



# Visual Localization based on Binary Features

Diploma Thesis Final Presentation

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and Dipl.-Ing. Georg Schroth

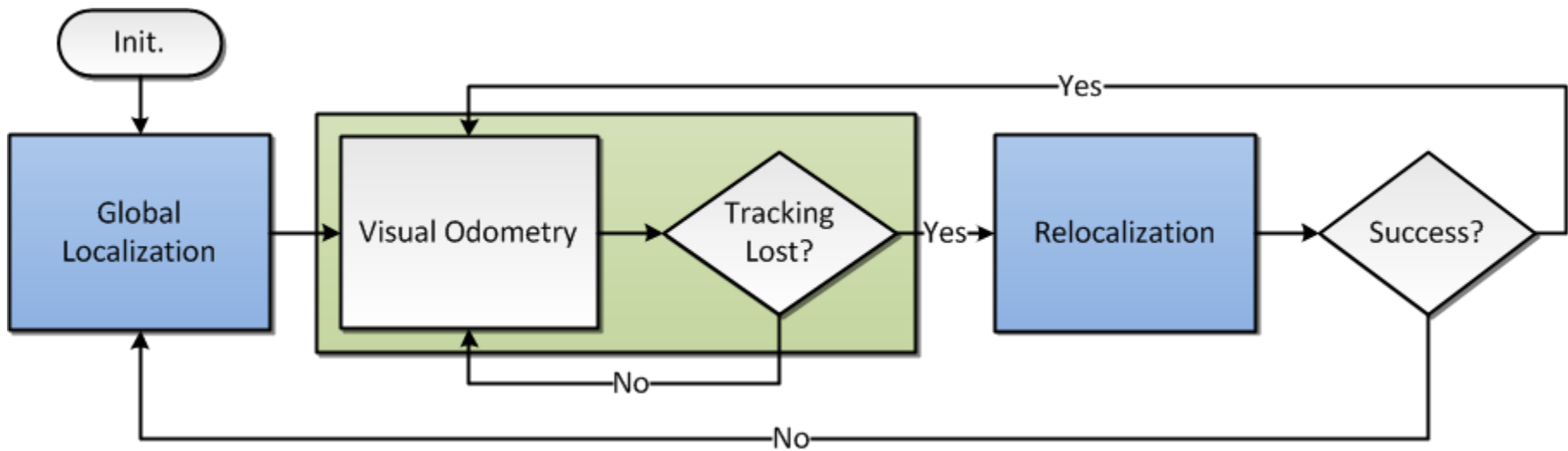
High accuracy possible

Low dependence on infrastructure

Binary features are very efficient

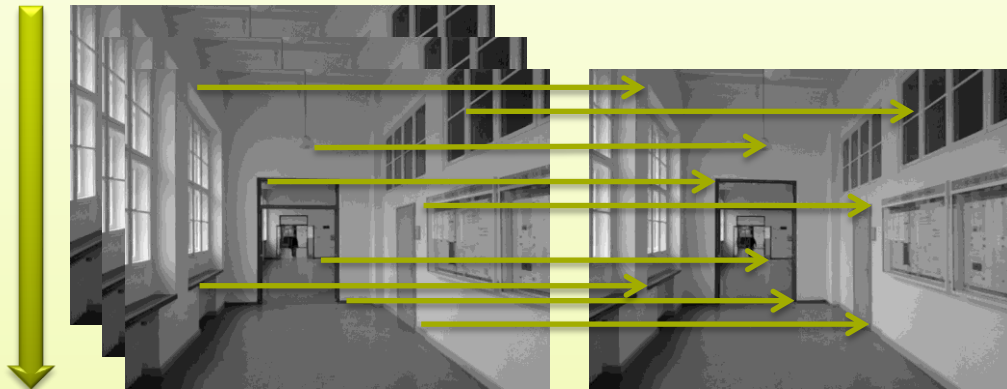


# Visual Localization System Overview



# Parallel Tracking and Mapping (PTAM)

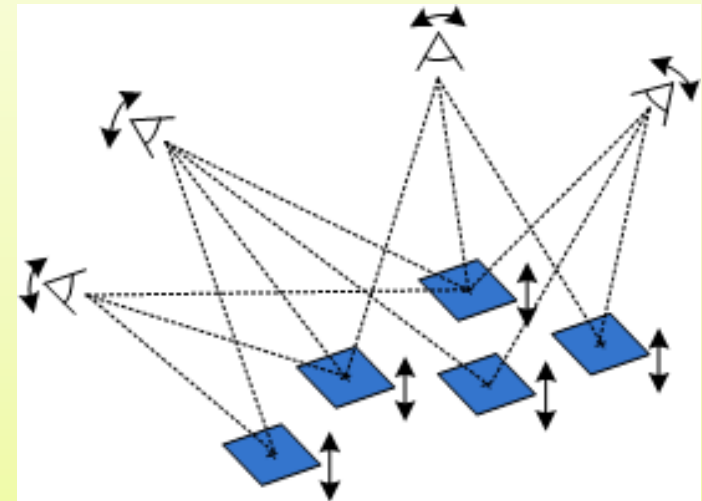
Frame-to-frame tracking



Pose refinement using 2D-3D point correspondences

Tracking thread

Bundle Adjustment of keyframes



Mapping thread

# PTAM Tracking Failure

Frame-to-frame tracking



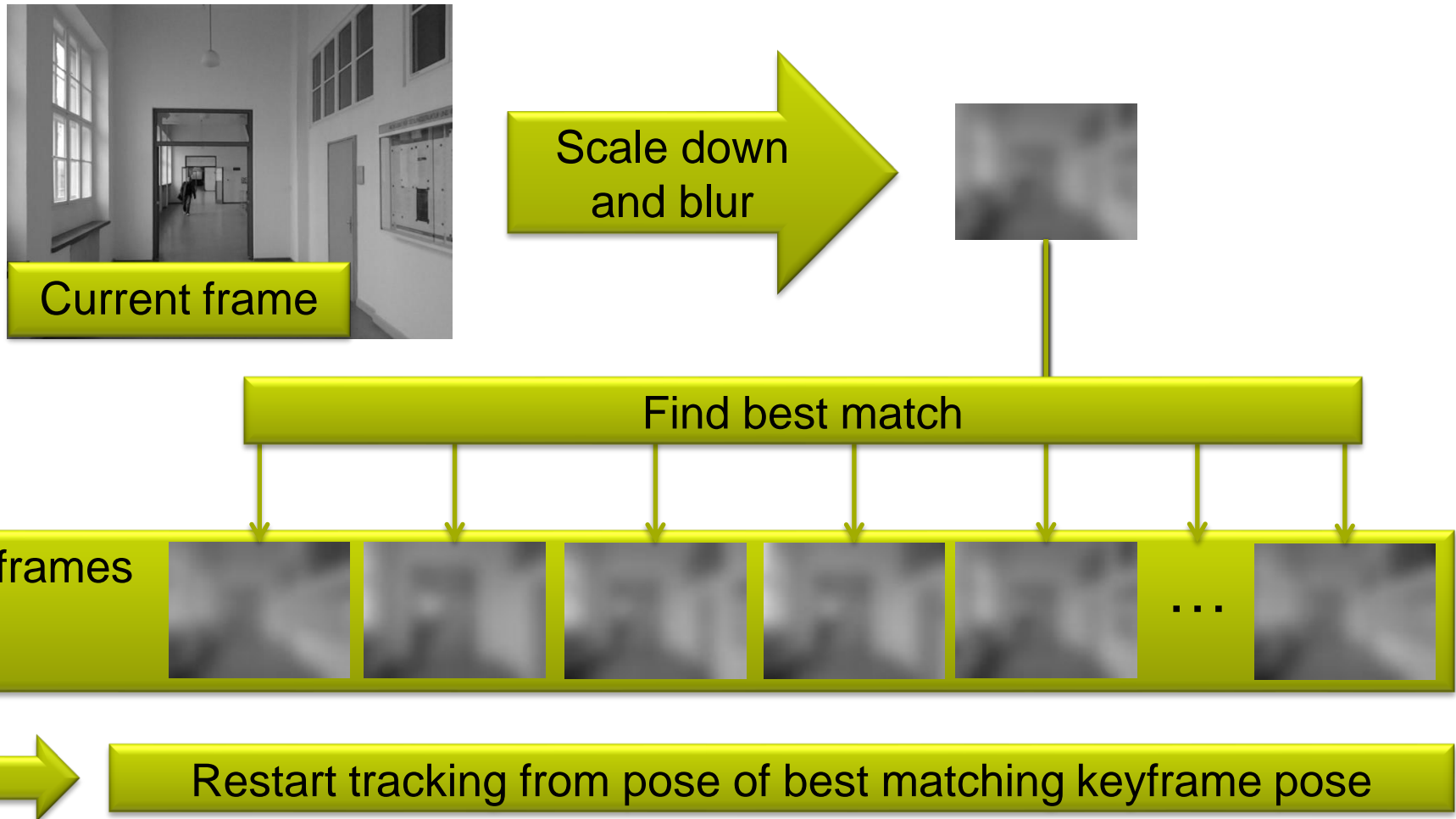
Pose refinement using 2D-3D point correspondences

- Motion blur
- Fast rotations
- Rapid lighting changes

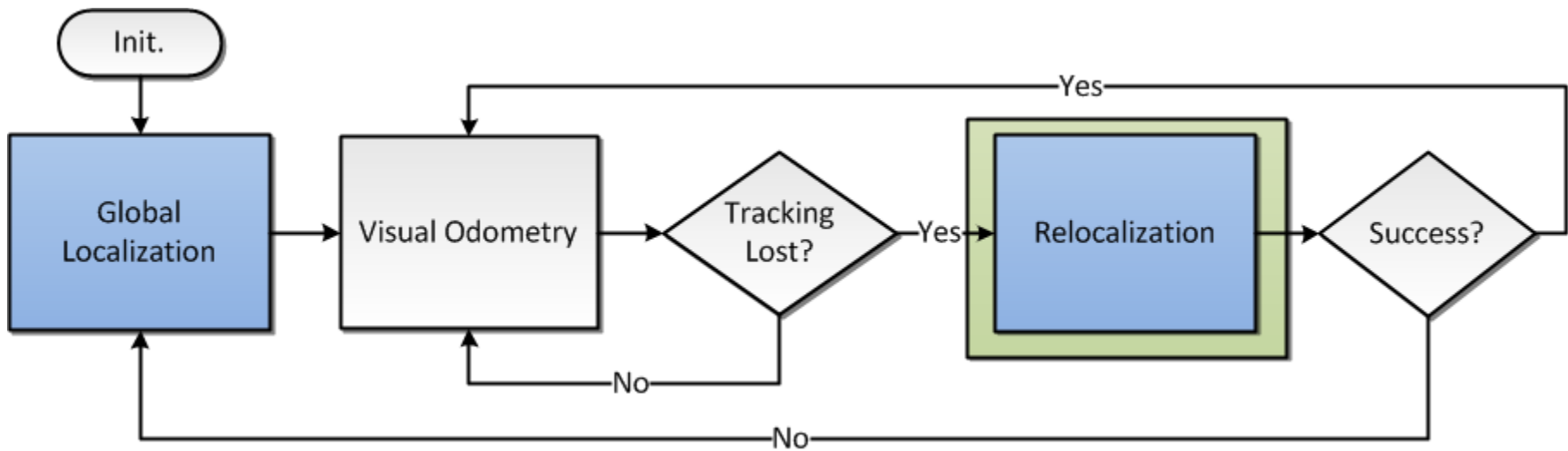


Loss of pose estimate

# PTAM's built-in Relocalization Algorithm

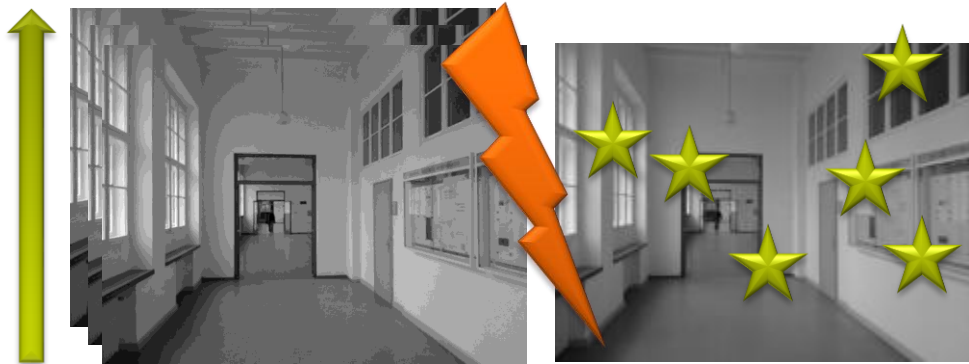


# Visual Localization System Overview



# Relocalization Strategy using Binary Features

Frame-to-frame tracking



Robust Levenberg Marquardt algorithm  
for pose refinement

Progressive Sample Consensus  
(PROSAC) for pose recovery

Extract  
binary  
features

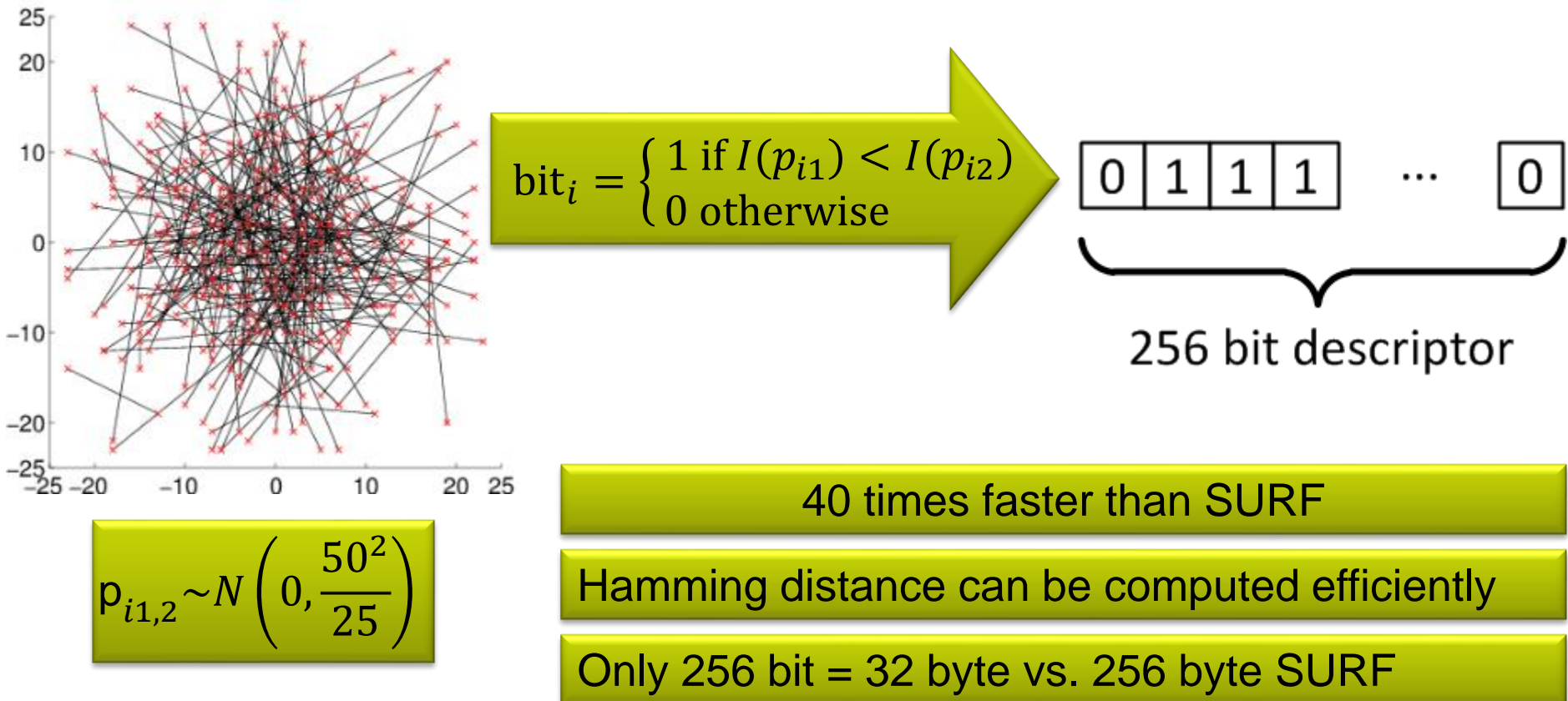
Map  
features

Locality-Sensitive  
Hashing (LSH)

2D-3D point  
correspondences

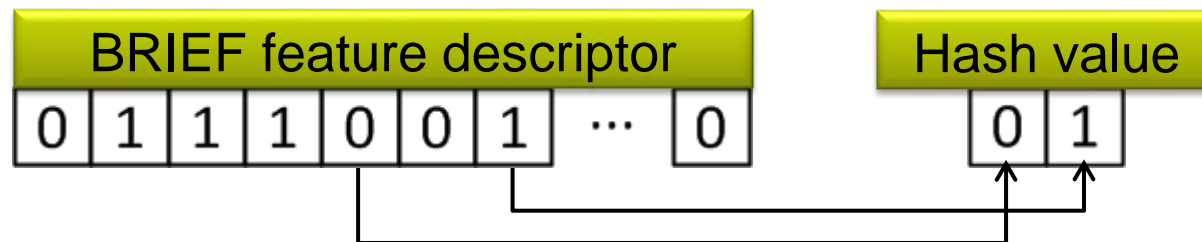


# Binary Robust Features (BRIEF)



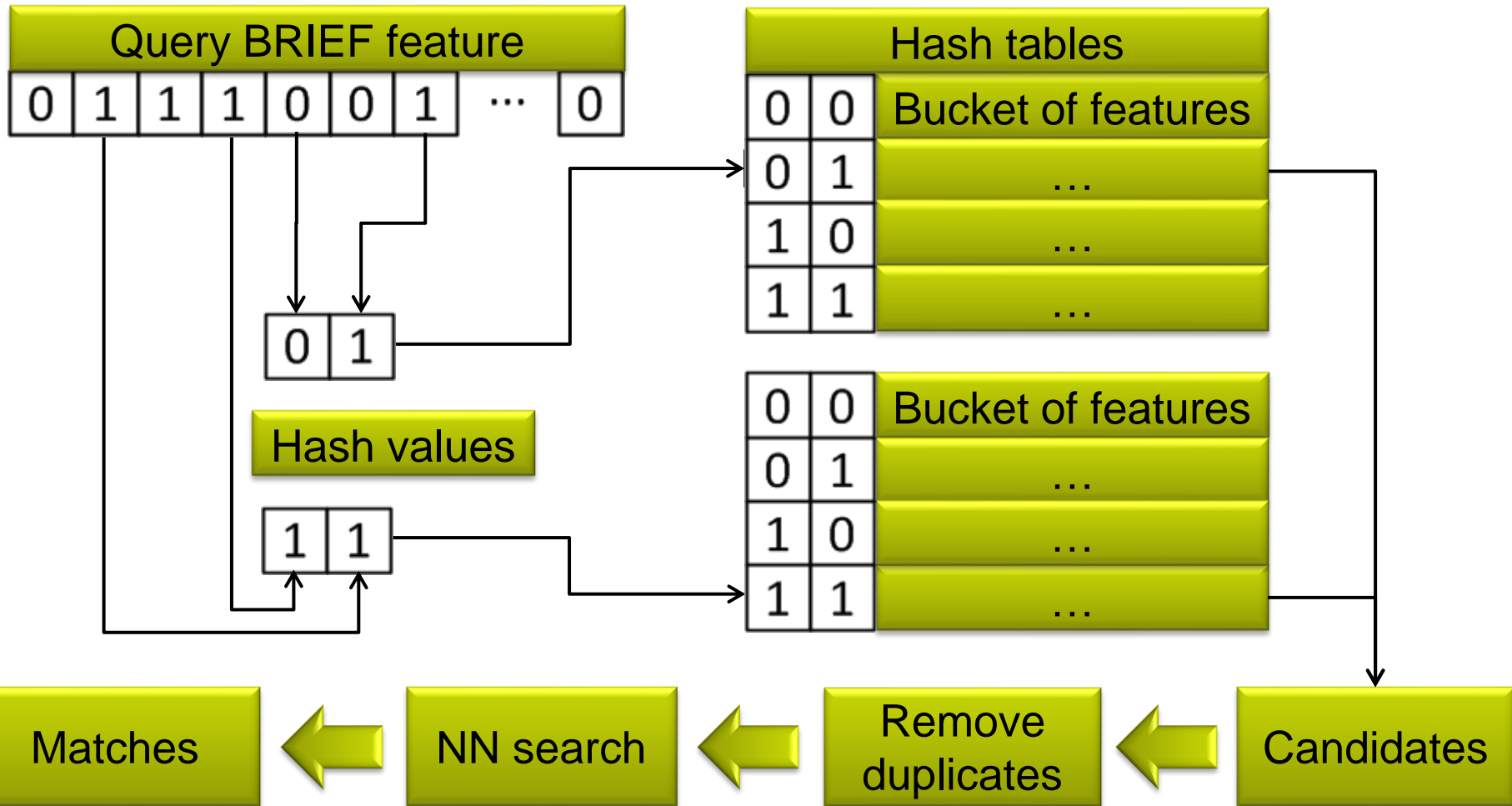
# Locality-Sensitive Hashing (LSH)

- Use hashing for approximate Nearest Neighbour (NN) search
- Hash function: look at  $m$  randomly selected bit positions in the BRIEF descriptor

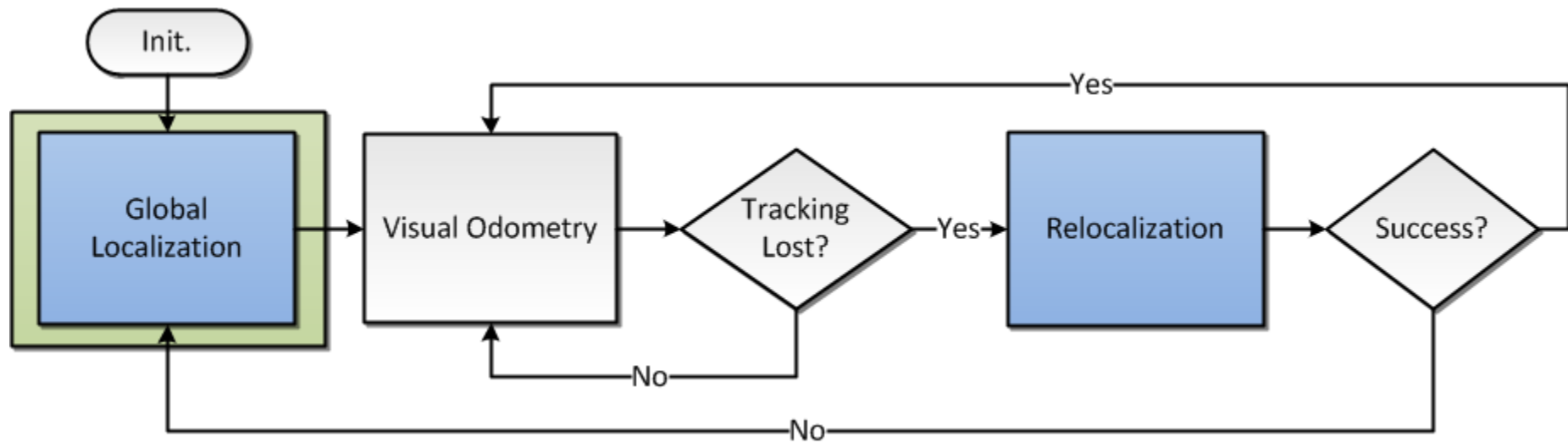


- Use  $l$  hash tables to improve probability to find true NN

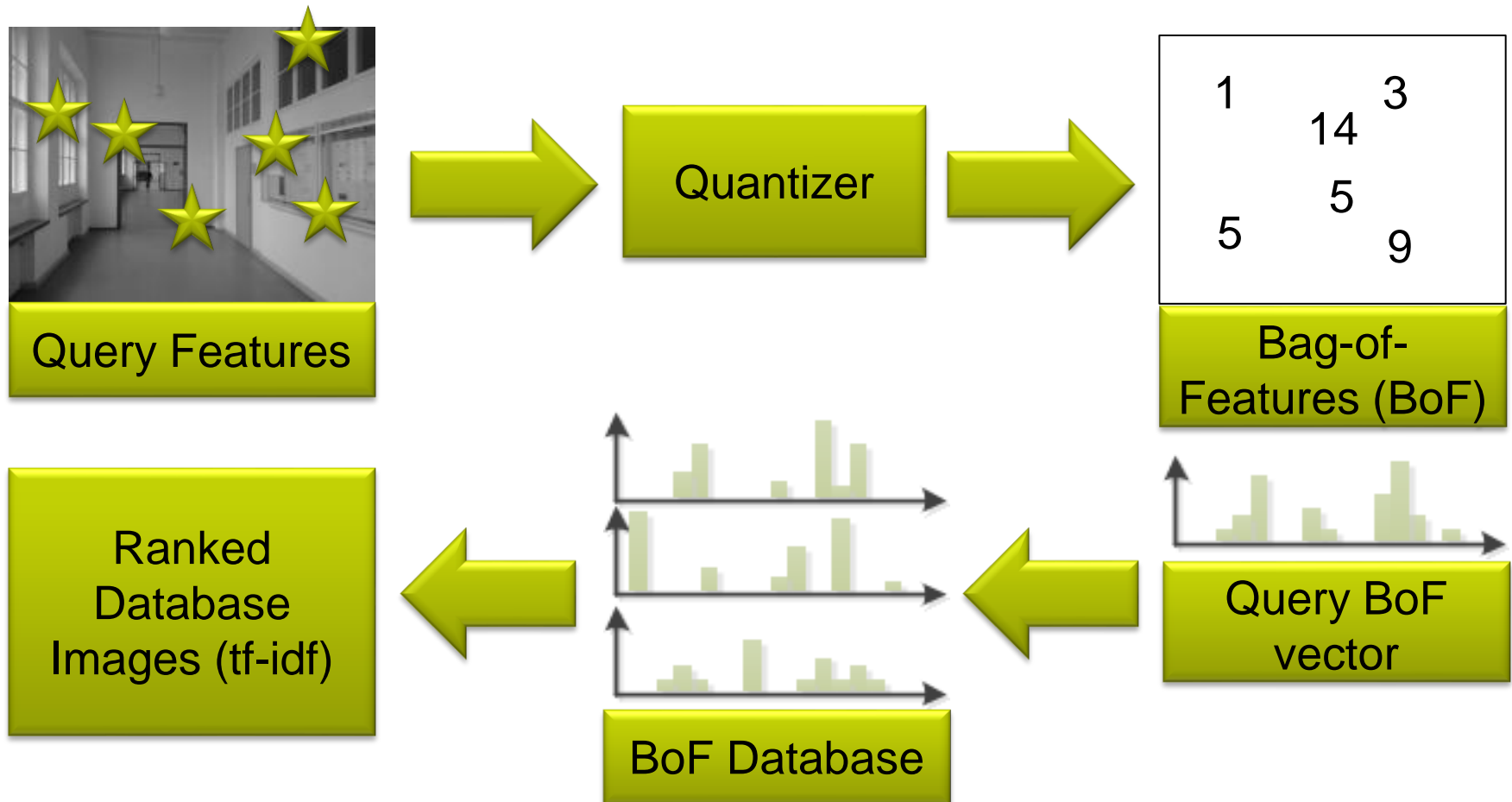
# LSH Query



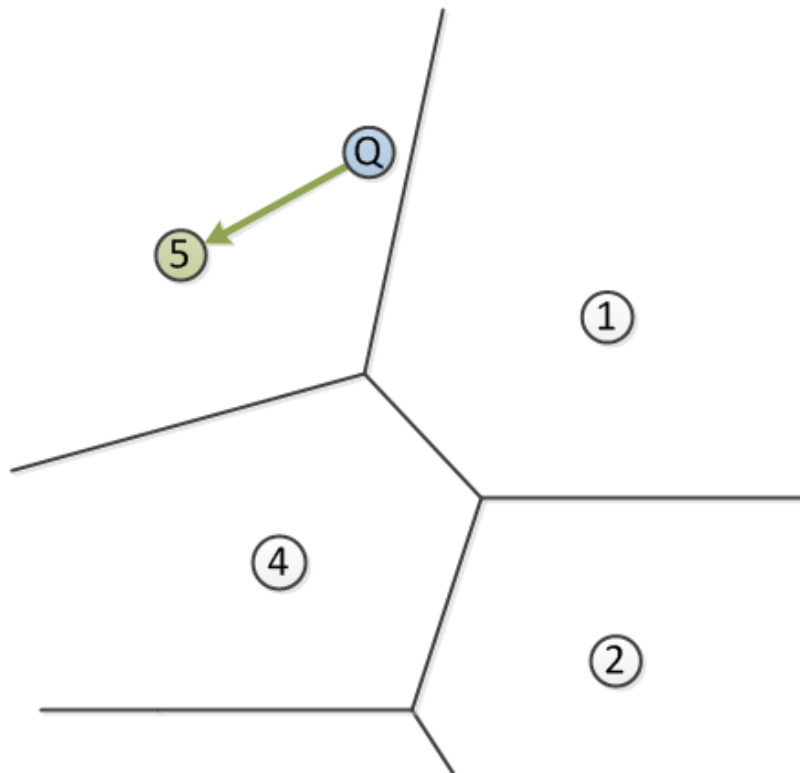
# Visual Localization System Overview



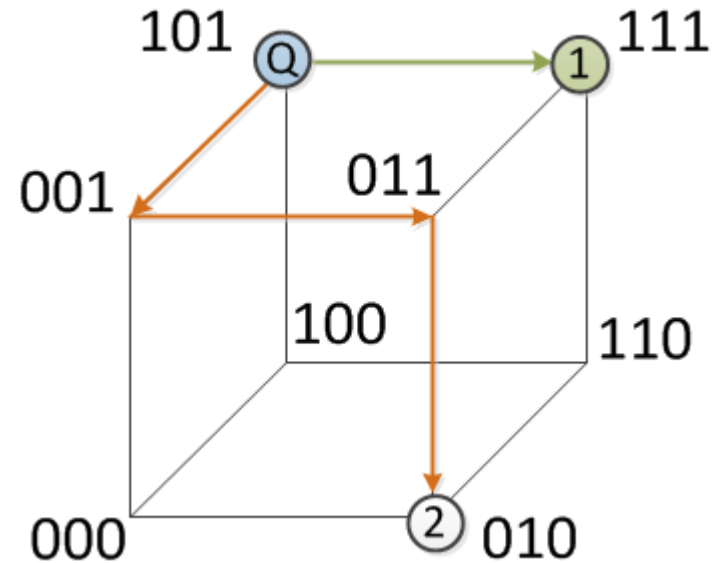
# Content-based Image Retrieval (CBIR)



# Quantizer for Binary Features



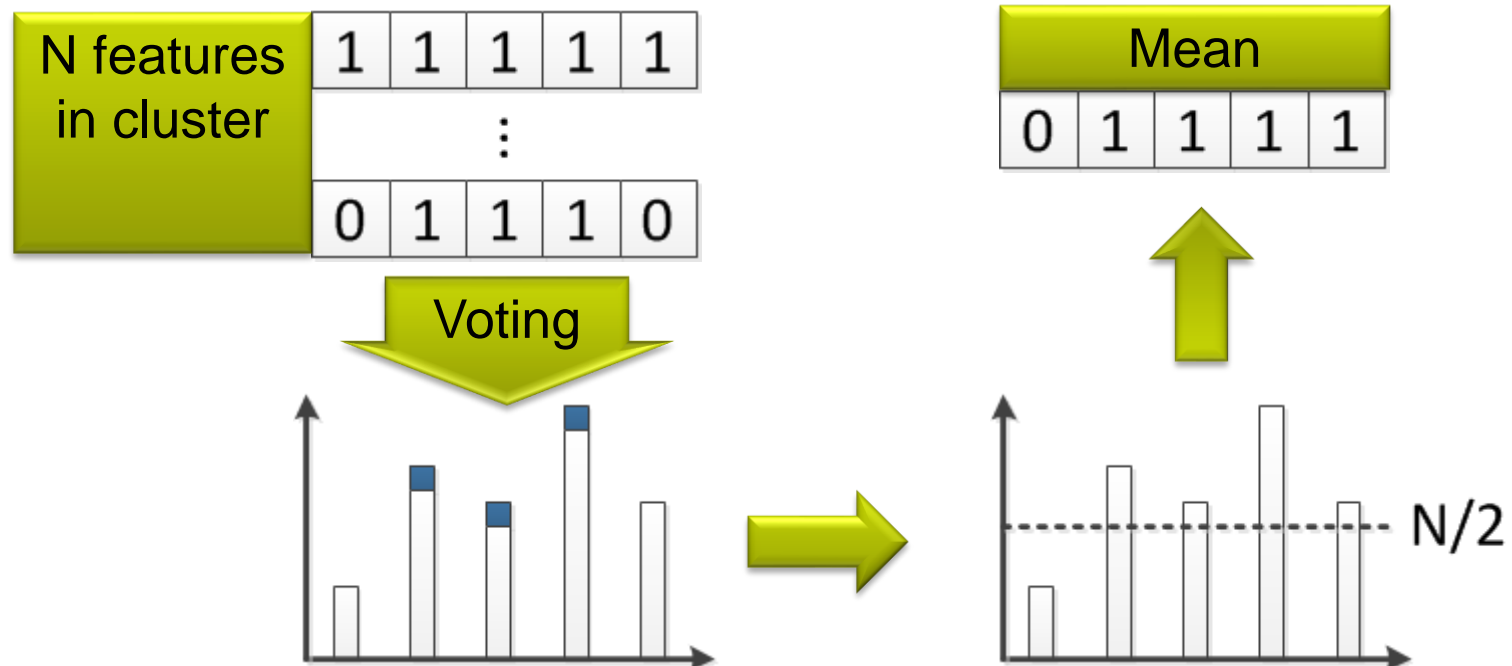
Centroid ID = visual word ID



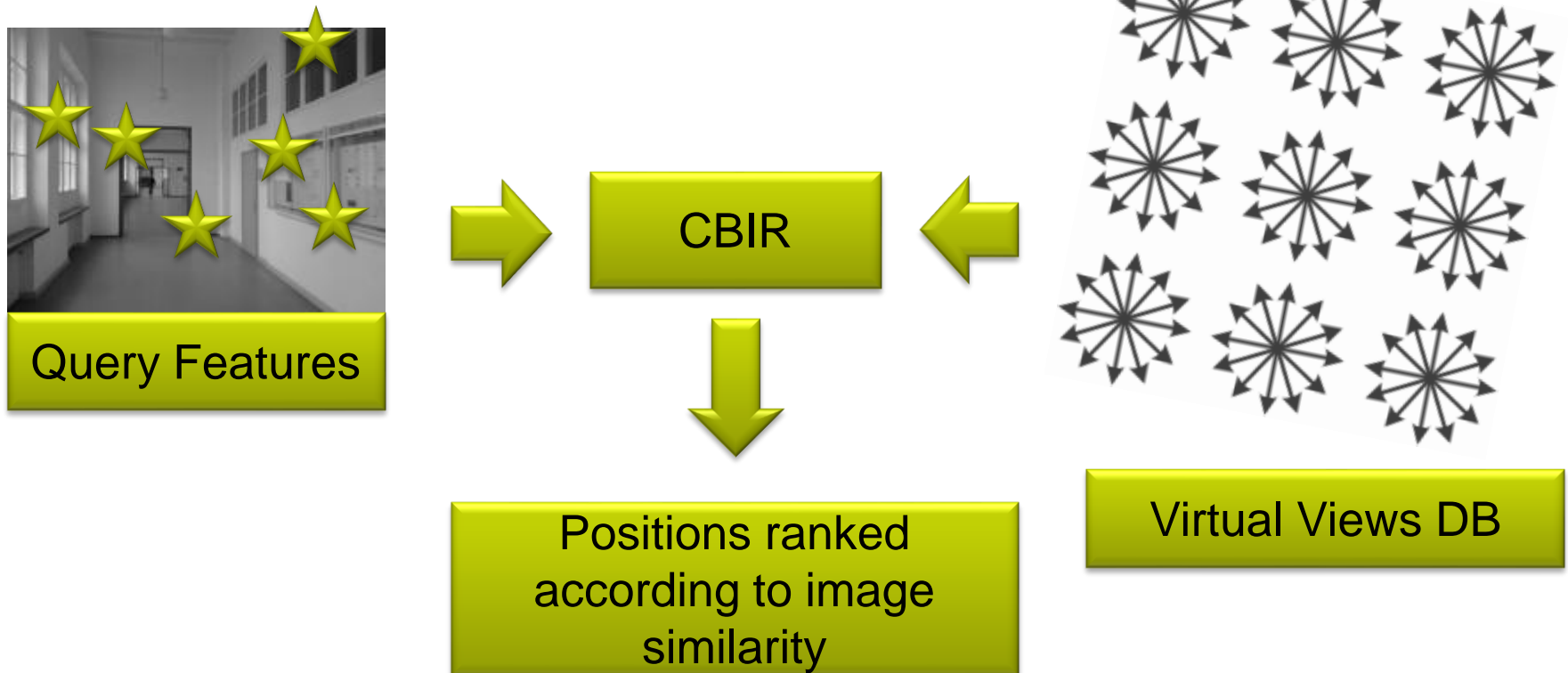
LSH to get closest centroid to a query feature Q

# k-Binary Means Clustering

1. Initialize k means from random features
2. Assign features to closest mean (Hamming distance)
3. Recompute means and go back to 2. if not converged



# CBIR from Virtual Views DB for Localization



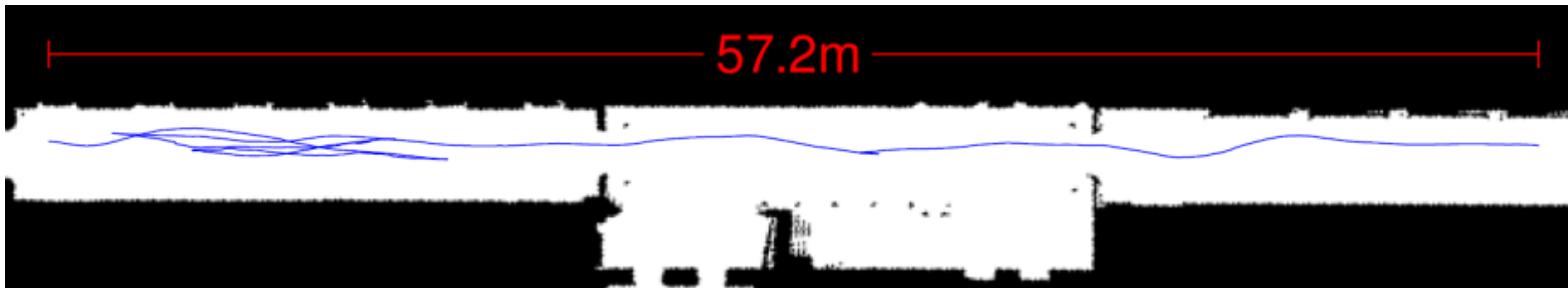


# Dataset for Relocalization Evaluation

Datalogger Application for Android for  
video and IMU data collection

Tablet mounted on Trolley to get  
groundtruth trajectory

Trajectory of 100m and 8:01min length



# LSH Parameters for Relocalization in 15k Features

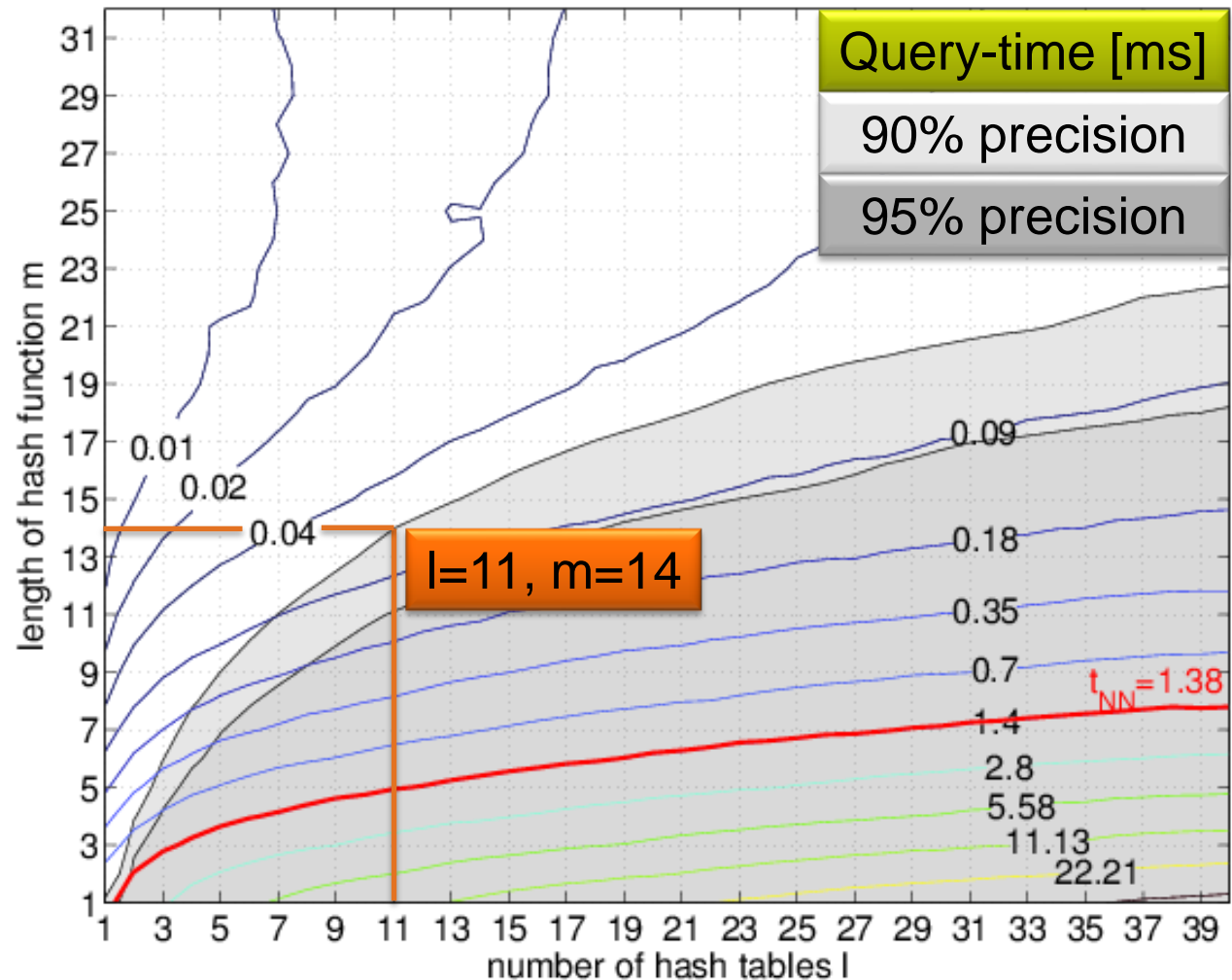
90% precision

59  $\mu$ s per query

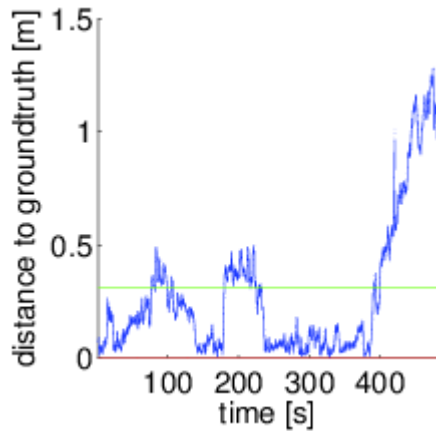


23x faster than NN

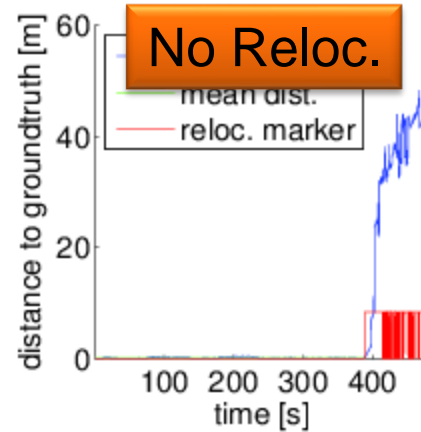
4.4 MiB memory consumption



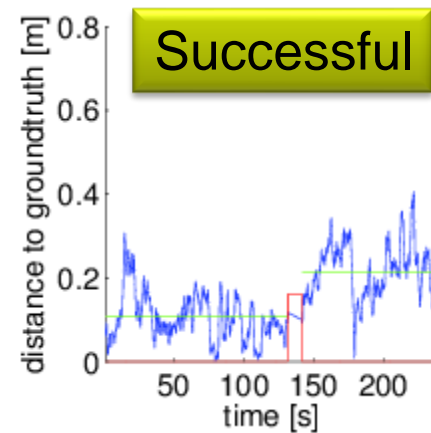
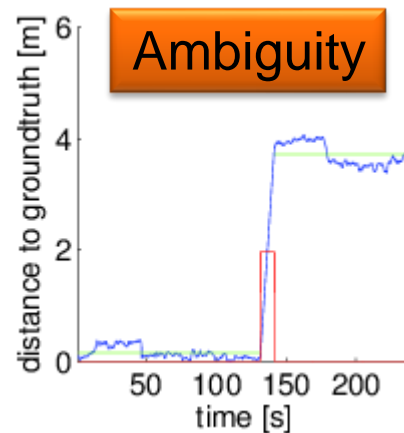
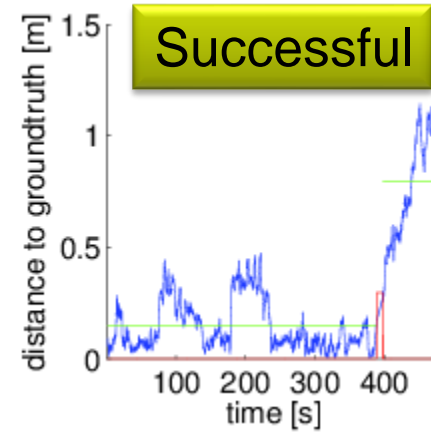
## No Relocalization



## Relocalization using keyframes



## Relocalization using BRIEF

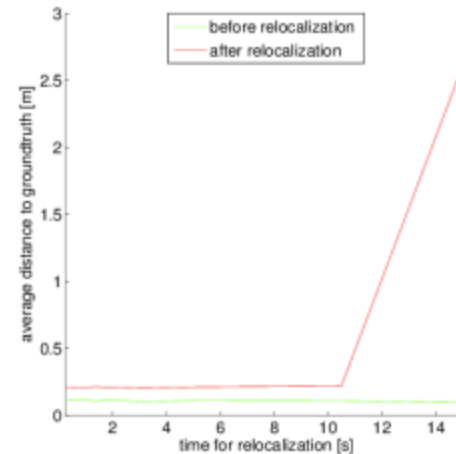
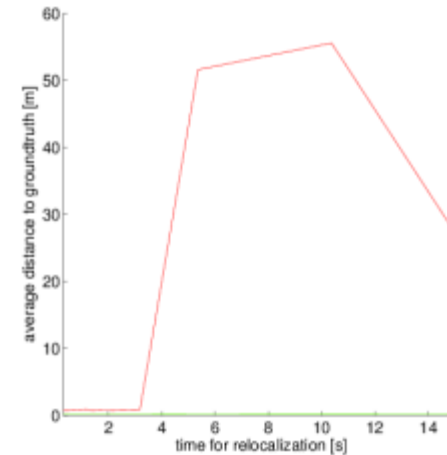


# Relocalization Timing

Average Duration of Relocalization:  
169ms

Time for extraction of the same  
number of SURF features: 450ms

## Impact of Relocalization delay on Accuracy



# Relocalization while Walking Straight

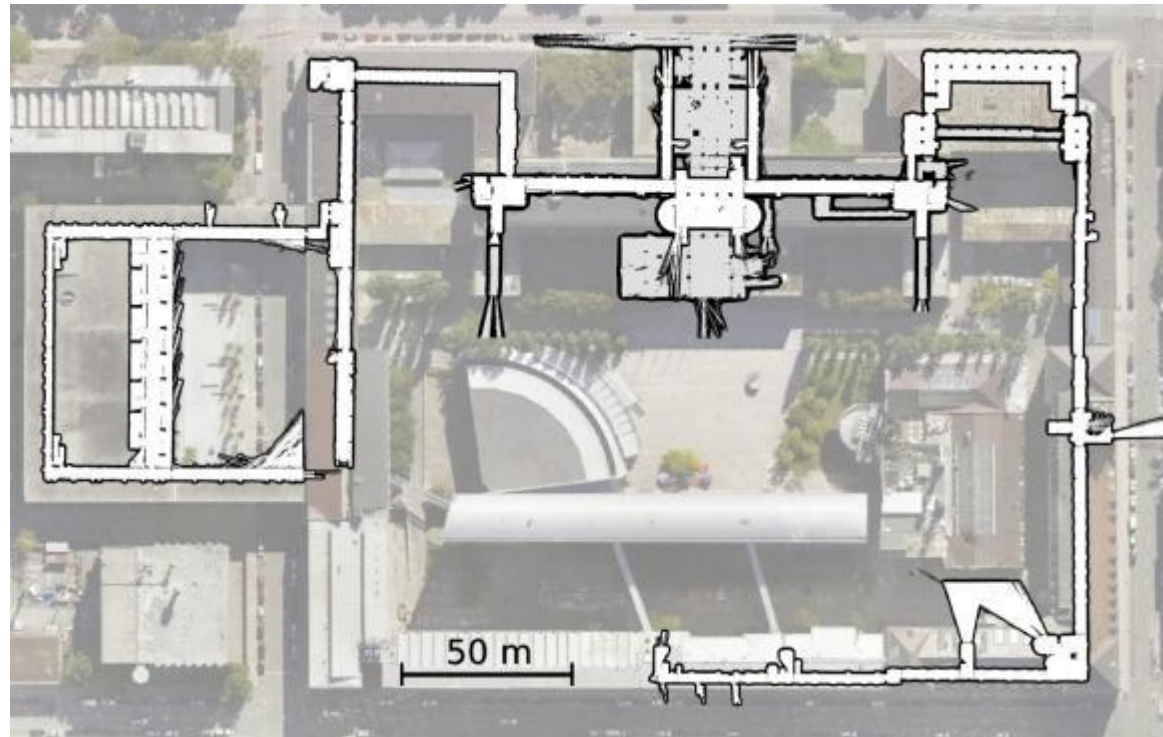


NAVIS

# Dataset for Large Scale Localization Evaluation

100k virtual views from  
TUMindoor dataset with  
35M BRIEF features

252 query images at known  
positions



# LSH Parameters for 200k kBM Quantizer for CBIR

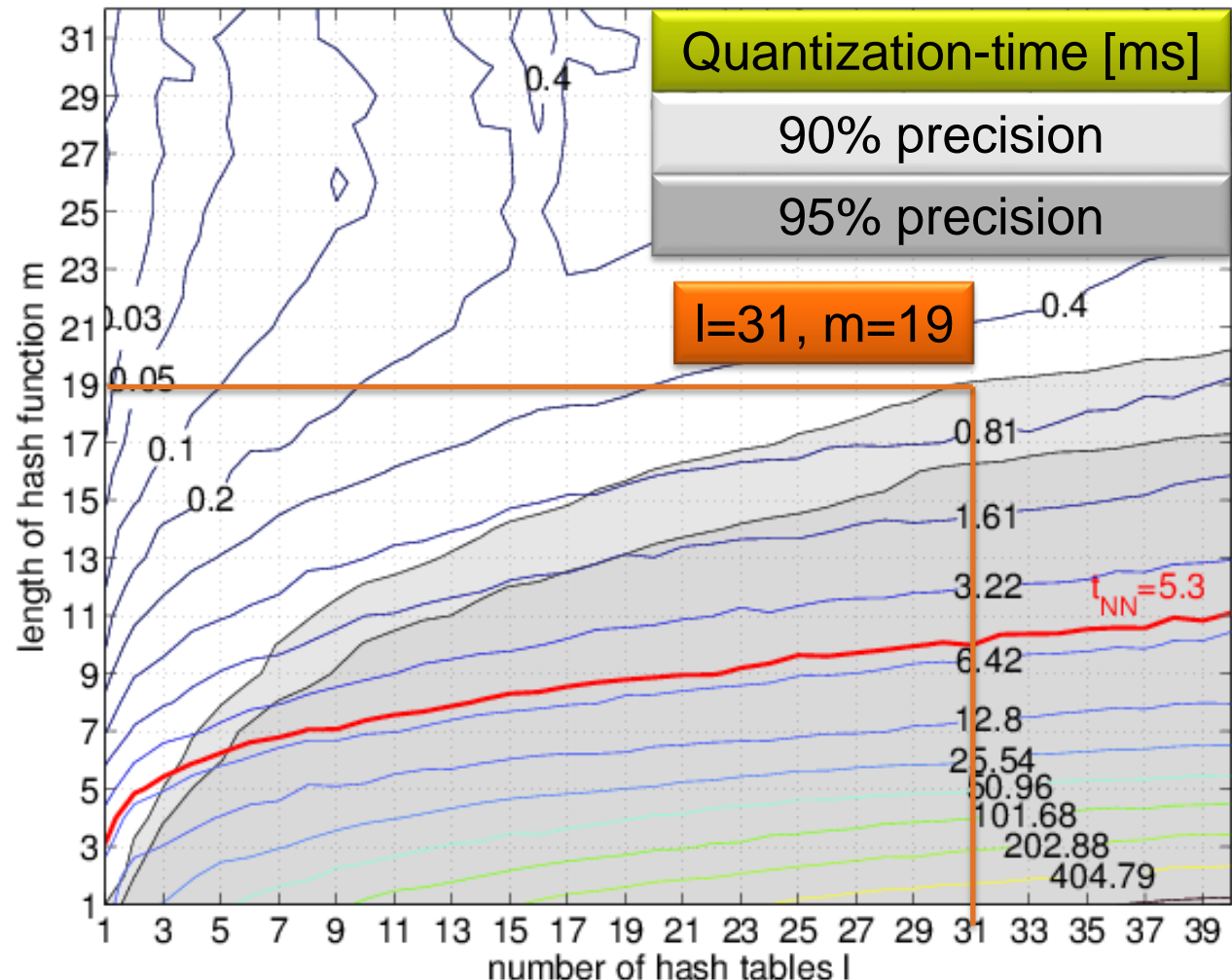
90% precision

560  $\mu$ s per query



9x faster than NN

142 MiB memory consumption



# Virtual Views CBIR

Duration of kBM clustering

200k quantizer: 4.5 h

500k quantizer: 13.5 h

Quantization time per BRIEF

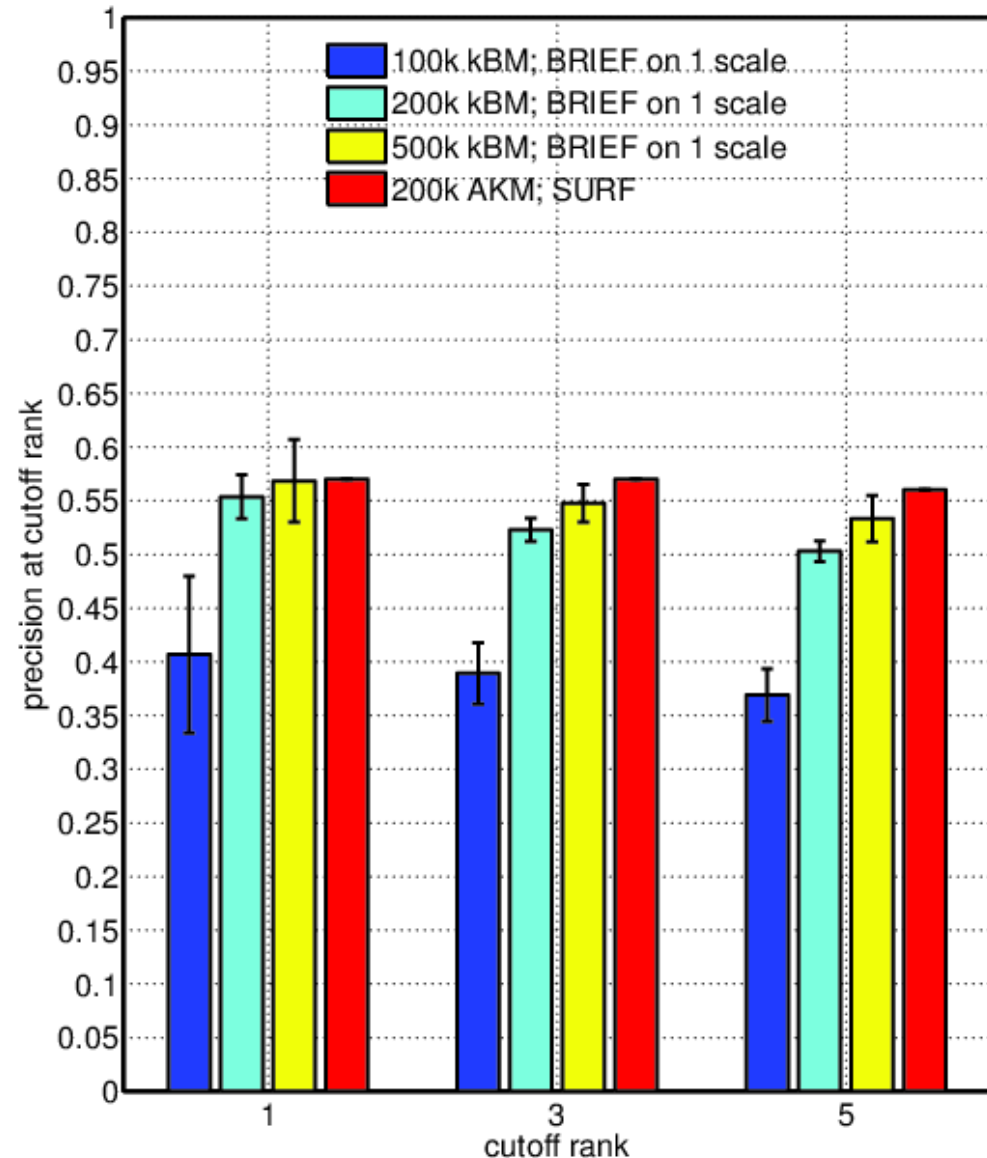
200k quantizer: 0.37 ms

500k quantizer: 0.90 ms

Storage on disk

200k quantizer: 6.2 MB

500k quantizer: 16 MB





# Conclusion

## Relocalization based on BRIEF

169 ms – 2x as fast as solely  
extracting the same number of  
SURF features

Robust in indoor environments

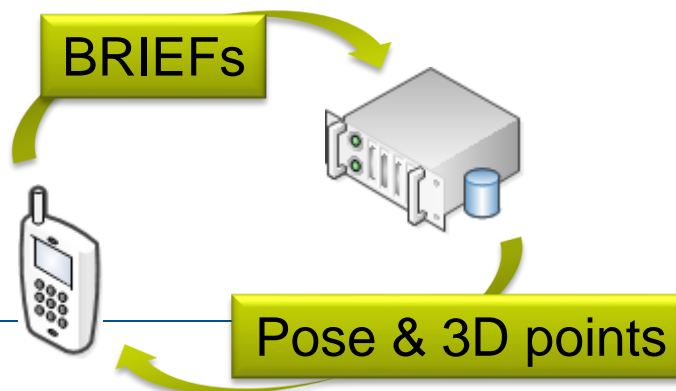
## kBM quantizer for CBIR

Virtual Views Localization  
Partial Vocabularies

BRIEF features enable fast localization without sacrificing accuracy

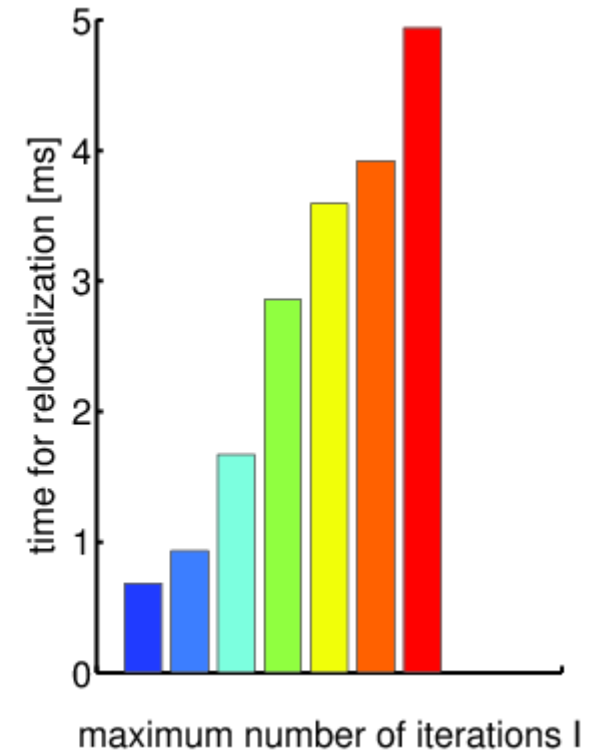
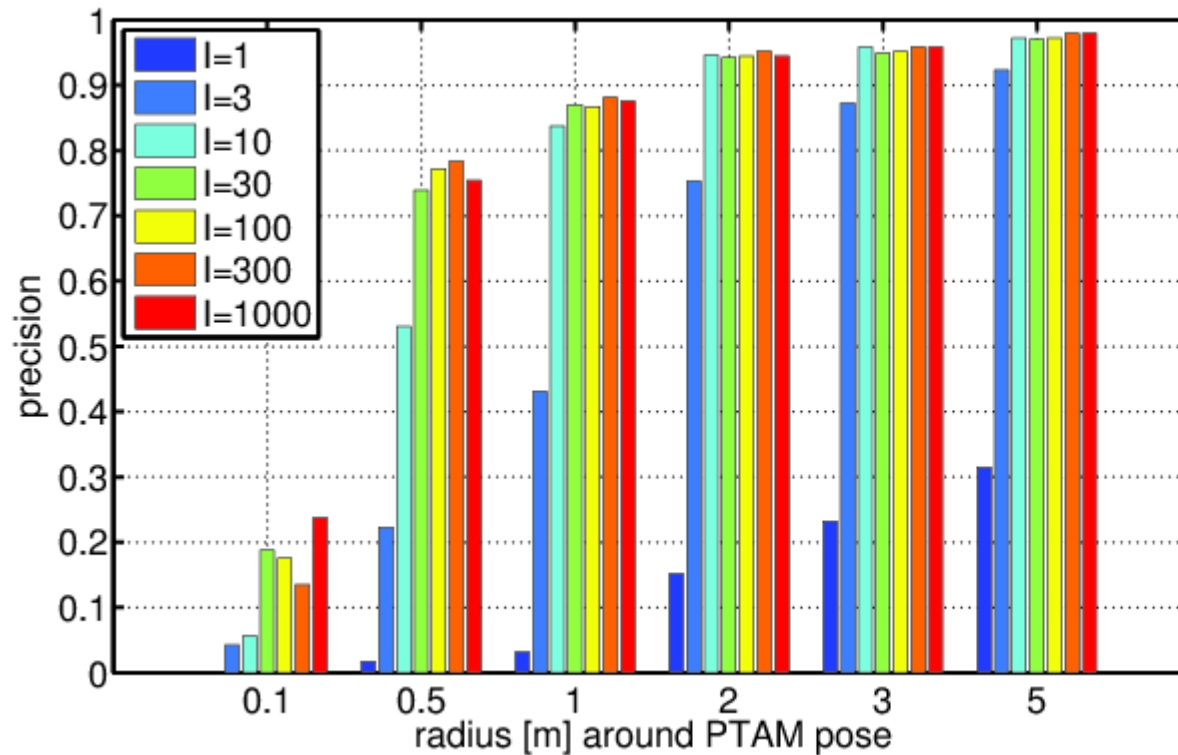
# Outlook

Global localization and PTAM  
initialization from Server

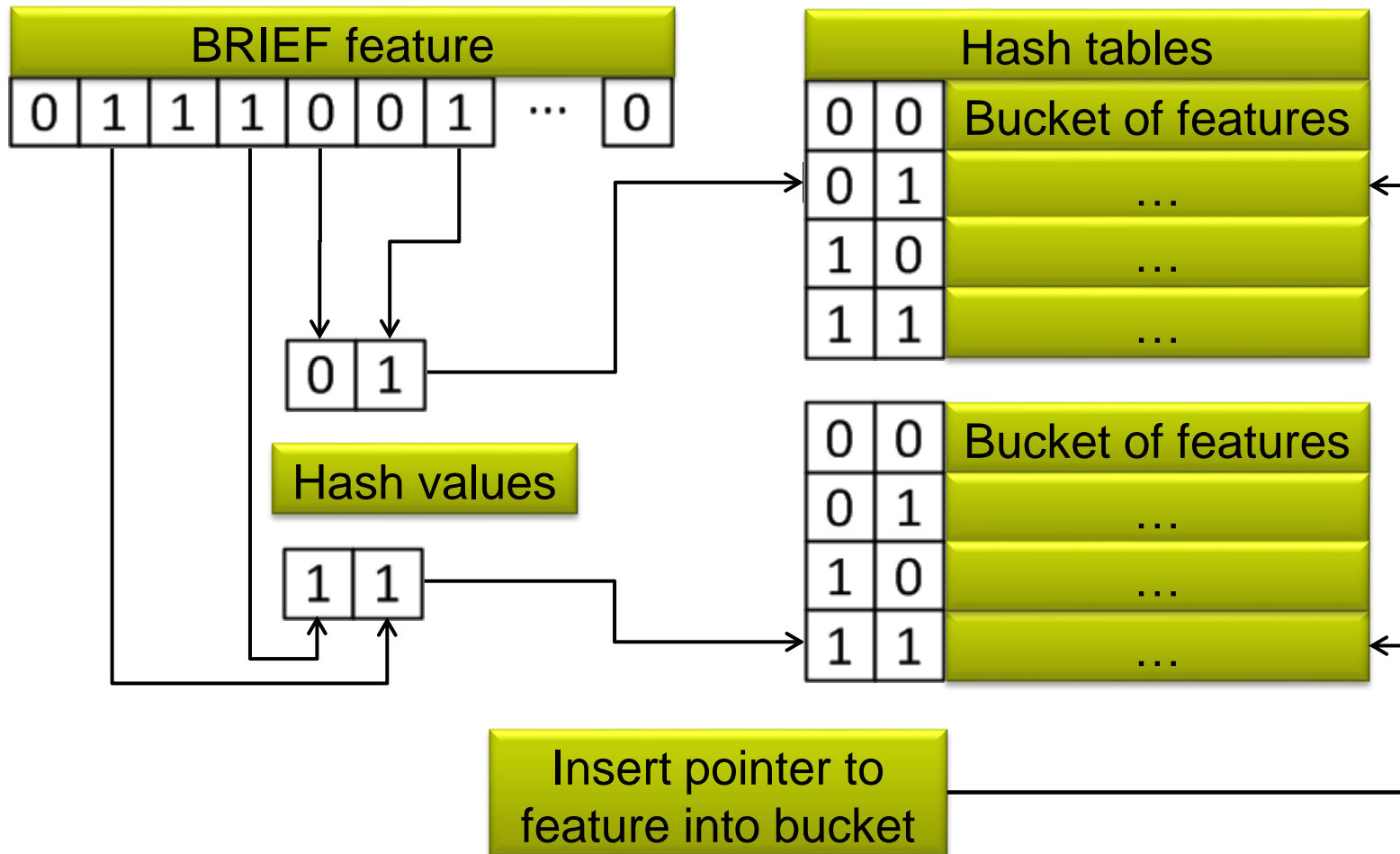




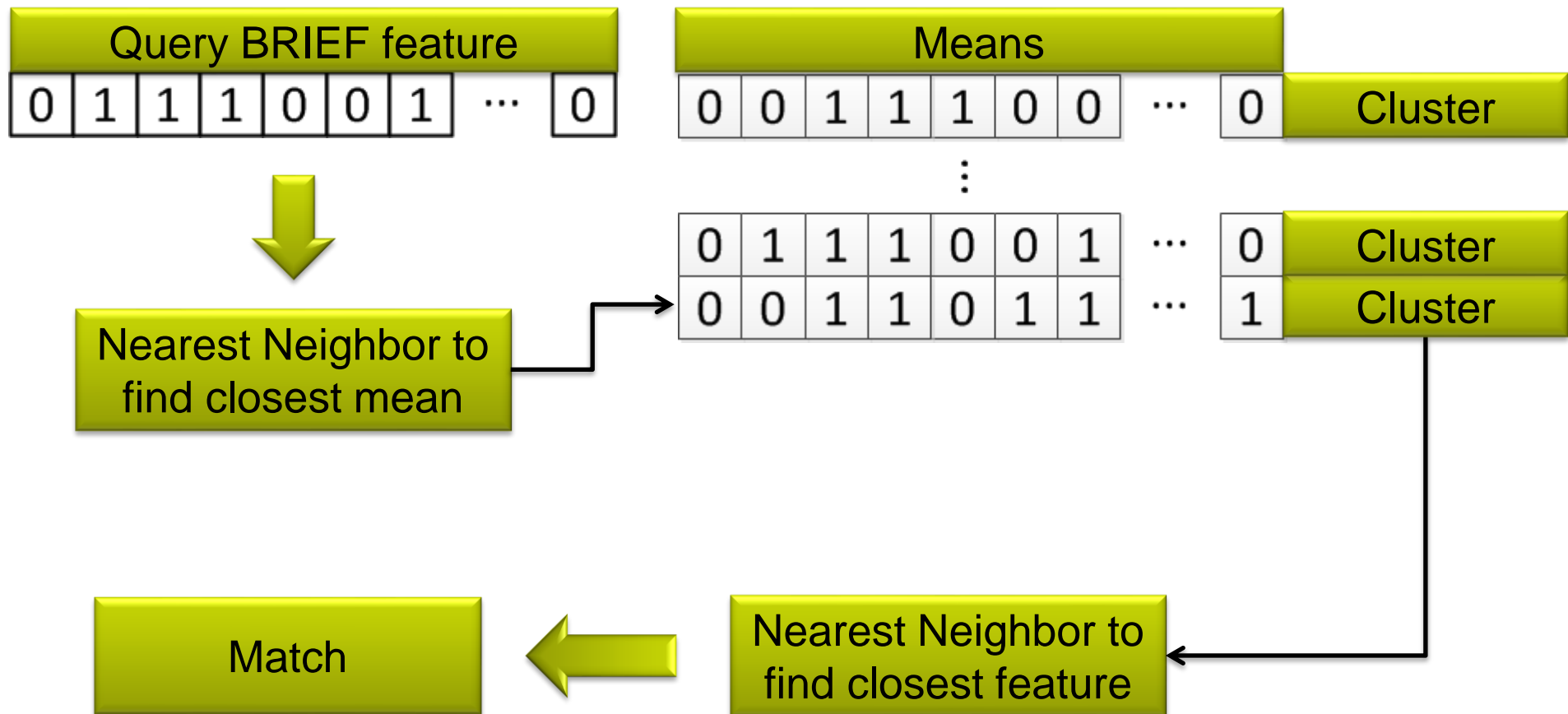
# PROSAC Precision and Timing



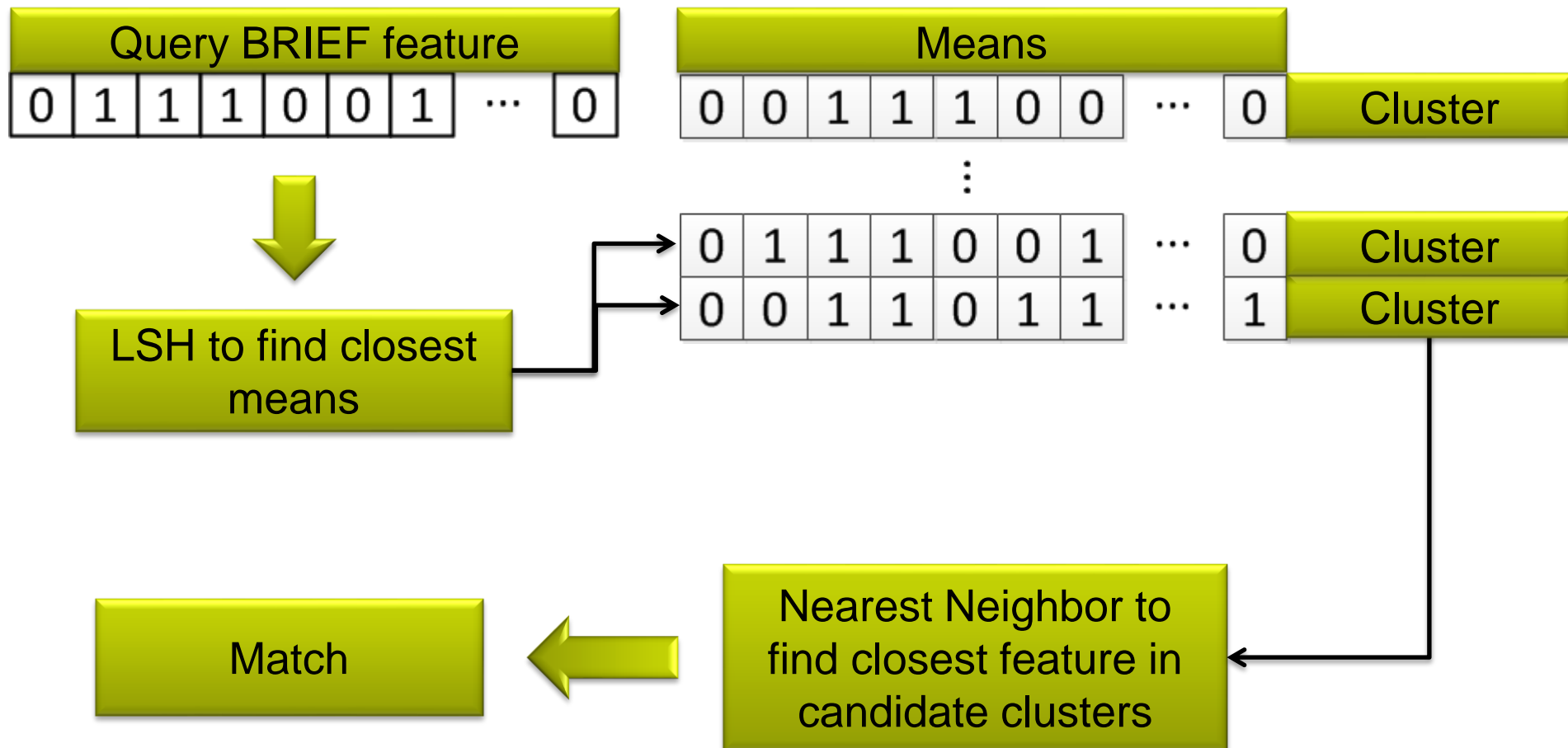
# LSH - Building the Hash Tables



# Nearest Neighbour k-Binary Means Query



# LSH k-Binary Means Query



# Relocalization Within Explored Territory



NAVVIS

# Conclusion

- BRIEF Feature based relocalization presents significant improvement over PTAM's built-in relocalization mechanism.
- BRIEF Feature based relocalization is twice as fast as solely extracting the same number of SURF features
- Novel kBM quantizer for visual word creation from binary features for CBIR

# Outlook

Global localization and PTAM initialization from Server

