Localization and Mapping and it represents the ultimate skill for any robot to be truly autonomous. This skill allows a robot to be placed in an unknown environment at an unknown location to build a consistent map and localize itself within this map. The last decade has seen a handful of research in SLAM and most recently, in visual based SLAM where one or multiple cameras are used obtain information about the environment. In our research, we investigate the use of onmidirectional cameras to build consistent maps of very large environments. In particular, we propose an Omnivideo Delayed State approach which we embed into an Exactly Sparse Information Filter to obtain an accurate spatial representation of the robots trajectory.

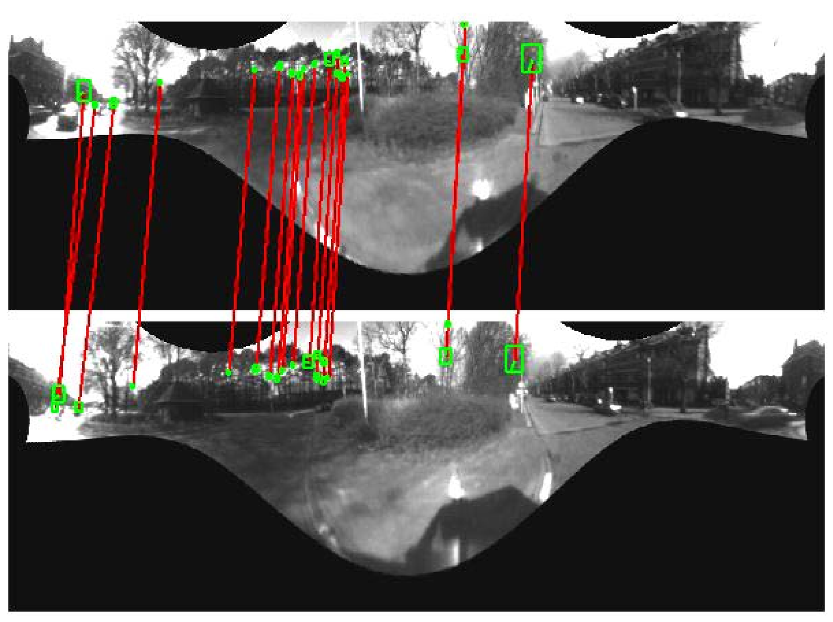
II. Mapping very large environments

- Golden standard EKF (O(n2)) is **only suitable for a few hundred map features**
- Information Filter (IF) is based on the computational gain of estimating the inverse of the covariance
- The state is now the **collection of previous robot poses** taken as landmarks
- Our trajectory based SLAM works in 4 steps

1. Omnivideo Images

- 1Mpx firewire camera
- **Hyperbolic mirror** on top allows a big percentage of the sphere to be visible
- Images recorded at 4Hz
- For every image, **SIFT features** are extracted
- Omnivision images are less sensitive to **crowded and changing environments**
- Image comparison is naturally independent of the point of view

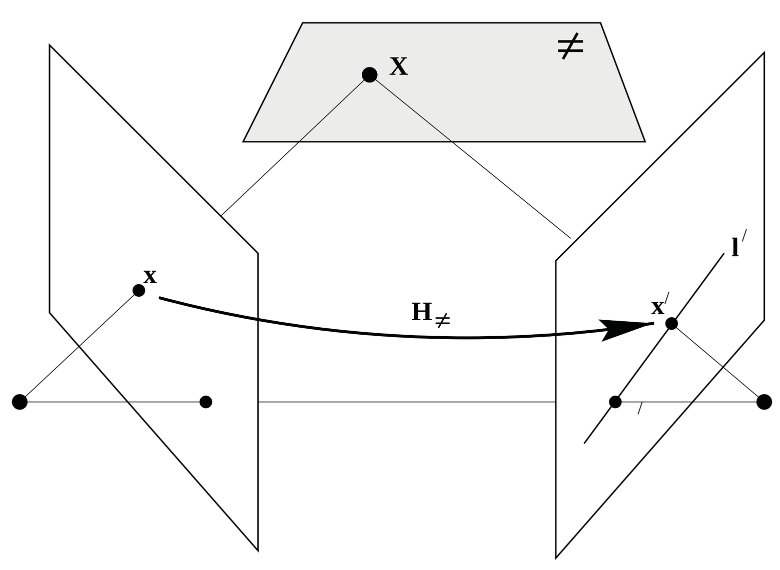
2. Data association



- Two problems need to be addressed: **have I been here before?** If so, **how is this information used in the SLAM algorithm?**
- A **robust image comparison** algorithm allows robust image matching
- From graph theory, we **cluster the images** and compare every new image with the cluster representative, improving over the O(n) complexity of a full comparison

3. Epipolar geometry estimation

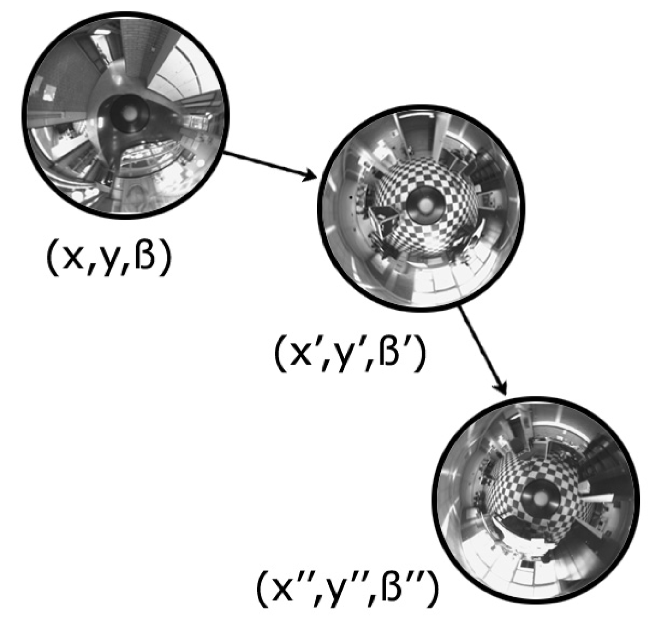
- We assume that the robot moves in a **planar surface**
- Using **3 matching points** we obtain the essential matrix
- **RANSAC** is used to discard outliers
- Further the essential matrix is decomposed in relative **heading and orientation**



For further info and datasets, refer to
http://staff.science.uva.nl/~iesteban

4. Exactly Sparse View Based Information Filter (ESIF)

- ESIF works in **two steps**
  - **Prediction**: odometry and motion model use to predict the next pose
  - **Update**: relative heading and orientation are used to improve the estimate
- IF estimates the **information vector** and **information matrix**
- The information matrix is **naturally sparse** as previous robot poses are not marginalized
- IF still requires **state recovery** (naive recovery is O(n3))
- We explore 5 different state recovery techniques



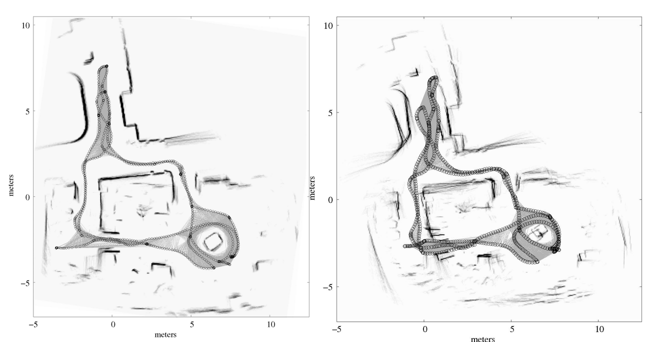
III. Experiments and Results

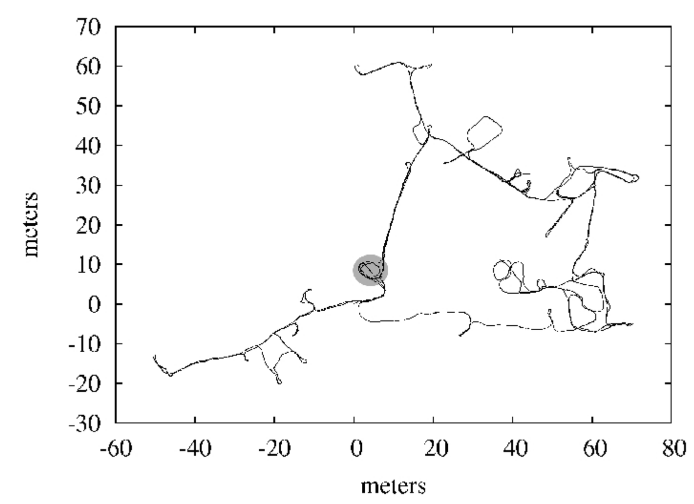
A. Experiments

- Small office. **875 images.** Loop around two connected offices.
- Large office. **10.125 images.** The **largest experiment in visual SLAM** to our knowledge. More than 80m of drift in odometry and 100 degrees in orientation.

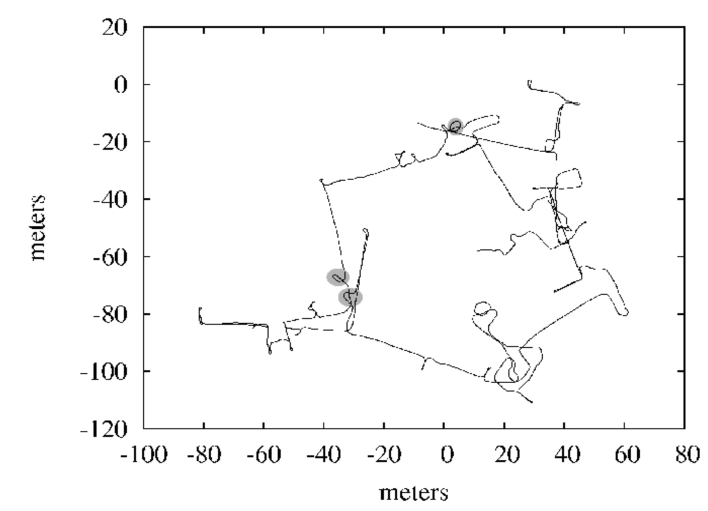
B. Results

- **Small office.** The results show that an accurate map can be built using an omnivideo system. Duplicated structures disappear after one loop (see right image).
- **Large office.** Very large loops can be accurately closed. Bending process caused by *"certainty of relations despite uncertainty of positions"*.

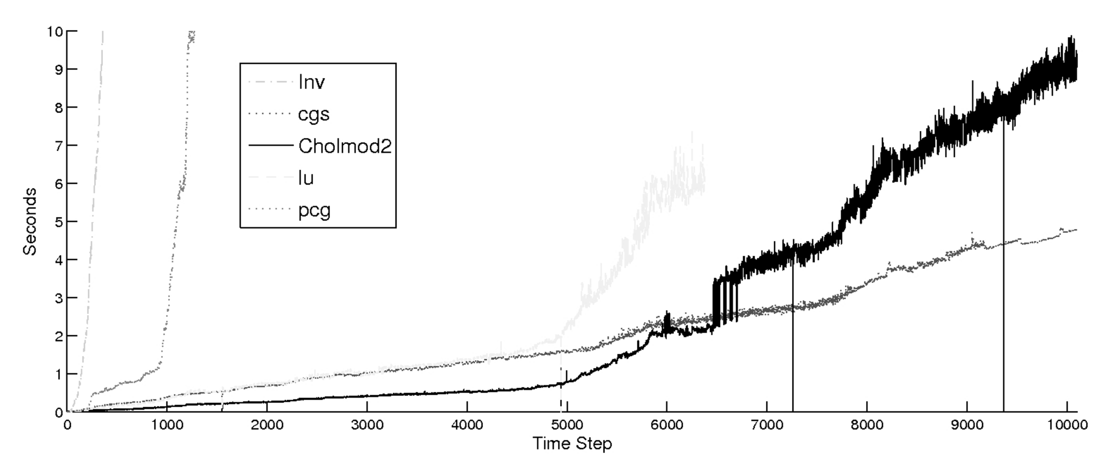




Gray circles represent the exact same location in the trajectory. The loop was closed after 5.200 images were taken.



- ESIF runs in close to **linear time**
- **PCG** is more suitable for very large environments (Cholmod is the current standard)
- Overall complexity is represented in the table below.



Step	Complexity
SIFT	**O(1)**
Data Association (at most)	**O(n)**
Epipolar estimation	**O(1)**
ESIF	**O(1)**
State Recovery (at most)	**O(n^2)**

C. Further research

- Investigate techniques to reduce the bending behaviour in large loop closure.
- Improve errors caused by linearization using batch techniques.

IV. Towards 3D reconstruction of very large environments

- The goal is **automatic 3D reconstruction** of outdoor large environments
- If the trajectory is accurately estimated dense 3D reconstruction can be employed
- **Information Filter** show very promising results for **very large scale mapping**
- We are improving our system with higher quality cameras (**LadyBug2**)
- Initial results from **very large outdoor city areas** are very promising

[References]

[1] D.K.S. Thrun, Y. Liu, A. Ng, A. Chahramani and H. Durrant-Whyte. ***Simultaneous Localization and Mapping with Sparse Extended Information Filter.*** International Journal of Robotics Research, 2004.
[2] R. Eustice, J. Leonard and H. Singh. ***Exactly Sparse Delayed-State Filters for View-Based SLAM.*** IEEE Transactions on Robotics, 2006