HARA: A Hierarchical Approach for Robust Rotation Averaging

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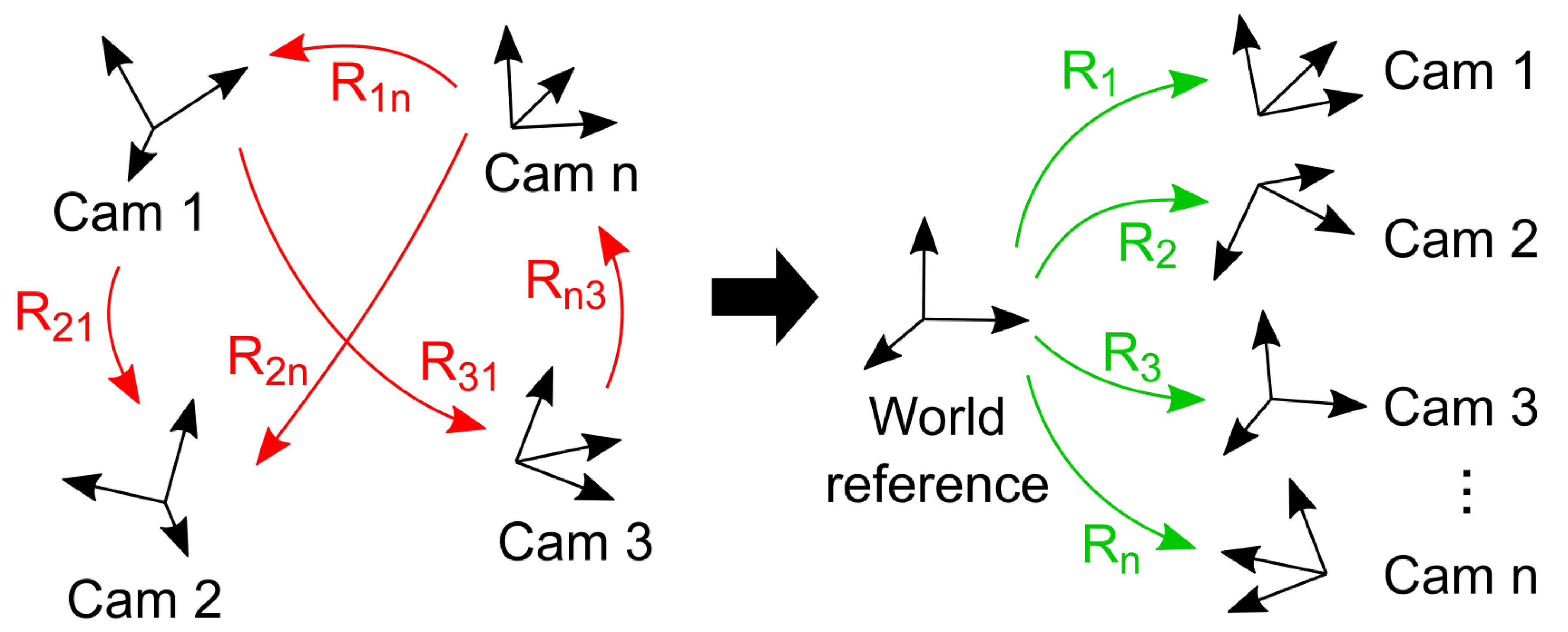
1. What is (multiple) rotation averaging?

- **Input**: Estimates of some of the relative rotations between cameras.
- **Output**: Absolute rotations of all cameras that best fit the input data.



- **Applications:** Structure-from-Motion (SfM), Visual Odometry (VO) and Simultaneous Localization and Mapping (SLAM).
- **Challenge**: In real datasets, the input could contain many outliers. They can significantly degrade the estimation accuracy if not handled properly.

2. Our approach

Improve the initialization to achieve better optimization results!

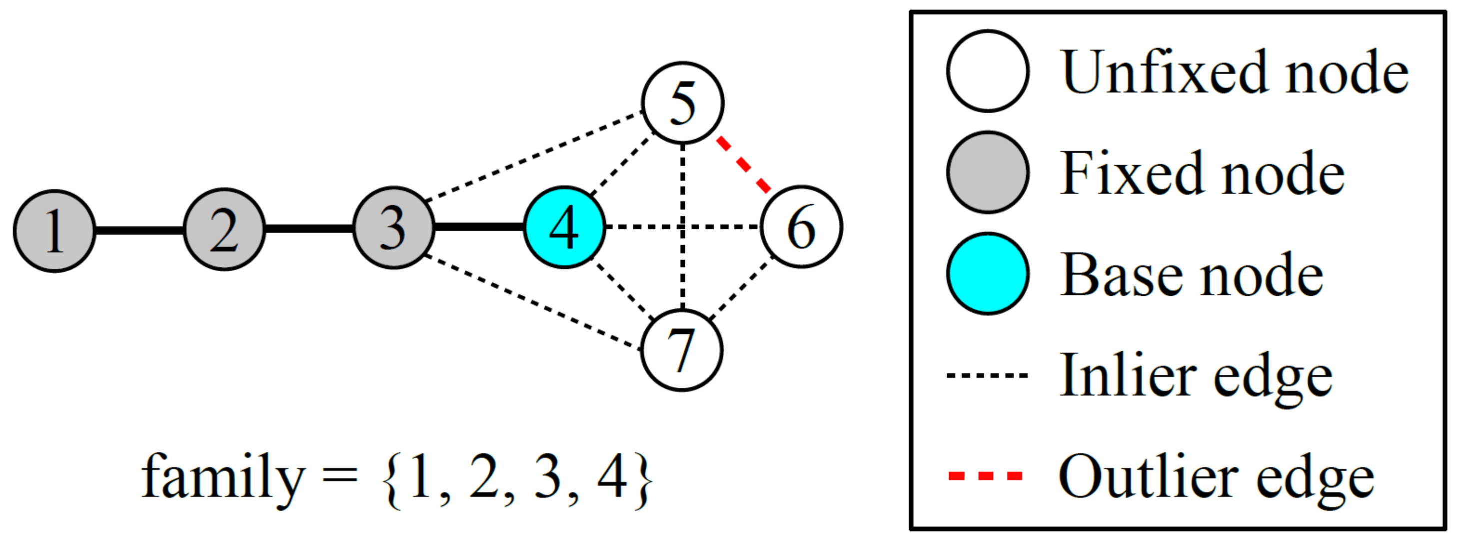
- **Step 1:** Robust initialization by building a spanning tree based on a hierarchy of triplet support.
- **Step 2:** Filtering the edges inconsistent with the initial solution.
- **Step 3:** Iterative refinement using [IRLS-0,5].

3. Definitions

- **Family** = Set of nodes added to the (yet-incomplete) spanning tree.
- **Base** = A recently added node from which the tree may branch out.
- **Consistent triplet** = Node (*i*, *j*, *k*) that satisfy the following condition:

$$d_{\text{chord}}(\mathbf{R}^{\text{in}}_{ij}, \mathbf{R}^{\text{in}}_{ik}\mathbf{R}^{\text{in}}_{kj}) < \text{Loop threshold}$$

- **# Triplet supports** = If we propagate away from the base to one of its neighbors, how many other neighbors support its rotation by forming a consistent triplet?



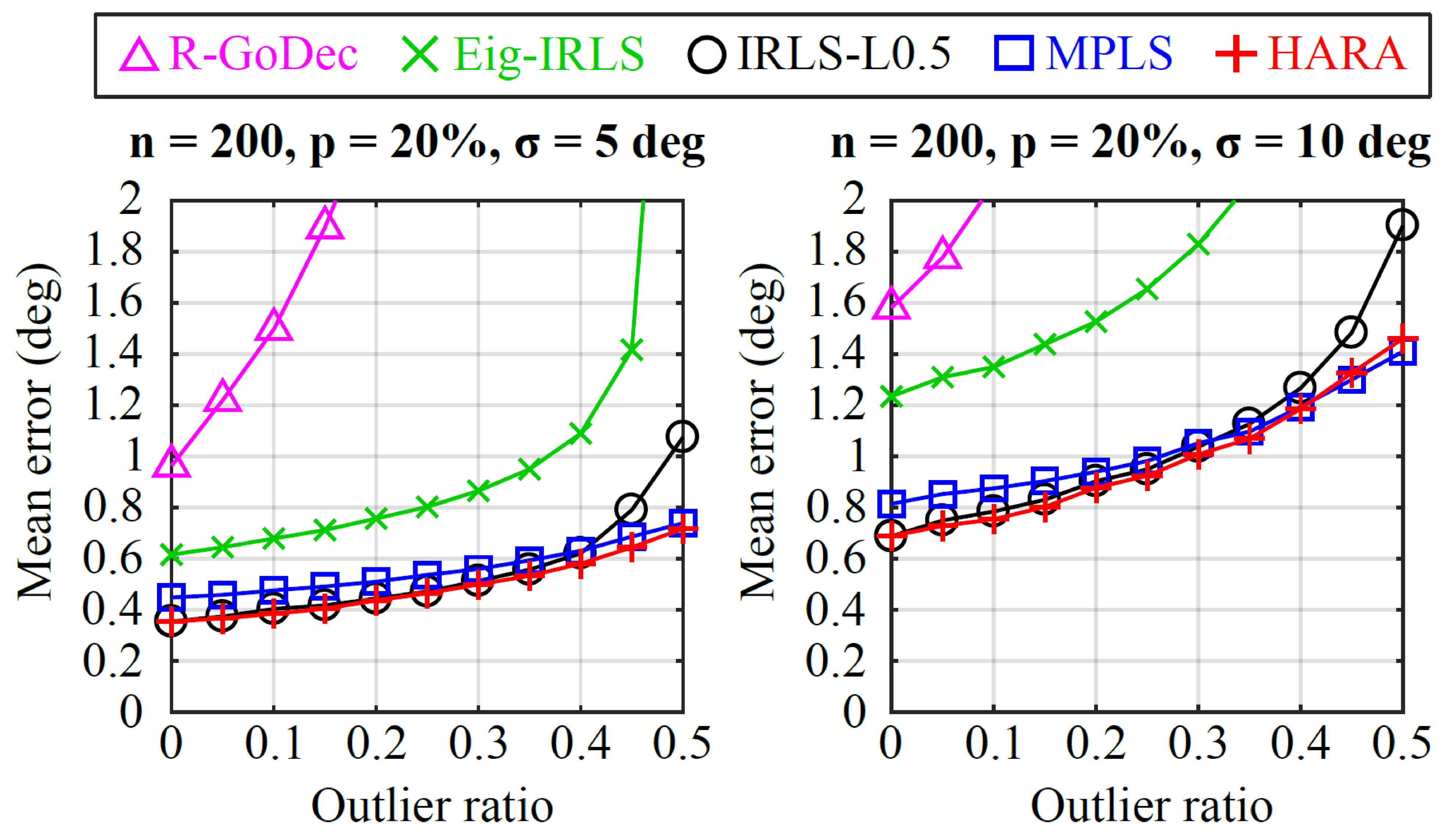
5 has two supports (3, 4, 5), (4, 5, 7)
6 has one support (4, 6, 7)
7 has three supports (3, 4, 7), (4, 5, 7), (4, 6, 7)

4. Hierarchical tree expansion

We alternate between the following two modes of tree expansion:

- **1st mode:** Expand the tree incrementally by adding first the neighbors with many strong triplet supports and later those with gradually weaker and fewer supports.
- **2nd mode:** When none of the family members can branch out (i.e., zero triplet support), add the neighbor that is most connected to the family via single rotation averaging.

5. Results:



Datasets	[IRLS-L0.5]	[MPLS]	HARA
Ellis Island	2.9	2.8	**2.1**
Madrid MTP	7.0	5.2	**4.8**
Notre Dame	3.5	2.7	**1.6**
Trafalgar	3.6	4.5	**3.5**
San Francisco	**3.6**	4.4	**3.6**

Mean error (deg) after L1 alignment

References

[R-GoDec, Eig-IRLS] F. Arrigoni et al., Robust synchronization in SO(3) and SE(3) via low-rank and sparse matrix decomposition, CVIU 2018.

[IRLS-0.5] A. Chatterjee and V. M. Govindu, Robust relative rotation averaging, TPAMI 2018.

[MPLS] Y. Shi and G. Lerman, Message passing least squares framework and its application to rotation synchronization, ICML 2020.