Spectral Clustering for Feature-based Metric Maps Partitioning in a Hybrid Framework

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- Introduction
- Perception: Landmark detection
- Normalized Spectral Clustering
- Graph-based Environment Representation
- Experimental Results
- Conclusions and Future Work

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Introduction

Scaling Problem in SLAM

- High computational cost and storage
- Linearization errors: inconsistent uncertainty estimation

Local map sequencing

- Independent stochastic maps
- Local maps related by spatial relationships

Local maps bound linearization errors effects

Introduction

Motivation

•Difficult global consistency for large maps

Advantages using topological maps

•Representation of the natural structure of the environment: topology

•Advantages imposing loop-closure in topological maps: computational complexity, multiple hypotheses

Mapping in two levels

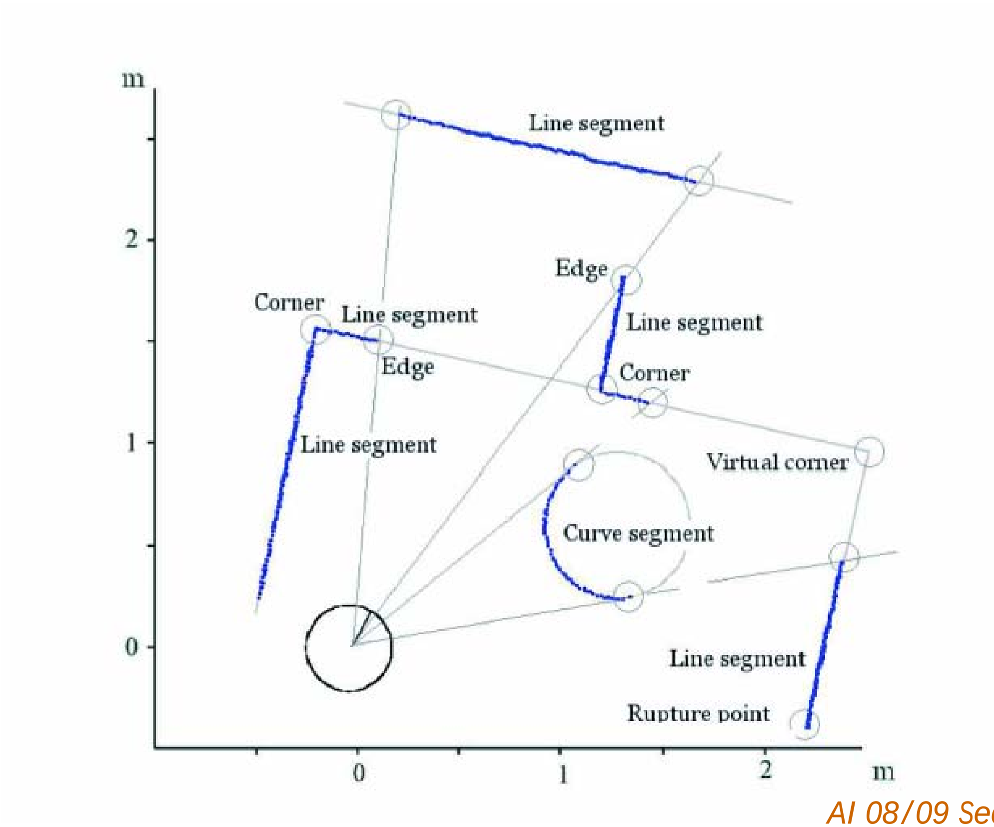
- Local or Metric Map: built as a stochastic independent map using EKF-SLAM
- Topological Map: natural structure of the environment composed by nodes and edges
- Relationships:
    - Local maps are nodes of the topological map
    - Edges represent spatial relationships between nodes

Contents

Perception: Landmark detection

Natural landmarks detection and characterization

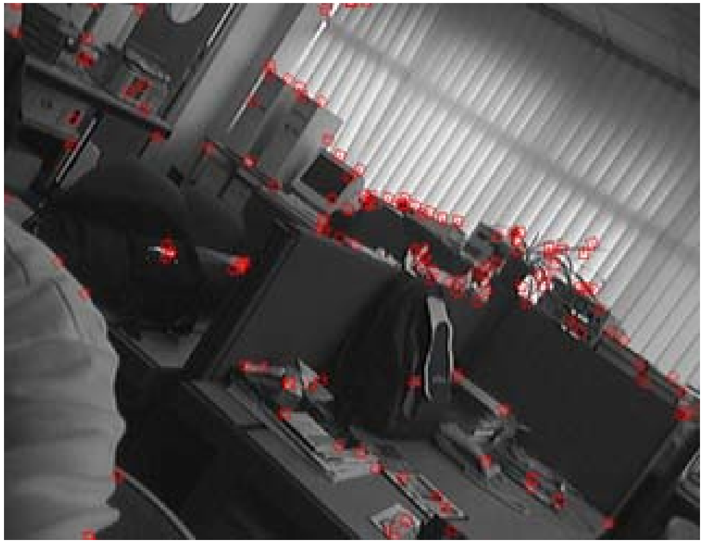
•Laser range finder: segmentation and characterization



Perception: Landmark detection

Natural landmarks detection and characterization

- Vision: local interest points



Perception: Landmark detection

Pre-segmentation stage

- Homogeneus regions: uBIP

Perceptual grouping stage

- The distance function consist of three components: color contrast, edges and disparity

$$\Upsilon(n_i, n_j) = \sqrt{w_1 \cdot \left(\frac{d(n_i, n_j) \cdot min(b_i, b_j)}{\alpha \cdot c_{ij} + \beta(b_{ij} - c_{ij})}\right)^2 + w_2 \cdot (disp(n_i) - disp(n_j))^2}$$

Visual landmarks detection and normalization stage

Perception: Landmark detection

Natural landmarks detection and characterization

- Vision: model-based landmarks

Visual landmarks

Experimental results

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Normalized Spectral Clustering

Spectral Clustering approach

- Optimal balanced partition of a graph: minimization of the normalized cut problem (NP-hard)
- Spectral Clustering makes this optimization problem tractable: relaxation

Normalized Spectral Clustering

Spectral Clustering algorithm

- Unnormalized Graph Laplacian Matrix

$$L = D - W.$$

- Eigenproblem

$$Lv = \lambda Dv$$

- K-means

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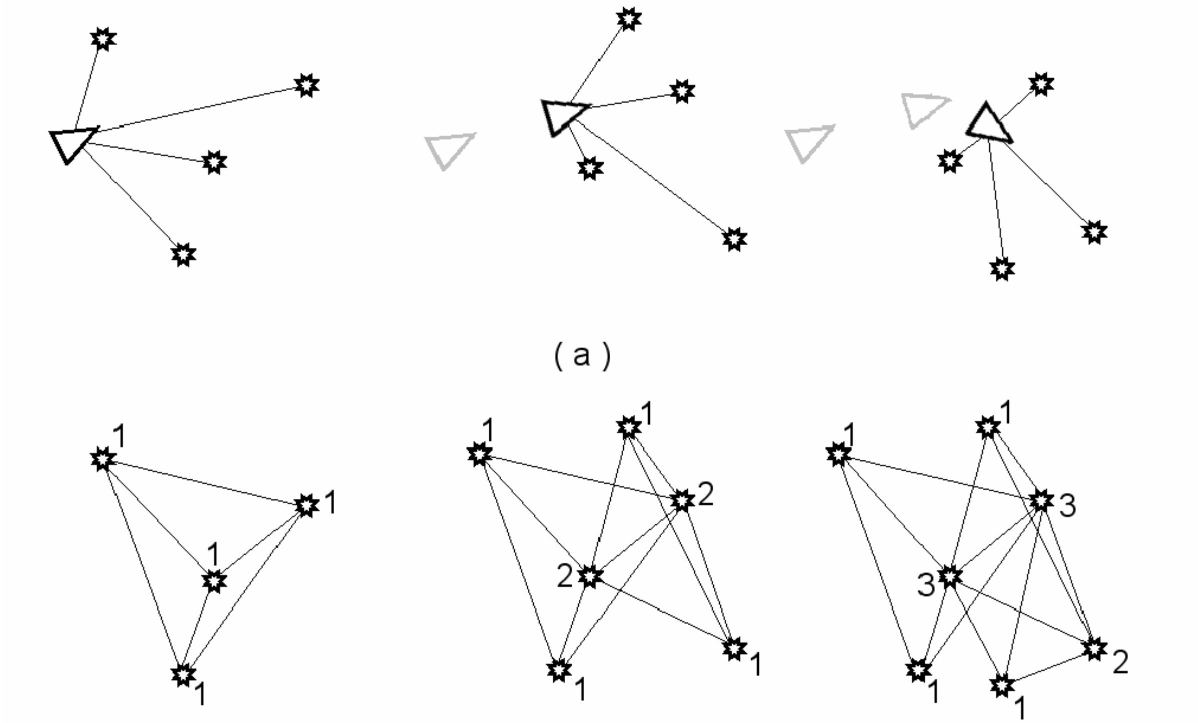
The Covisibility Graph

•An auxiliary graph is built during the navigation process: concept of locality of the features

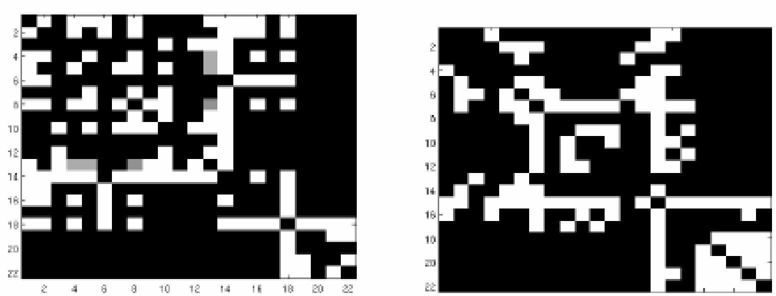


The Similarity Function

- Similarity function should be defined to obtain a similarity or adjacency matrix: Covisibility rate

$$CR_{ij} = \frac{a_{ij}}{\min(n_i, n_j)}$$

- Properties of the similarity matrix: symmetric, non-negative and band diagonal



Map Partitioning

- Minimization of the normalized cut using spectral clustering

$$Ncut(A,B) = \frac{cut(A,B)}{assoc(A,V)} + \frac{cut(A,B)}{assoc(B,V)}$$

$$assoc(A,V) = \sum_{u \in A v \in V} w_{uv}$$

- Validation: combined threshold

$$Ncut \leq Ncut_{min} \quad \& \quad eigv_2 \leq eigv_{2min}$$

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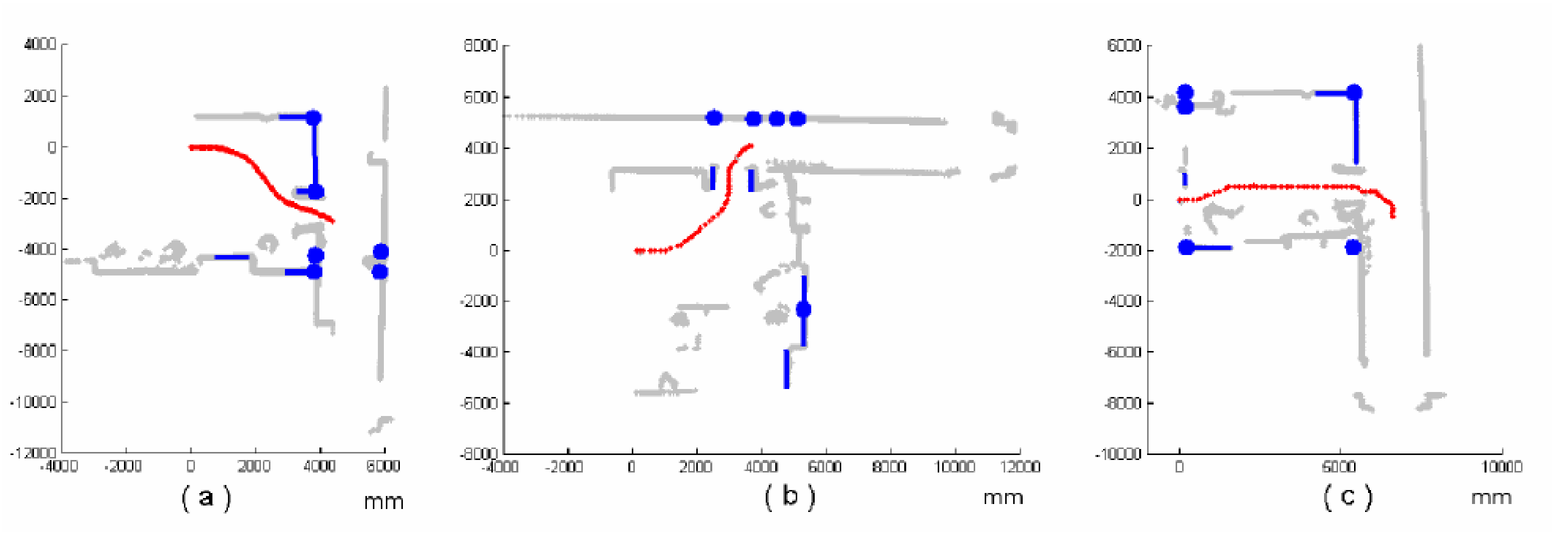
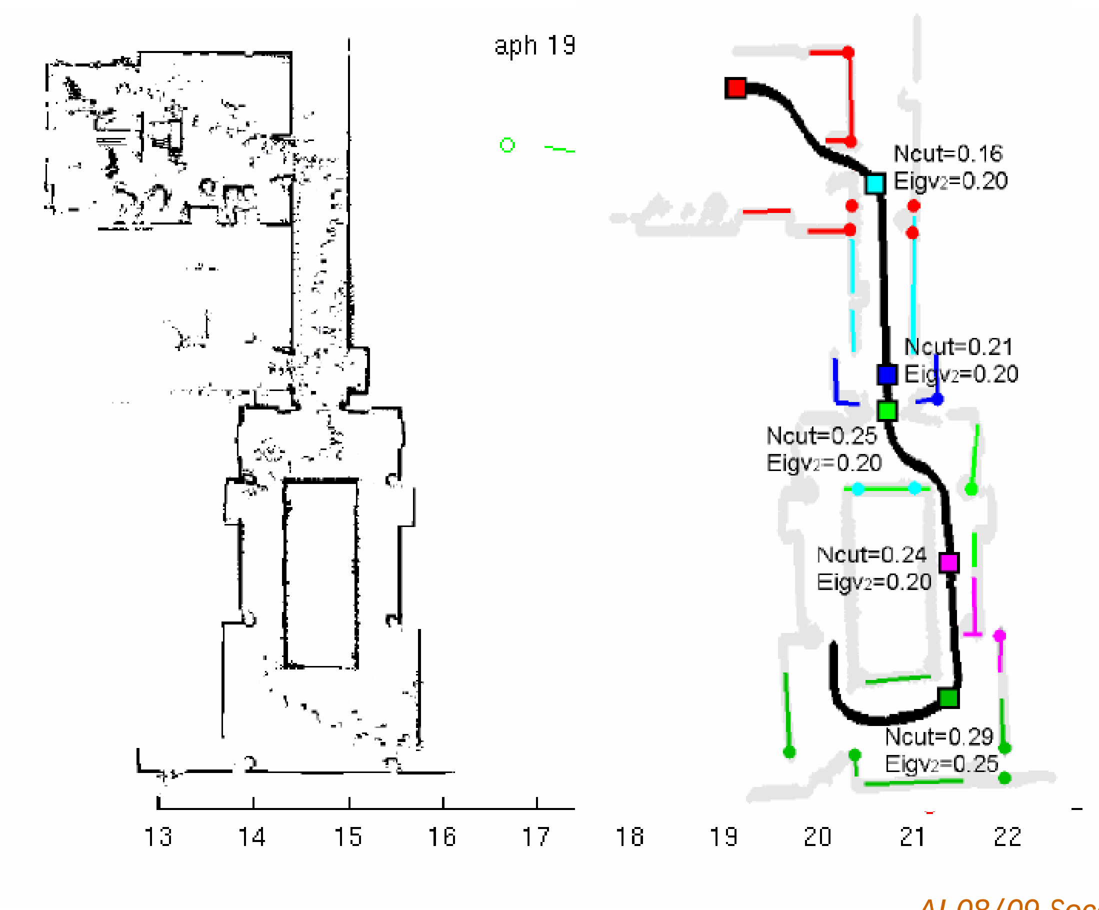
Submap generation for hybrid mapping

Experimental results: laser features



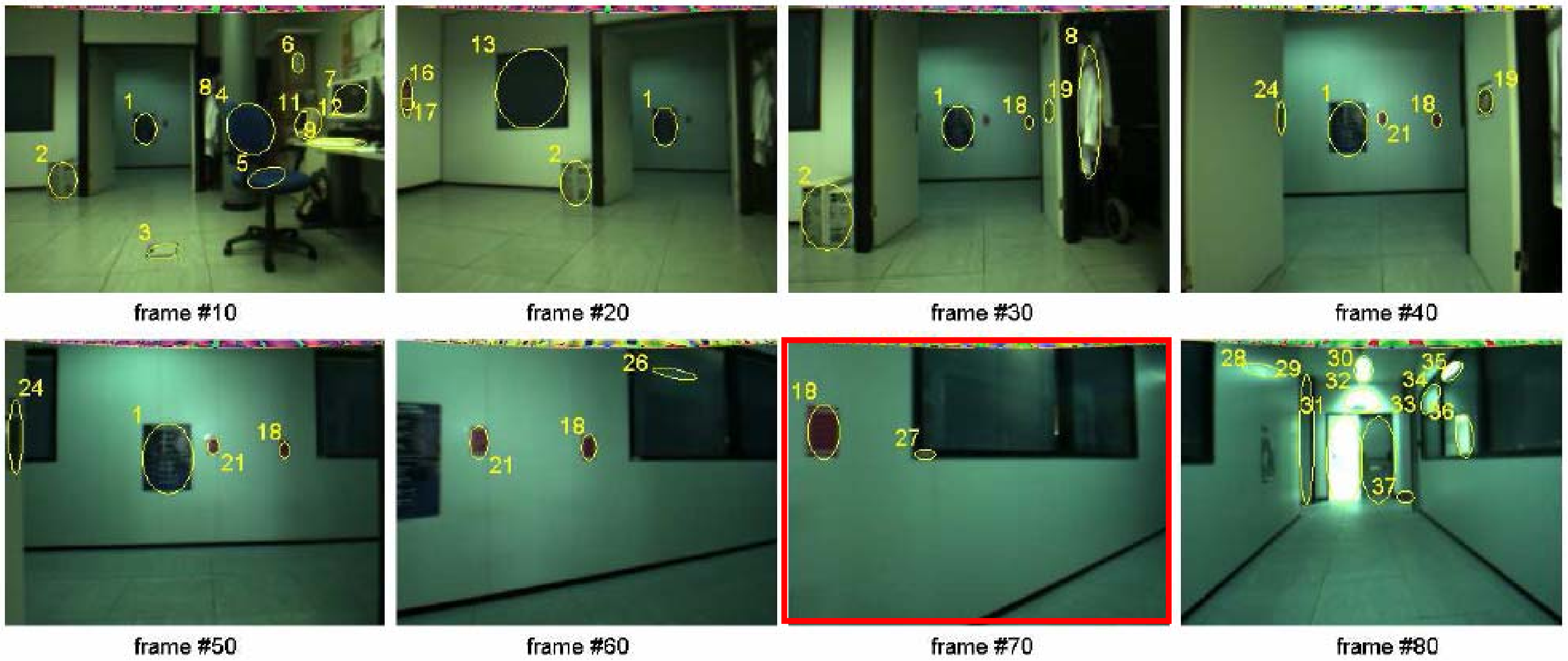
Submap generation for hybrid mapping

Experimental results: laser features



Submap generation for hybrid mapping

Experimental results: visual features



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Conclusions and Future Work

Conclusions

- Appearance-based submap generation
- Map Partitioning based on feature maps without constraint about any sort of features and sensor
- No information about robot trajectory is needed
- Similarity function defined using the concept of locality (covisibility rate)

Conclusions and Future Work

Future work

- Adaptive criterion according to the environment for map partition
- Integration in a hybrid SLAM framework

Actual work

- Monocular SLAM: increasing scalability and robustness
  - Region detector for interest points labelling and place recognition

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- **Thanks for your attention!!**

R. Vázquez-Martín

- **Any questions/advise?**

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