Sparser Relative Bundle Adjustment: constant-time maintenance and local optimization of arbitrarily large maps

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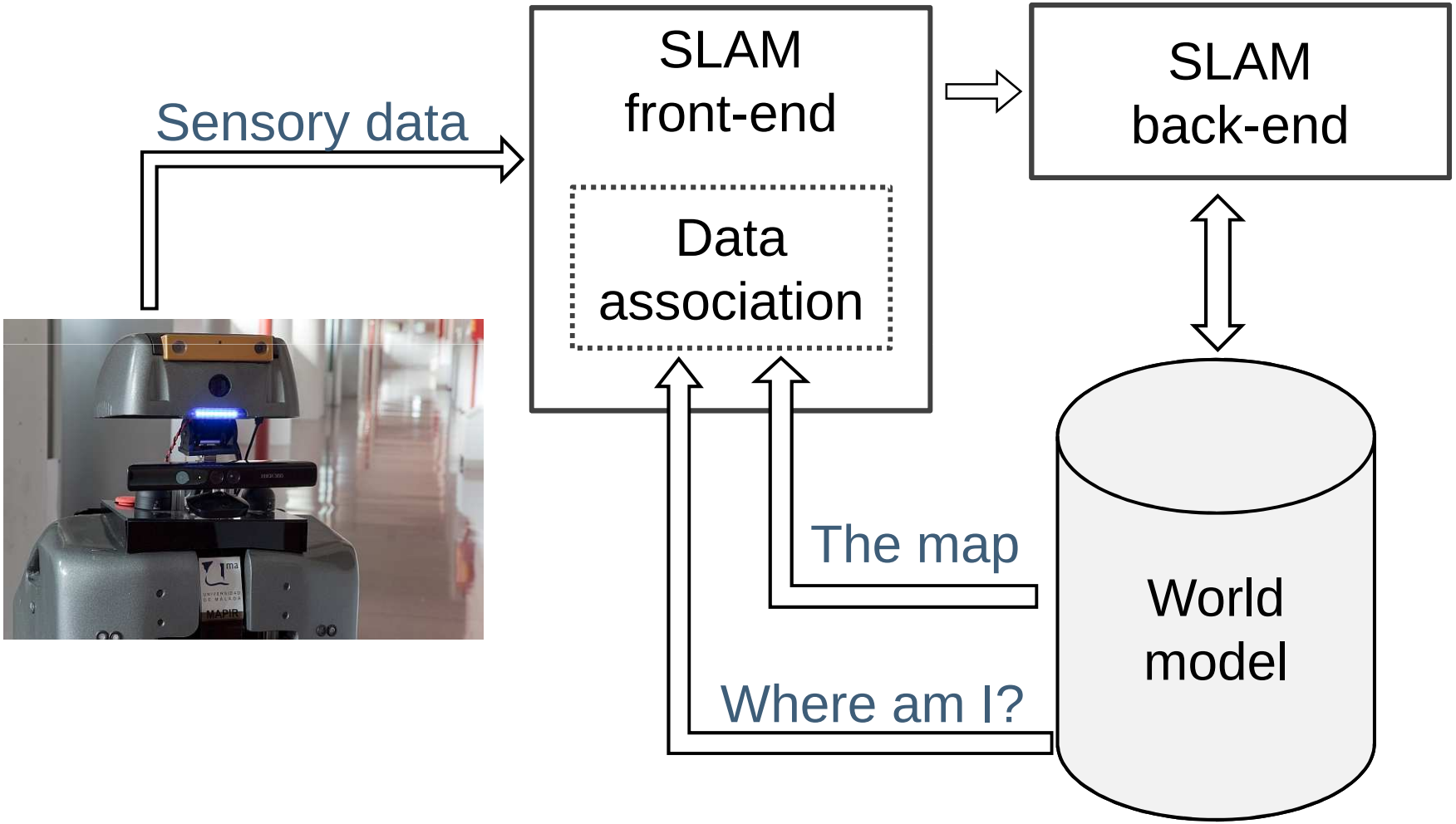
Long-term goal: truly autonomous robots

Most roboticians agree a robot must autonomously learn **how the world looks like** and **where it is**:

SLAM

Ideal SLAM pipeline… for a life time?



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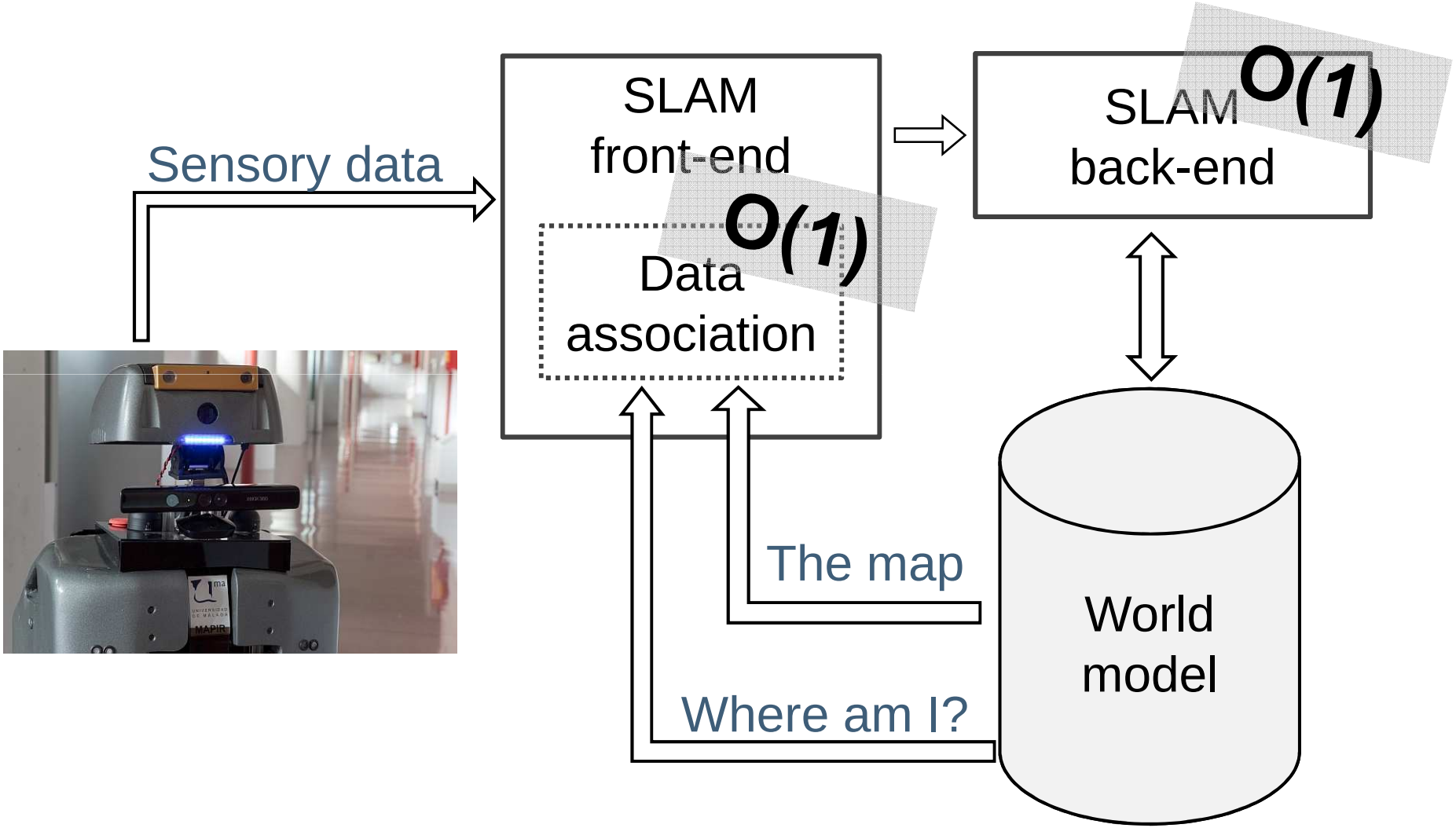

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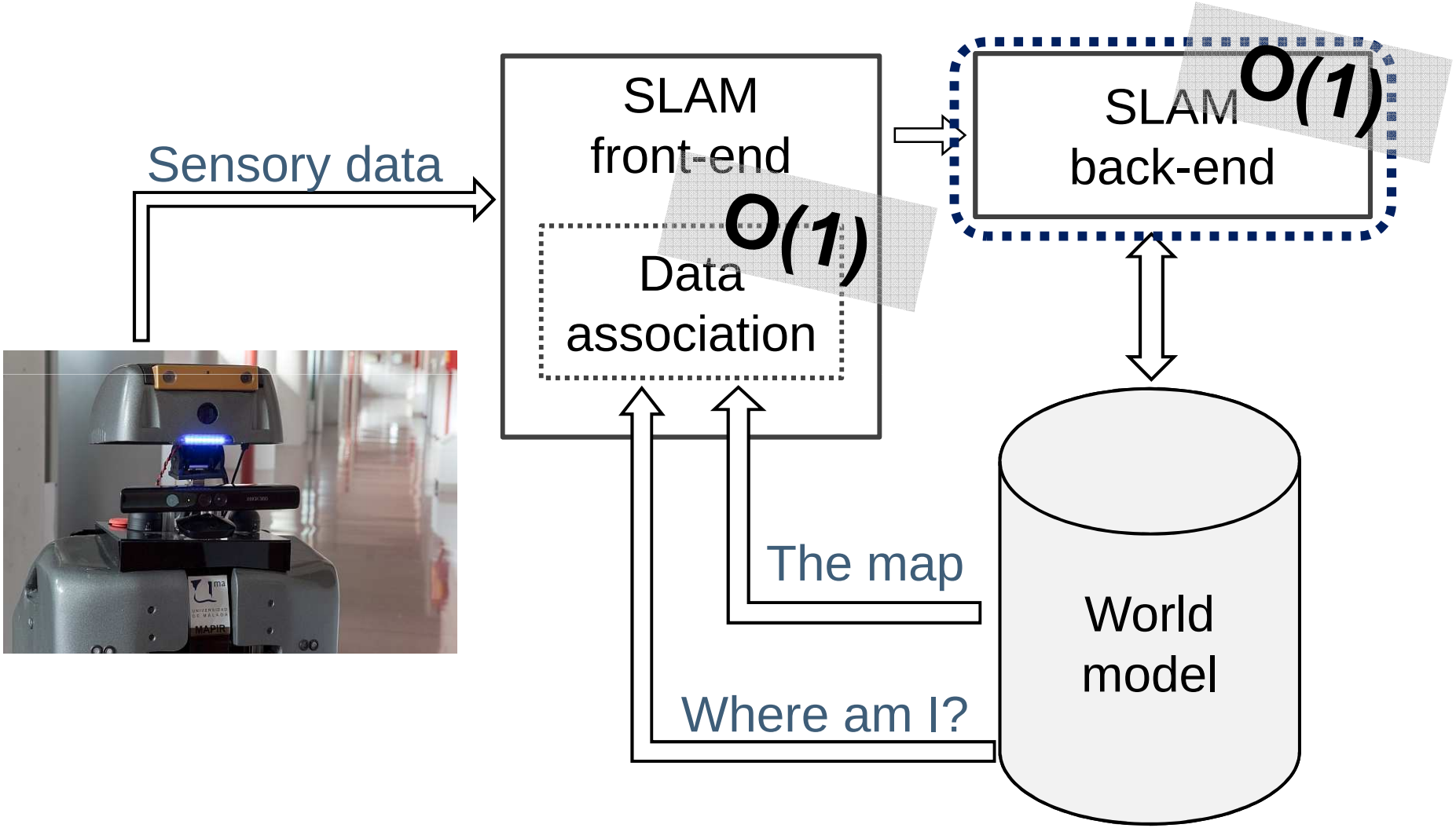
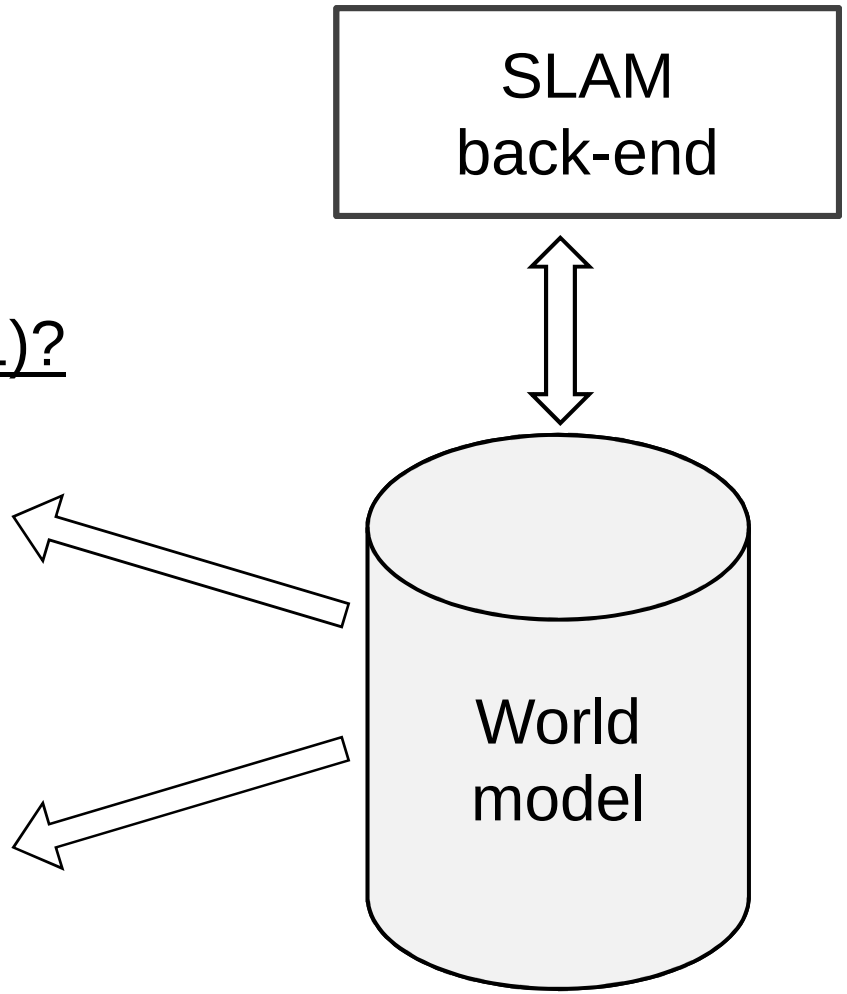


That's the question

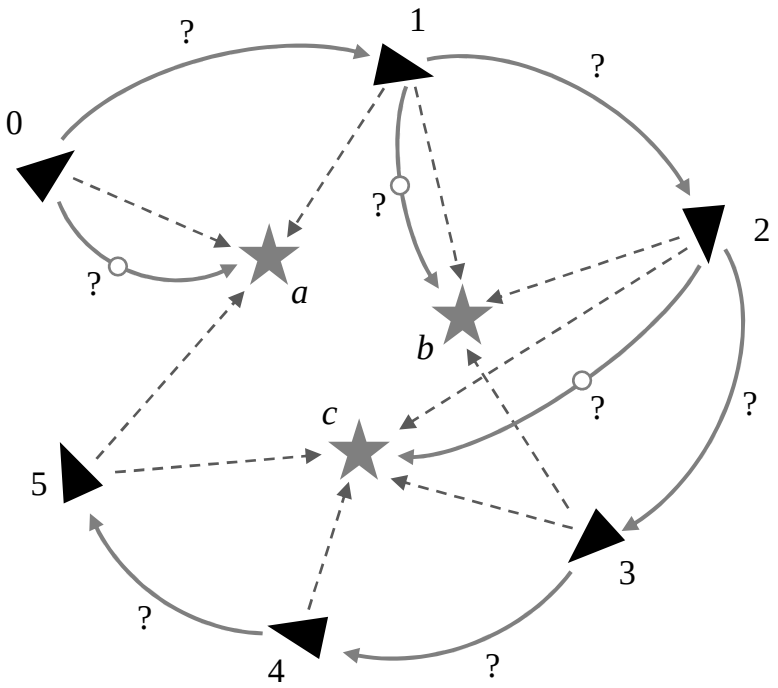


<u>Rational decision towards O(1)?</u>

To use global coordinates

Not to use global coordinates

SLAM in relative coordinates



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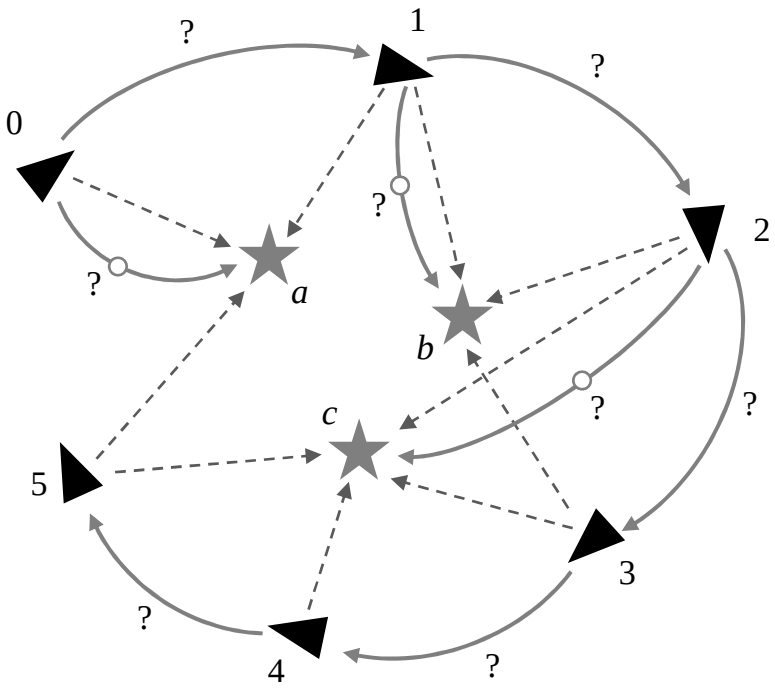


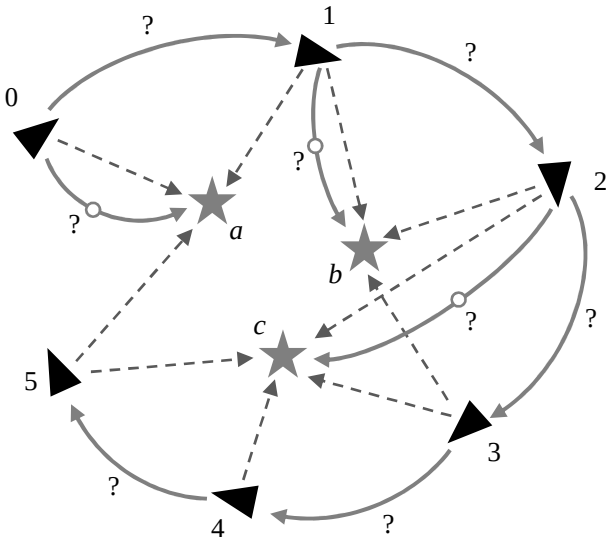
Unknowns:

- Keyframe-to-keyframe poses
- Landmark relative positions

Known data:

- Observations

SLAM in relative coordinates

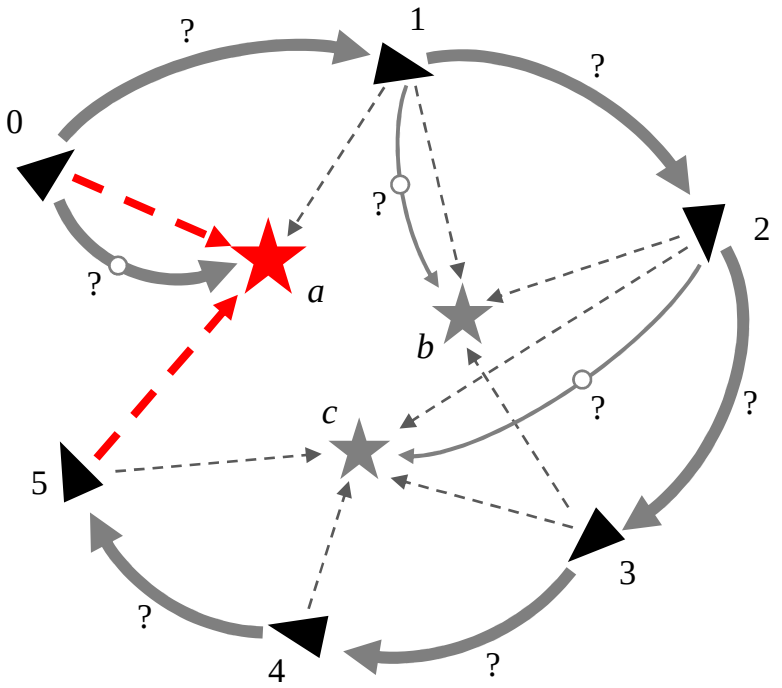


Key for O(1): *Locally* consistent maps

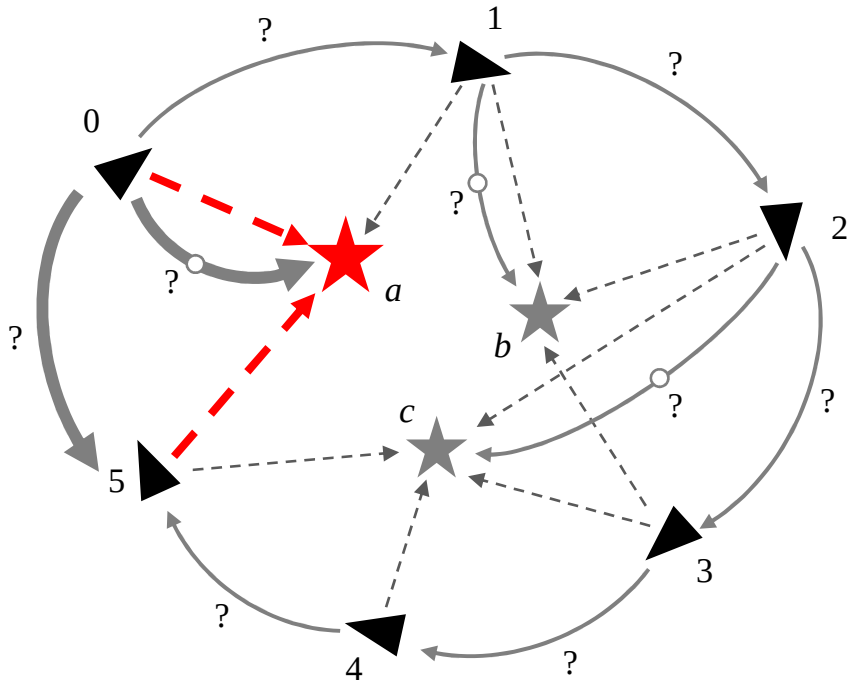
Introduced by Gabe Sibley and colleagues:

- **G. Sibley**, "*Relative bundle adjustment*," Department of Engineering Science, Oxford, 2009.
- **G. Sibley, C. Mei, I. Reid, and P. Newman**, "*Adaptive relative bundle adjustment*", RSS 2009.

Loop closing in *relative* SLAM



vs.

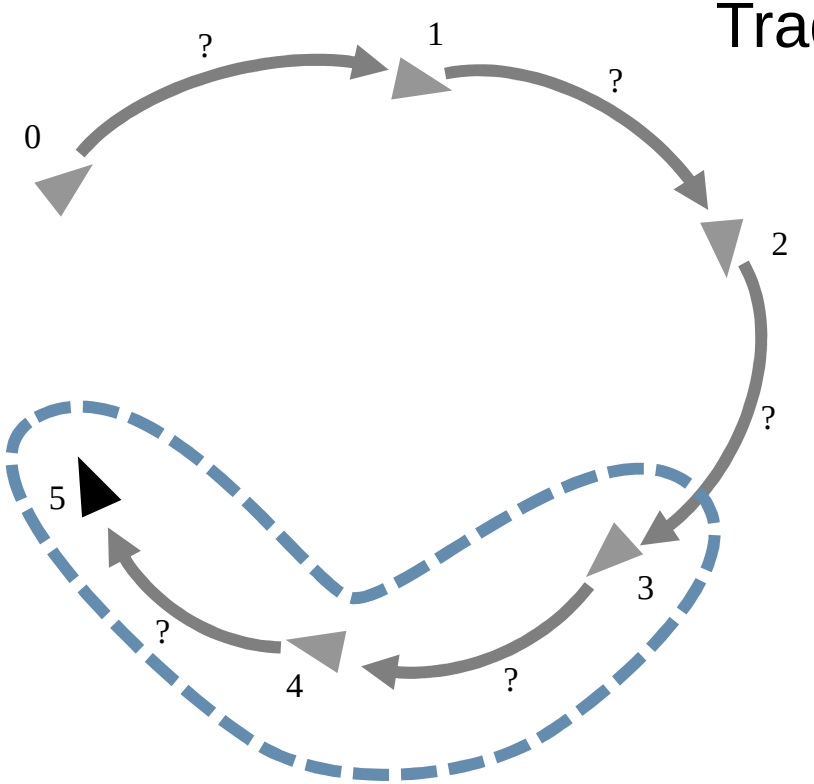


Edge creation and the locally-consistent area

✓ Fewer unknowns

✓ Consistent maps are **larger**

Tradeoff ?



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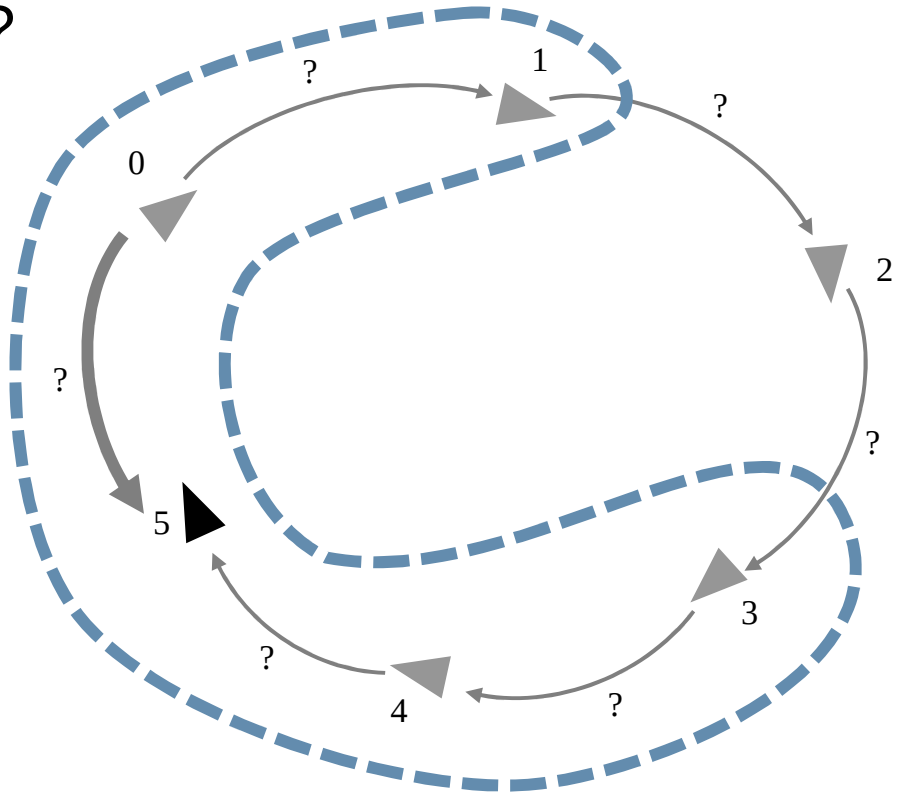

A totally new problem: edge creation

The problem of edge-creation:
Given a set of observations, how many and which edges should be created?

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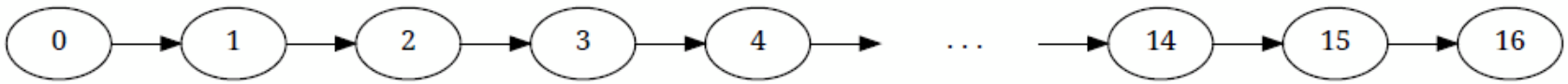
Optimal solution? We still don't know

The power of the edge creation policy

Different **policies**:

- The “intuitive” linear graph policy: (→ RBA [G.Sibley *et al.*])



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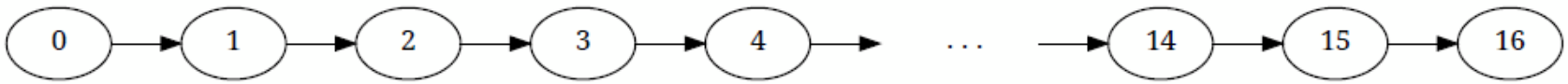
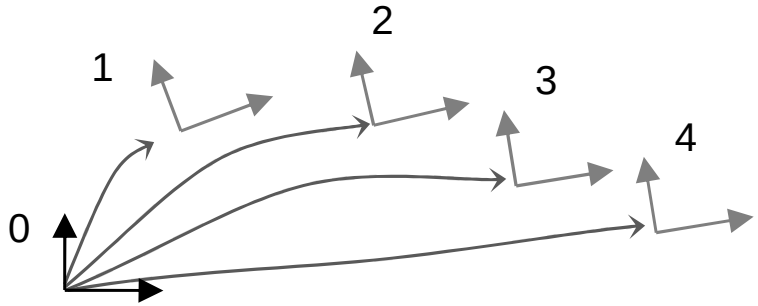


- All edges to the same keyframe: (→ becomes *global* SLAM)



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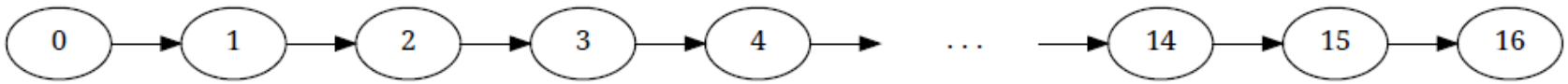

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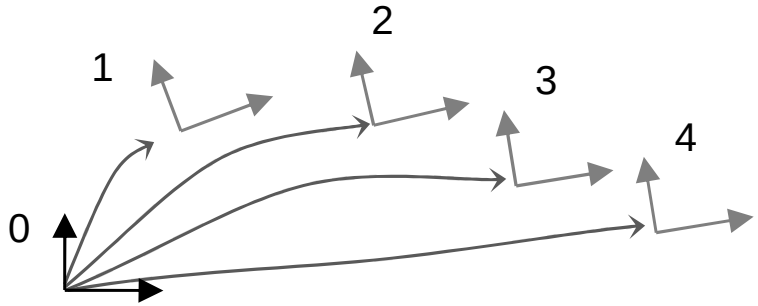
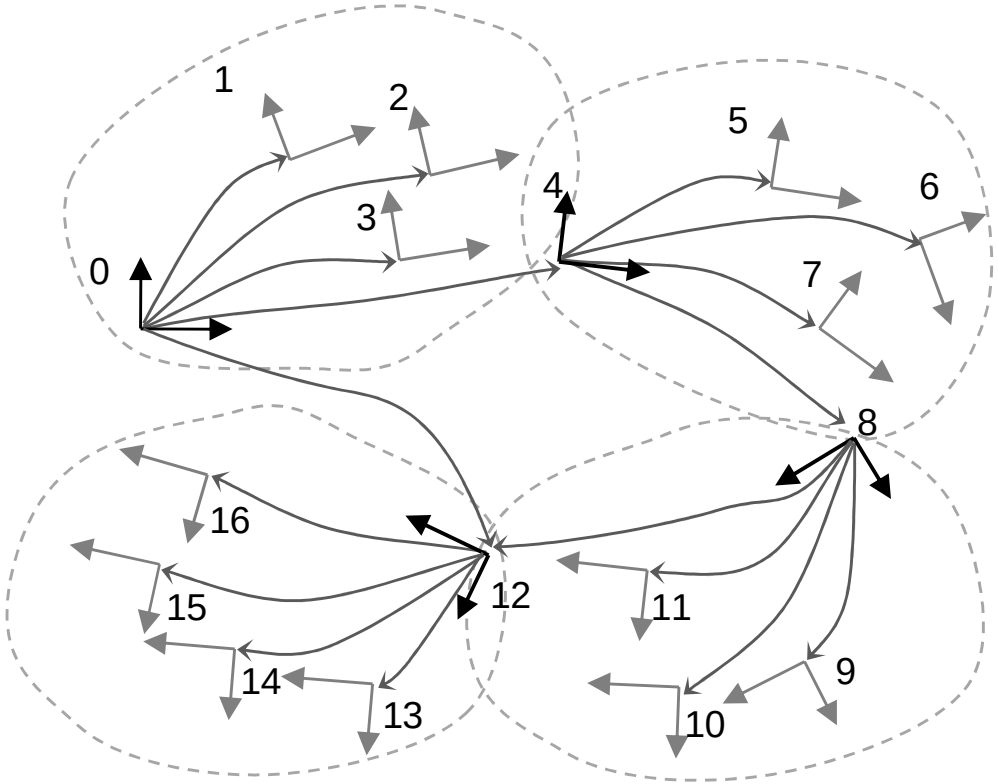


- Something in between?

Our proposed policy

Inspired by hierarchical **submapping** methods:



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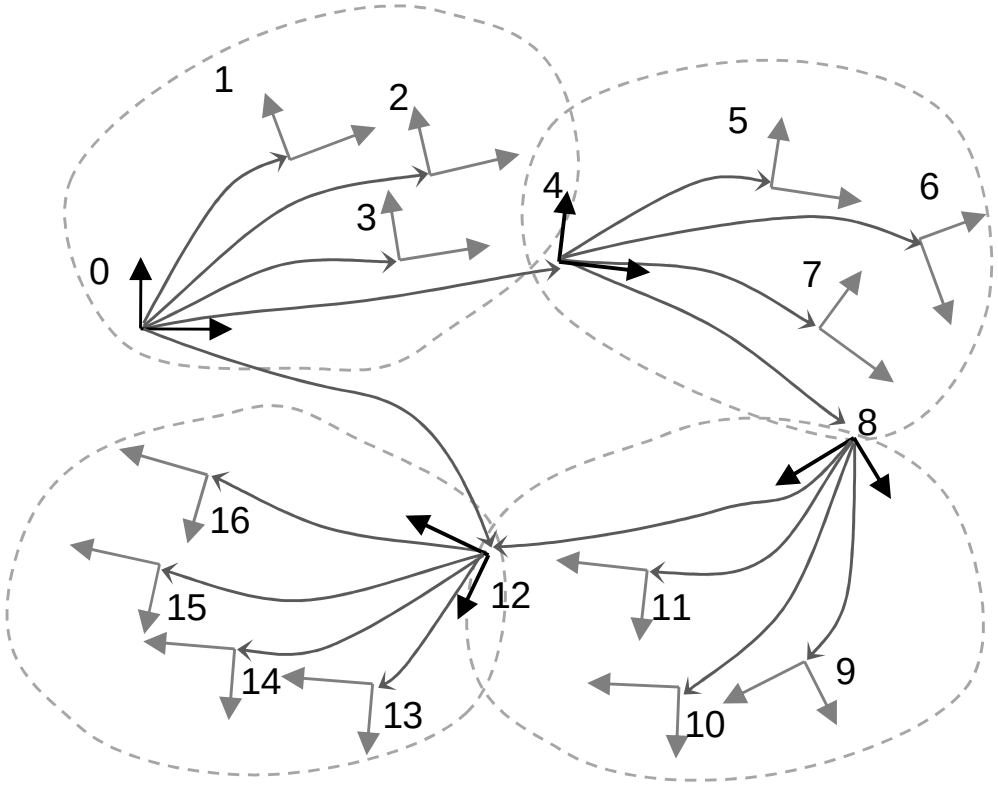
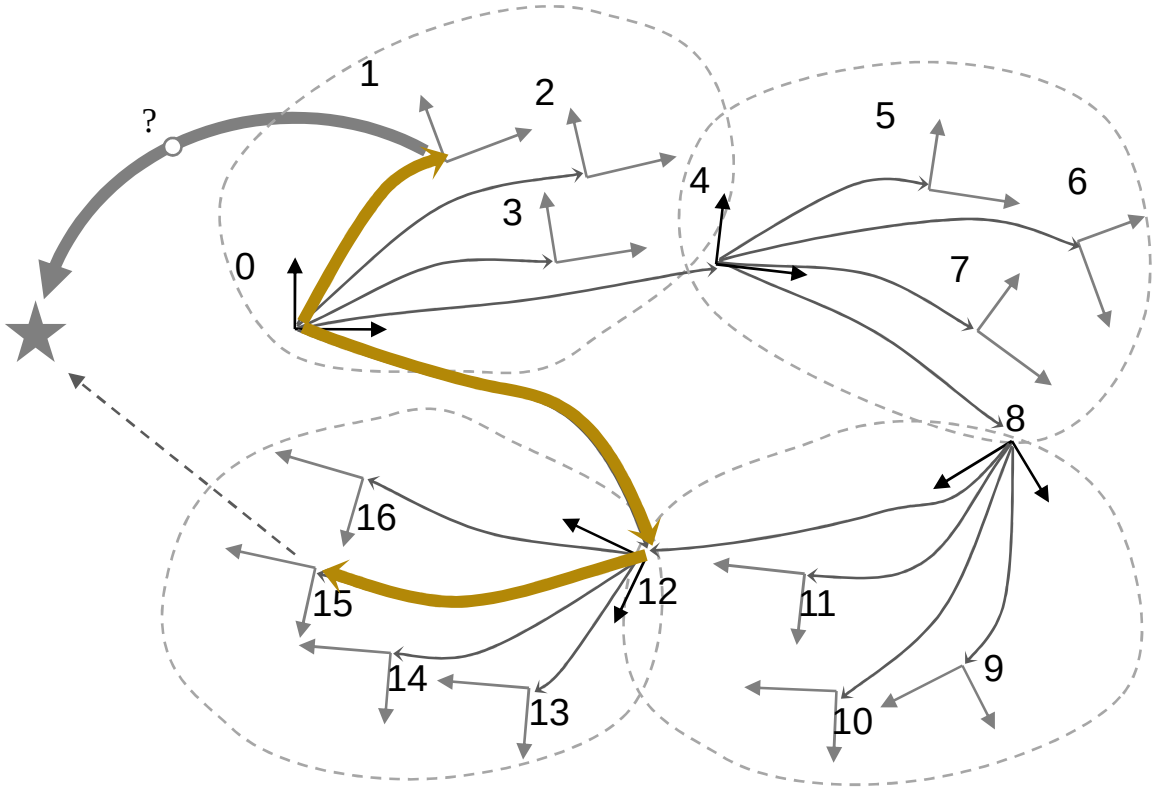


Probably, the first framework that **seamless integrate global and relative** coordinates.

The need for spanning trees in RBA



Observation model of landmark include **the path** from:
observer KF → base KF

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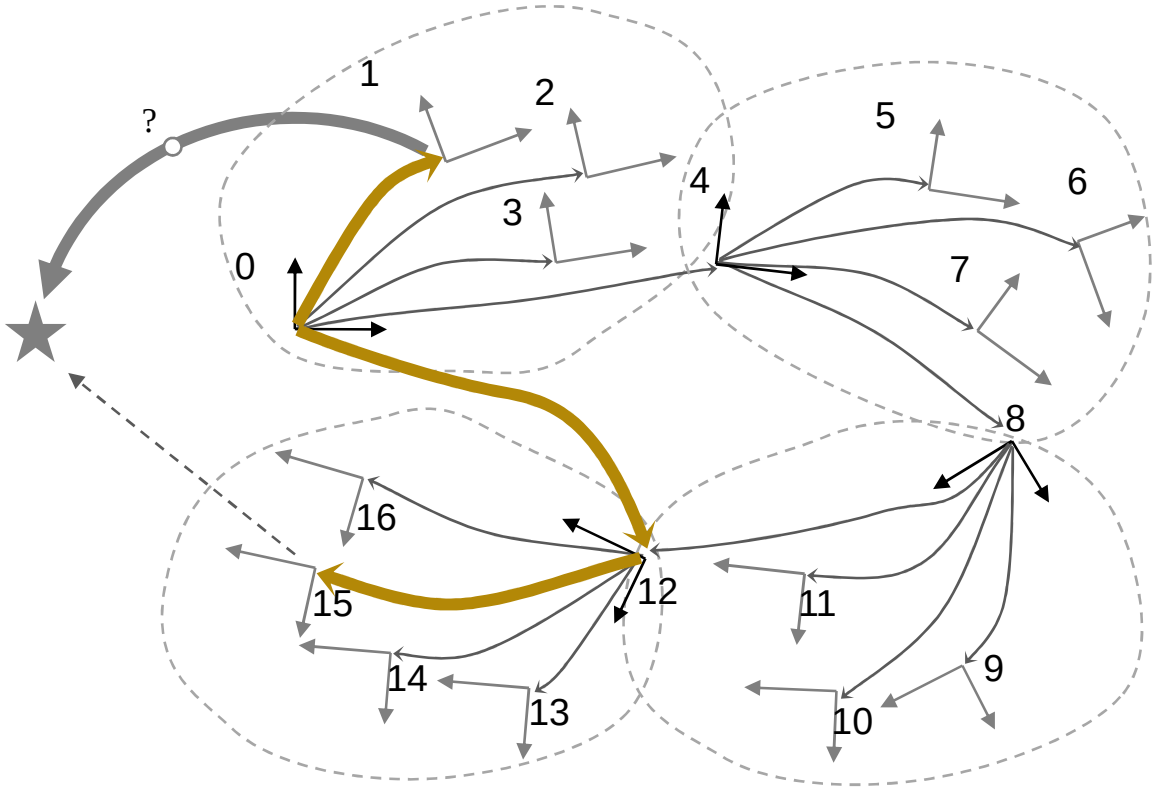

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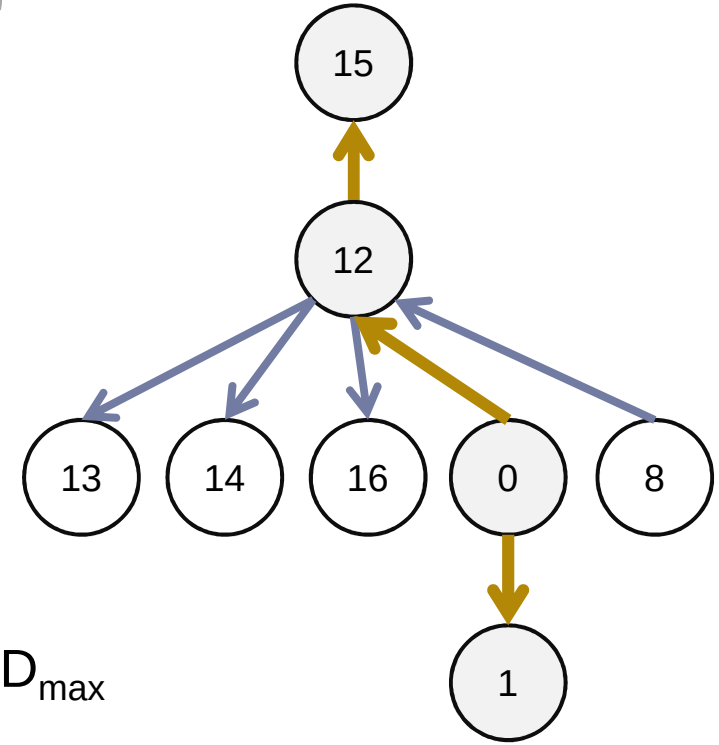
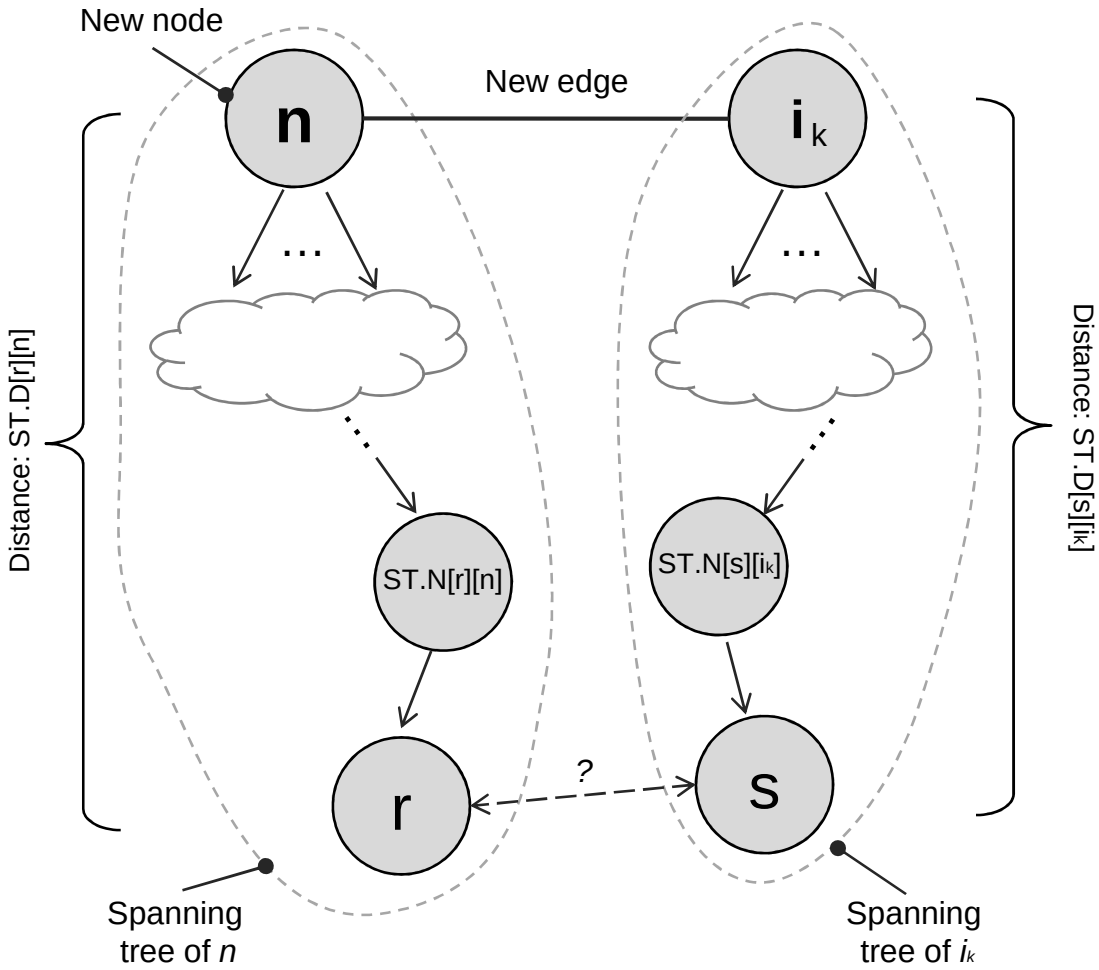


→ Keep STs up to a maximum topological depth D_{max}

An algorithm for updating STs: basic idea



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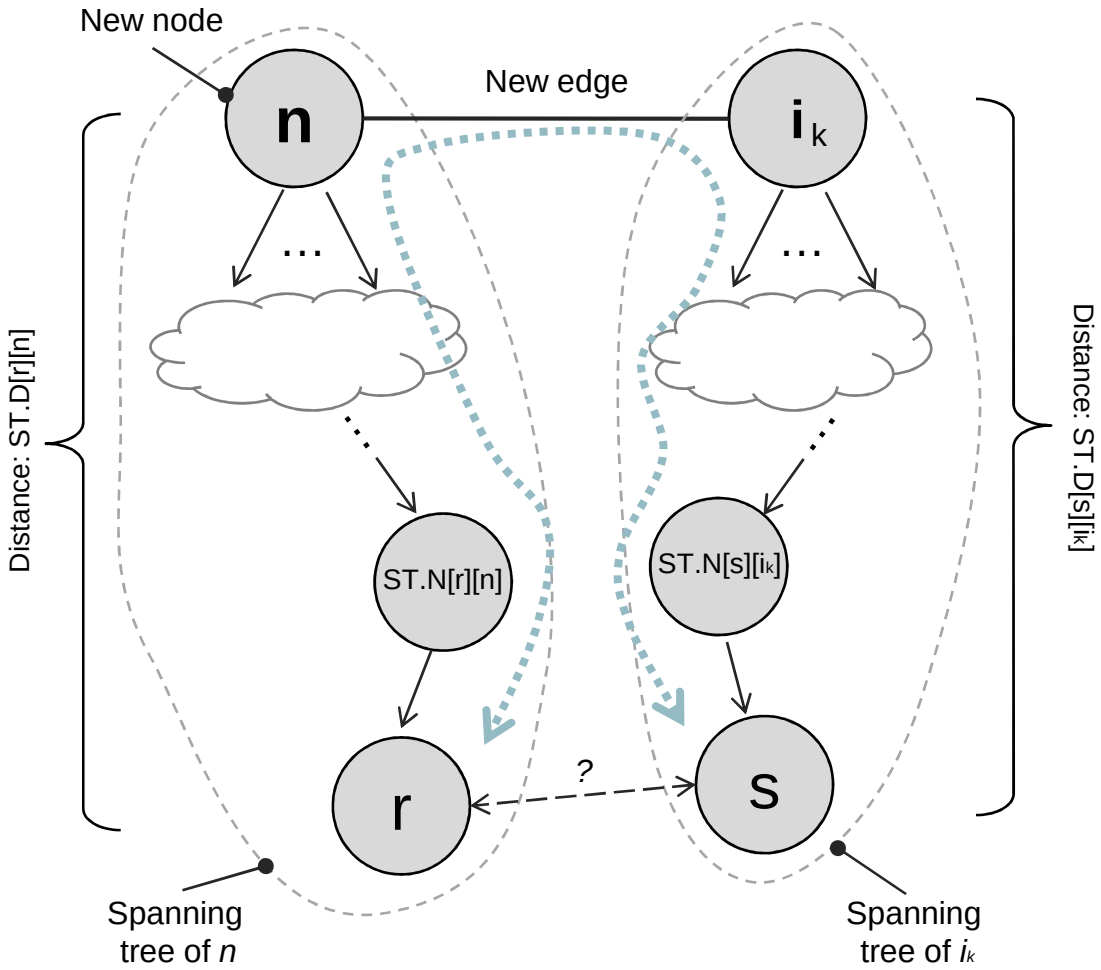


For all *r* and *s*:
Is the new path shorter?
Is a new path in range of D_{max}?

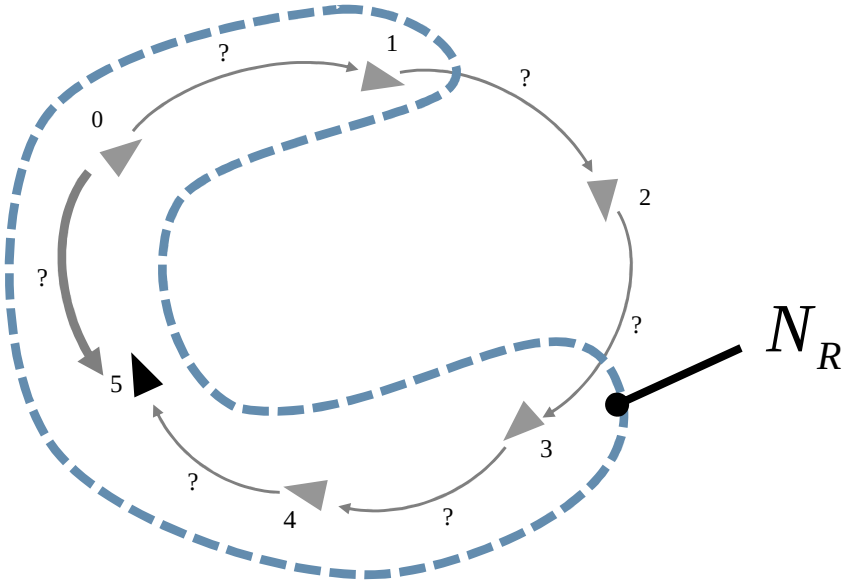
Update the STs accordingly:

- `r`→`s`: Go towards "n"
- `s`→`r`: Go towards "i_k"

An algorithm for updating STs: complexity

Computational complexity:

$$O\left(N_R^2 \log N_R\right)$$



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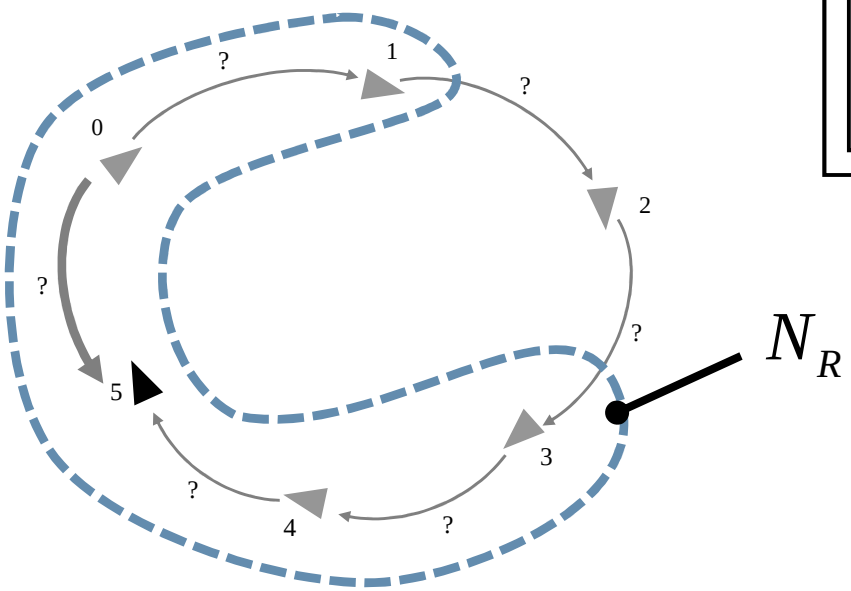
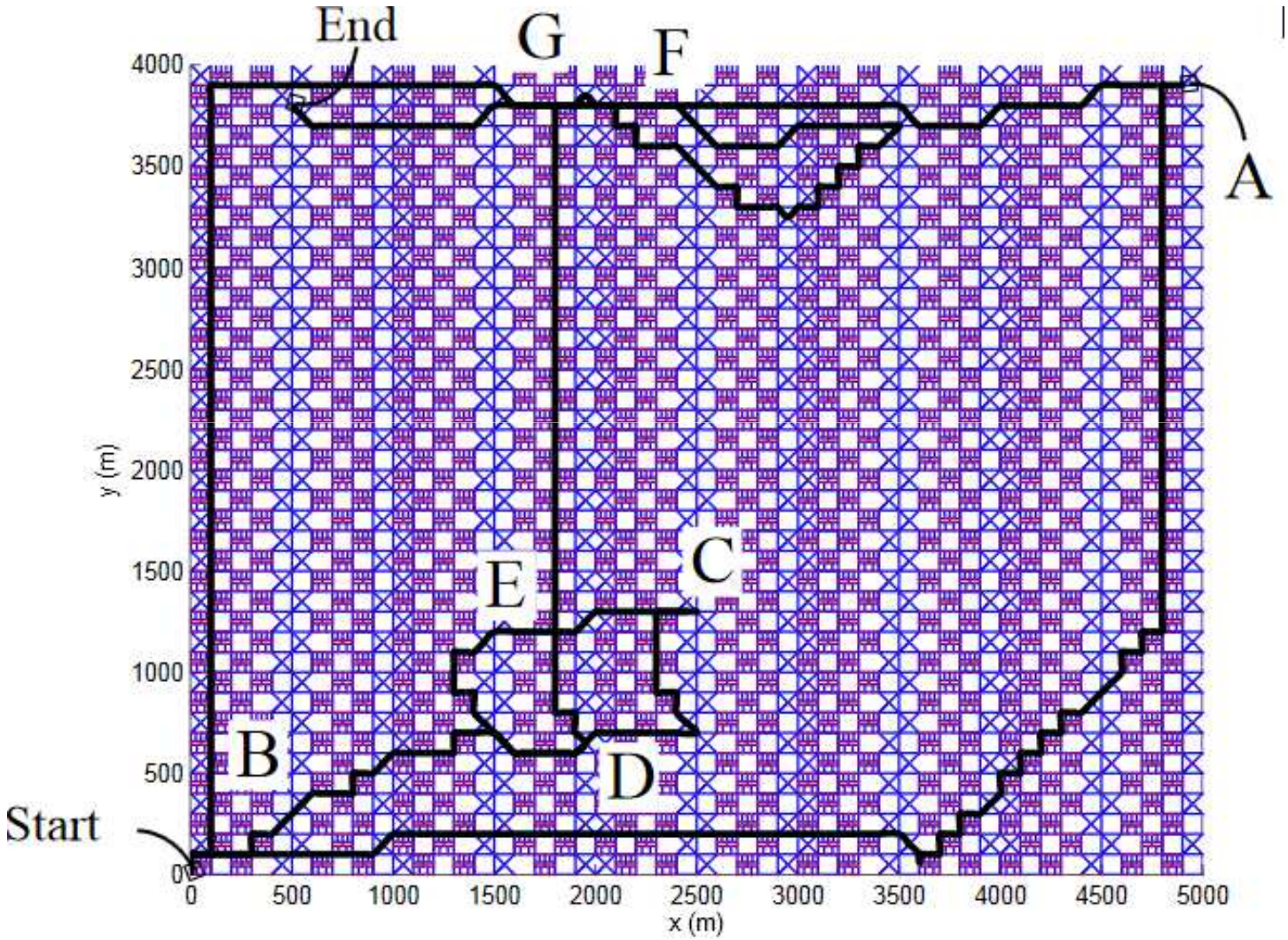
In practice: O(1)



Experiments

Experiments: (1) Monocular SLAM



- 4/4: Results

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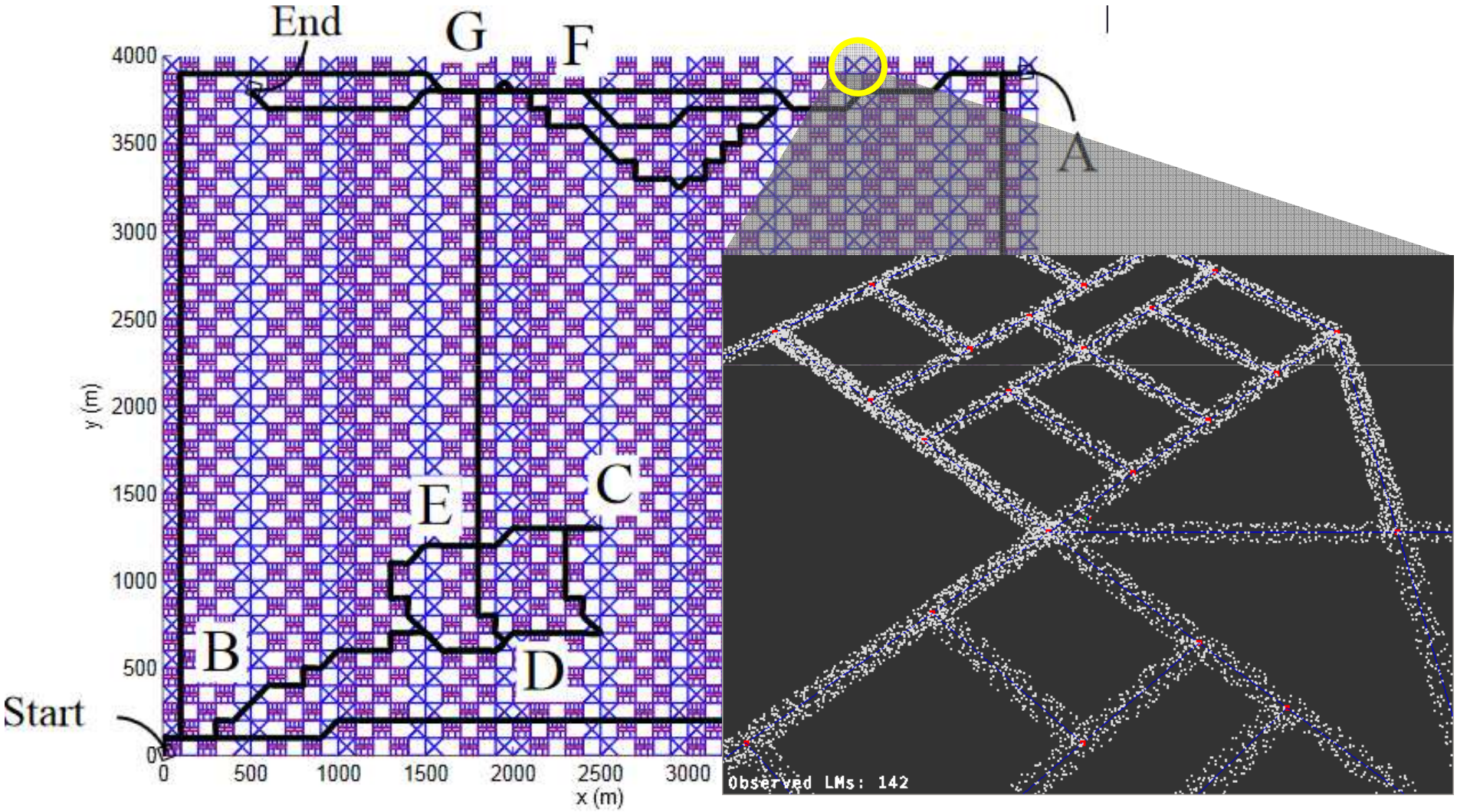
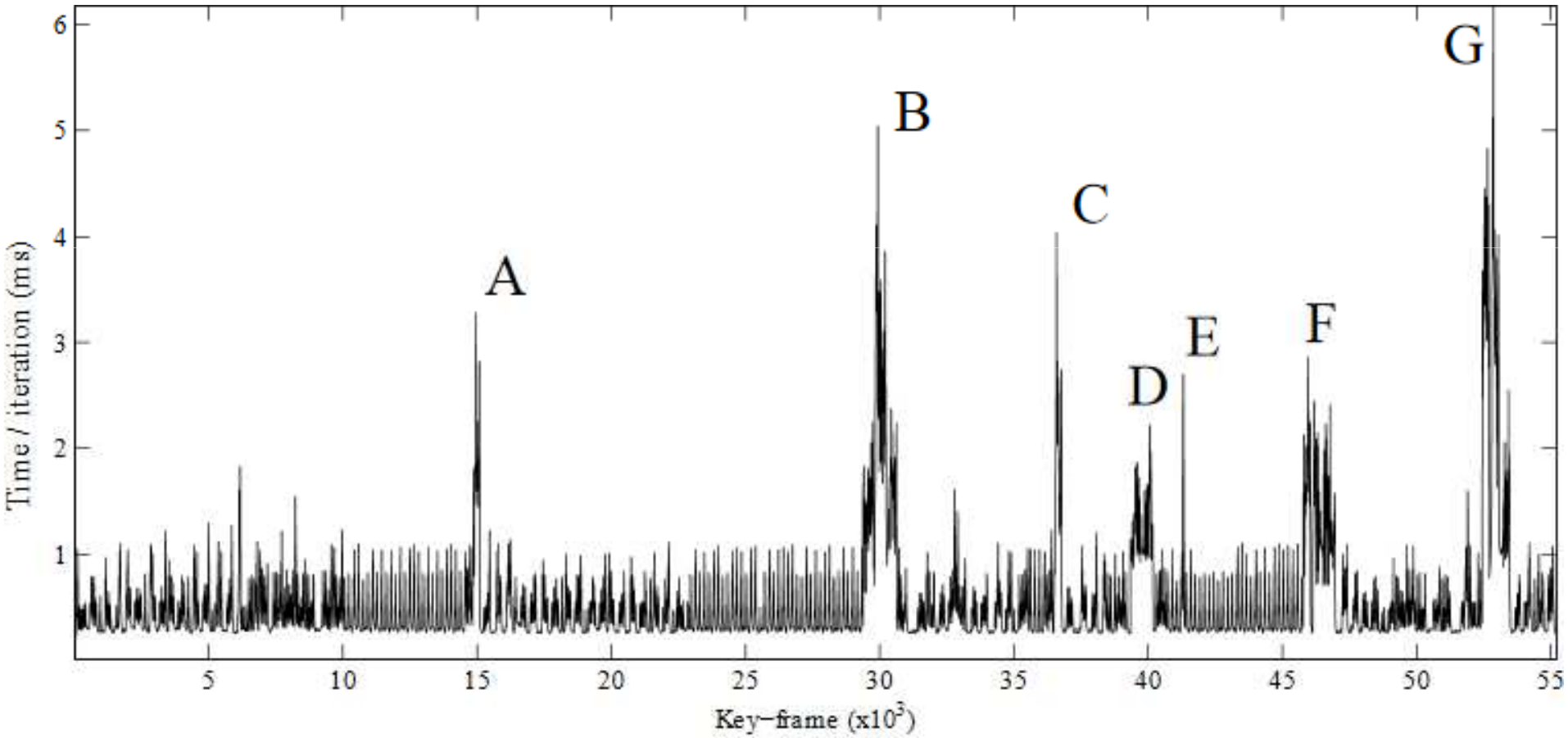


Experiments: (1) Overall processing time

Total: 55,000 keyframes, 4,000,000 observations, 400,000 landmarks



Experiments: (2) 2D graph-SLAM demo

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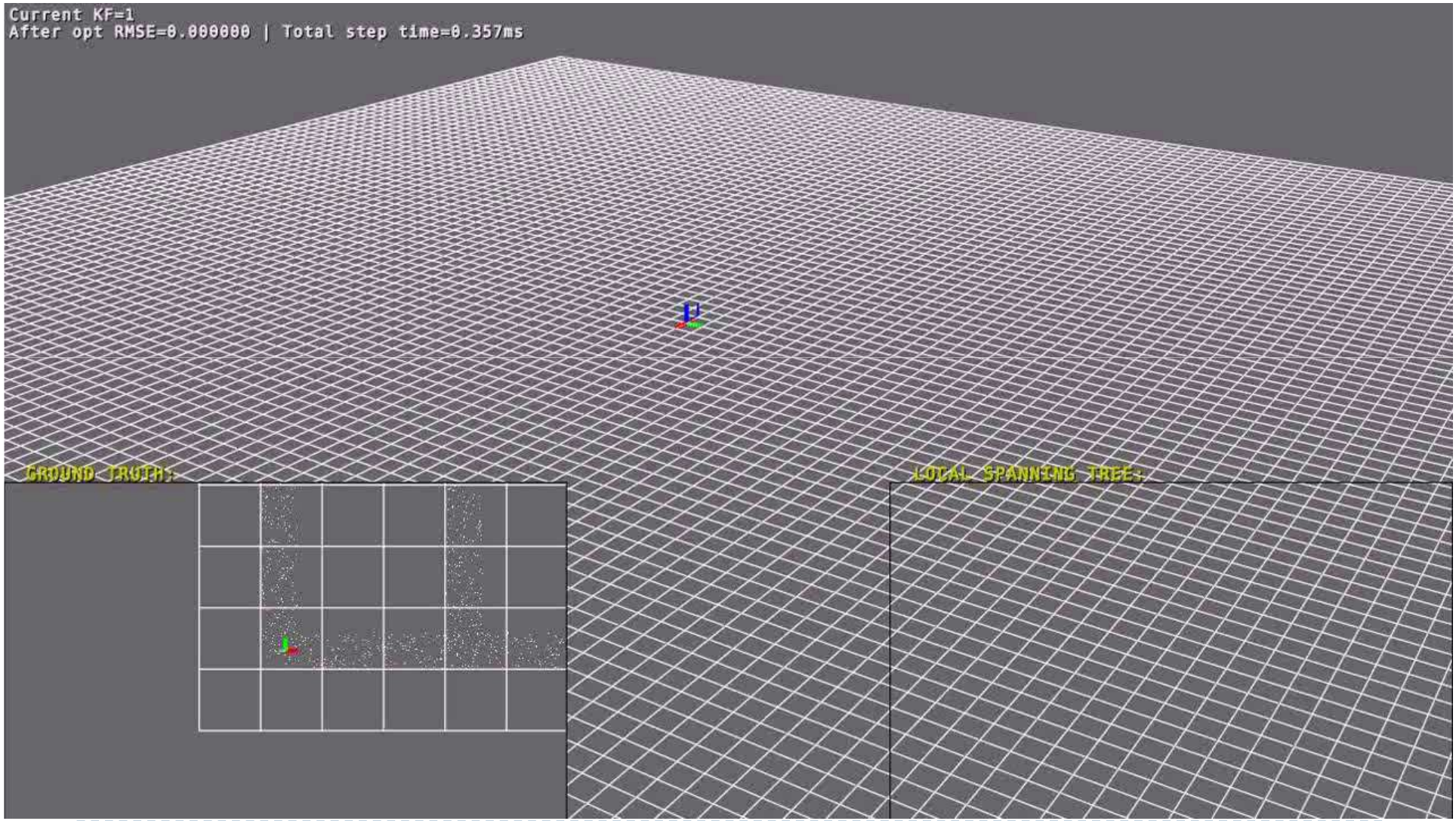
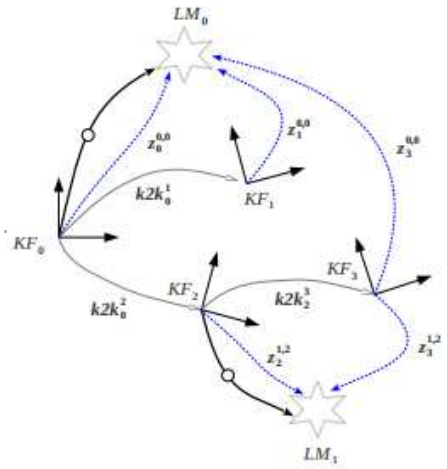
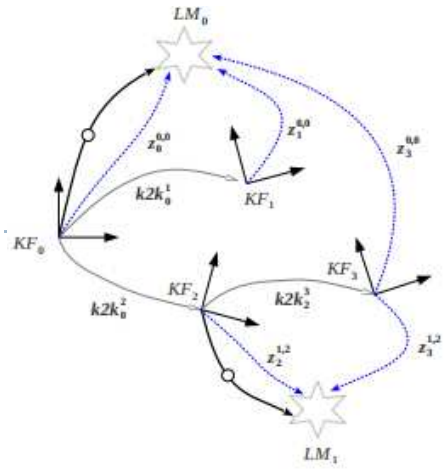


- 4/4: Results

Conclusions



Conclusions



- Contributions:
  - ➢ Proposal of **edge-creation policies** as worthy of research.
  - ➢ **Blended global-relative** coordinates, similar to submapping.
  - ➢ O(1) algorithm for **online updating** of spanning trees.

Open source release

Public C++ implementation.
Policy-based design → flexibility

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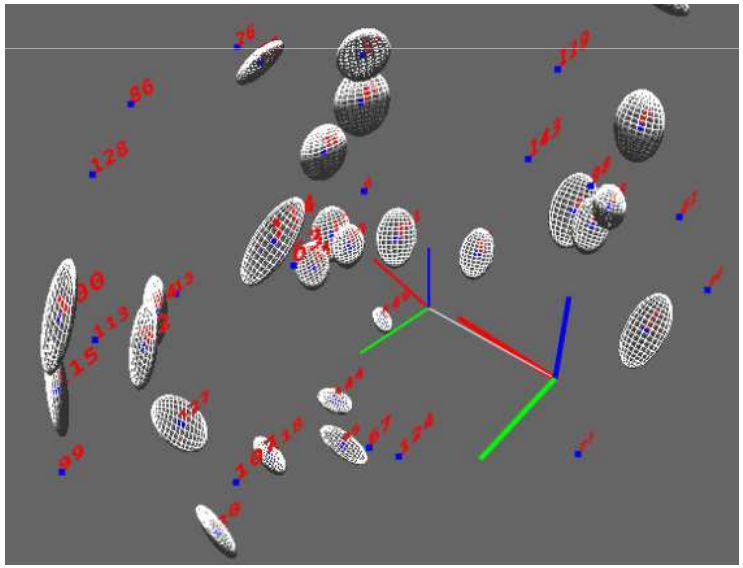
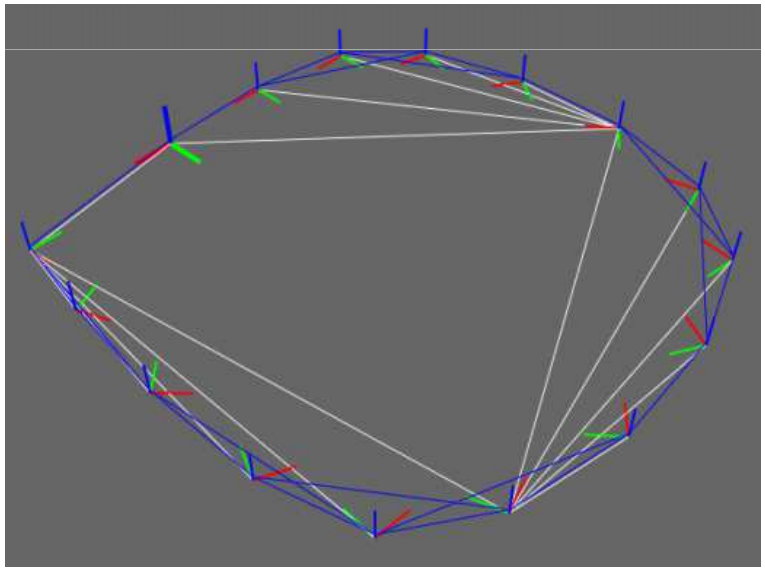
Policy-based design → flexibility

```
typedef RbaEngine<
  kf2kf_poses::SE3,          // Parameterization  KF-to-KF poses
  landmarks::Euclidean3D,    // Parameterization of landmark positions
  observations::RangeBearing_3D // Type of observations
  >
  my_srba_t;
```



SLAM and BA-like problems

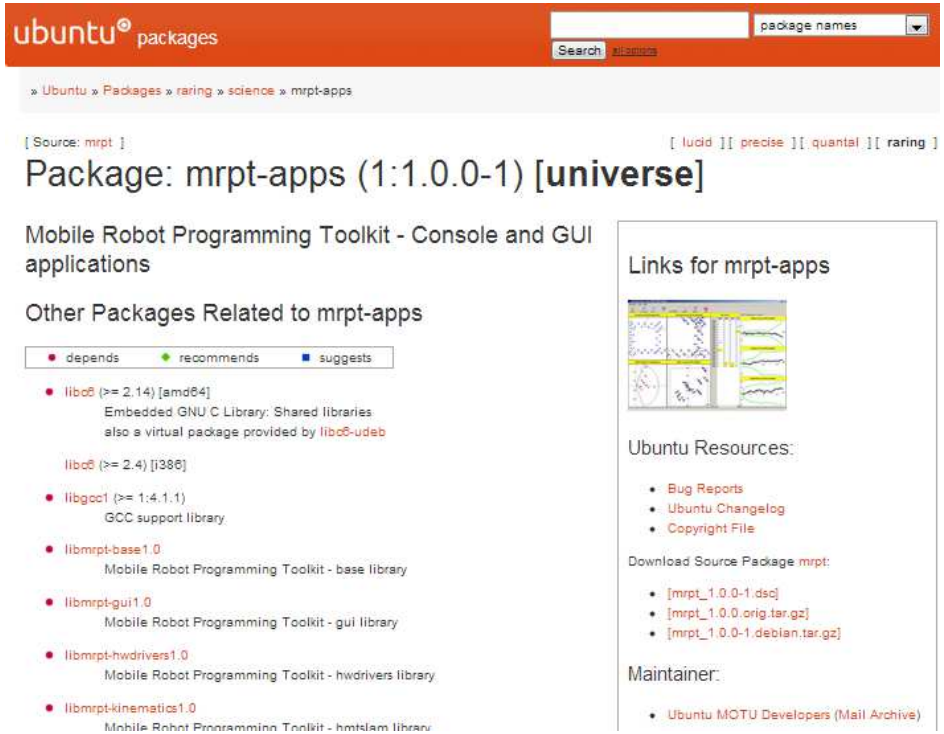


Relative Graph SLAM

Open source release

Available in Ubuntu 13.04 official repository (other distros → can use PPA)

```
$ sudo apt-get install libmrpt-dev mrpt-apps
$ srba-slam --help
```



More online:

`http://www.mrpt.org/srba`

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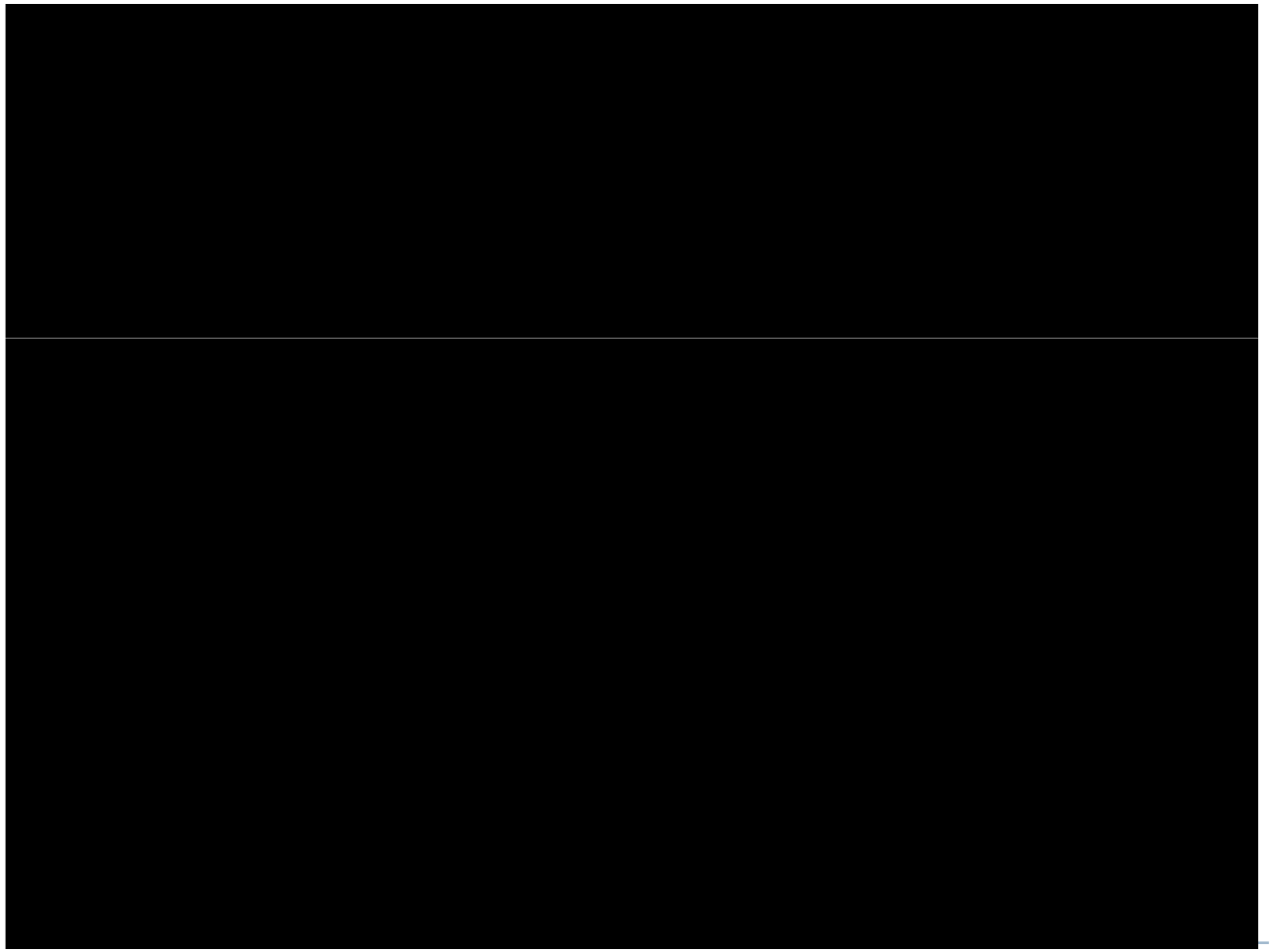

Thanks for your attention!

More info online:
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