Scalable Monocular SLAM

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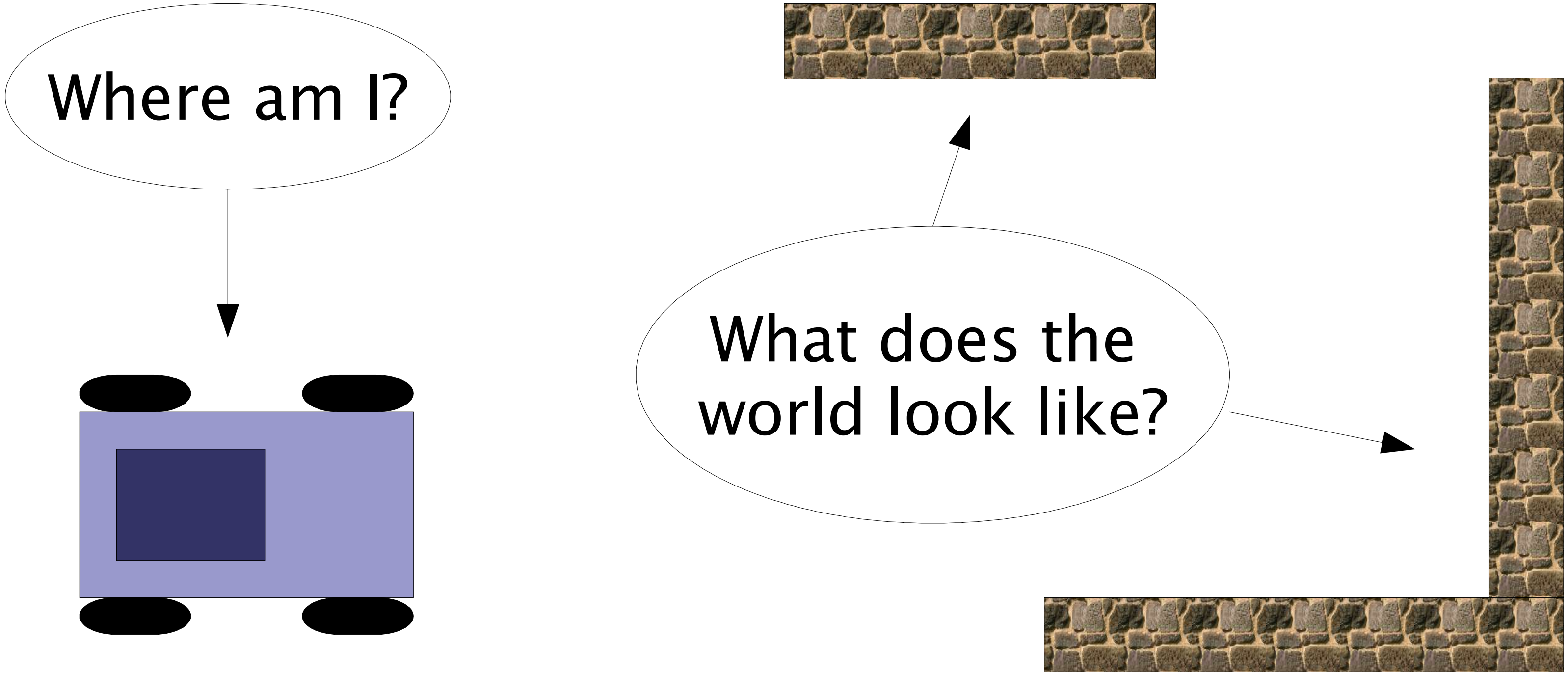
Simultaneous Localization and Mapping

Goal: Estimate structure and motion online.



Simultaneous Localization and Mapping

Goal: Estimate structure and motion online.

Causal

Only observations up to the current time are available

Time–Bounded

Each processing step must complete in limited time

Contributions

Application of
Rao-Blackwellized Particle Filtering:
Frame-rate monocular SLAM
with hundreds of landmarks

Novel Partial Initialization Algorithm:

- Efficient estimation for new landmarks
- Use of new landmark observations to constrain pose

Conventional Approach: Kalman Filter SLAM

State Estimate

Gaussian for pose and landmarks

$O(N^2)$ space for N landmarks

Filter Update

Linearized Models

Full covariance is updated

$O(N^2)$ time

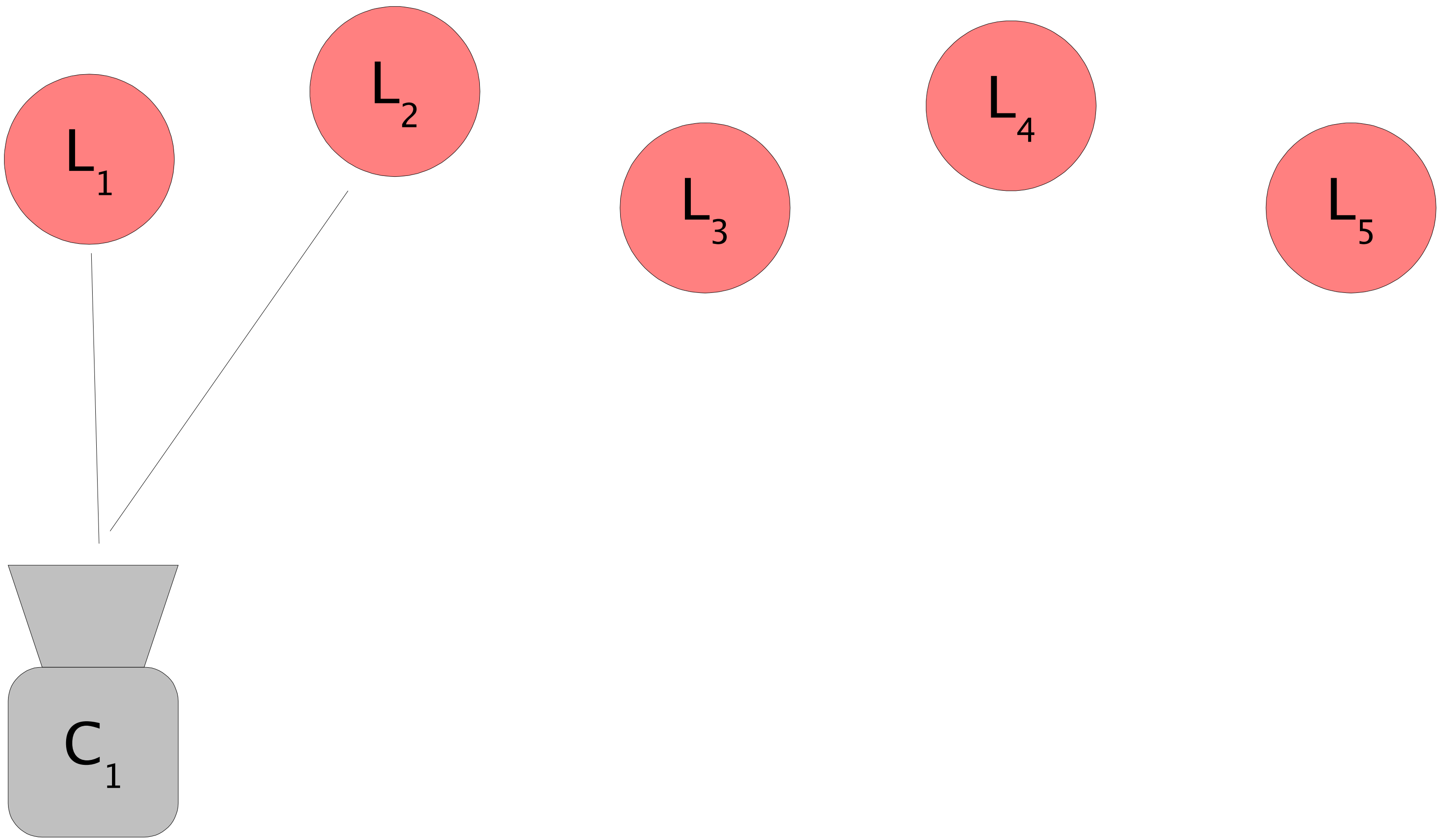
Gaussian Prior

Gaussian Likelihood

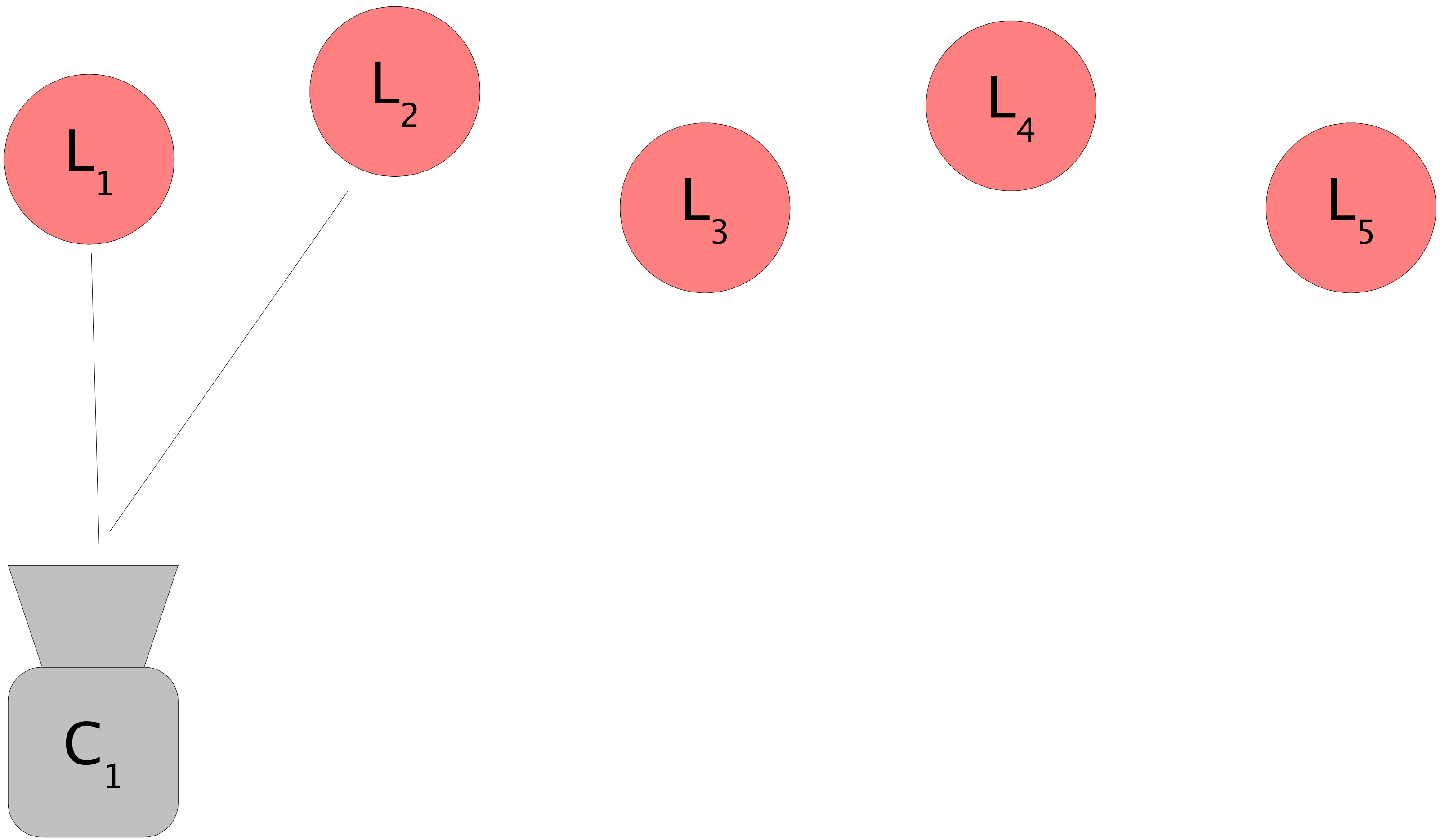
EKF

Gaussian Posterior

Landmark Dependence



Landmark Dependence



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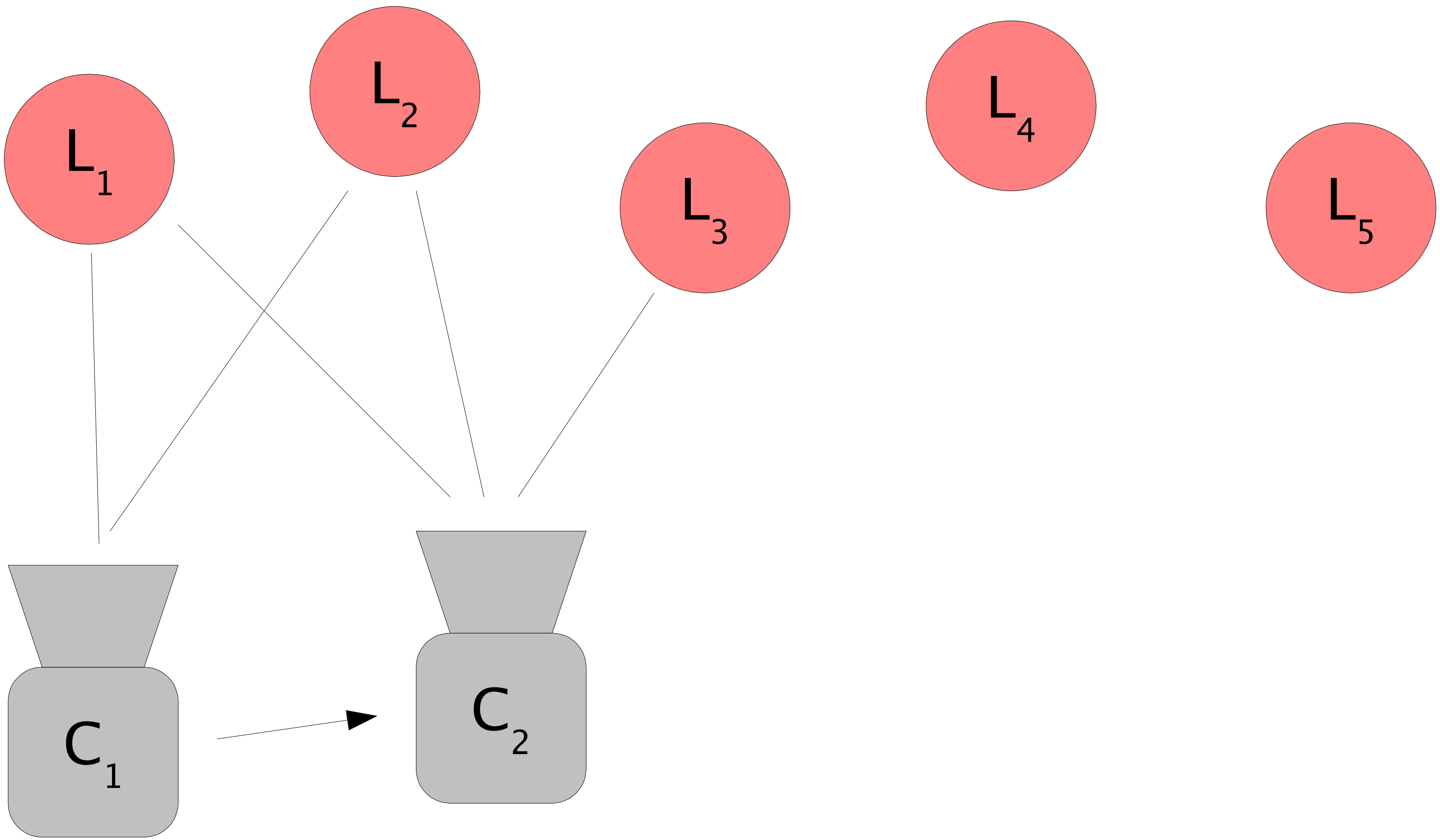
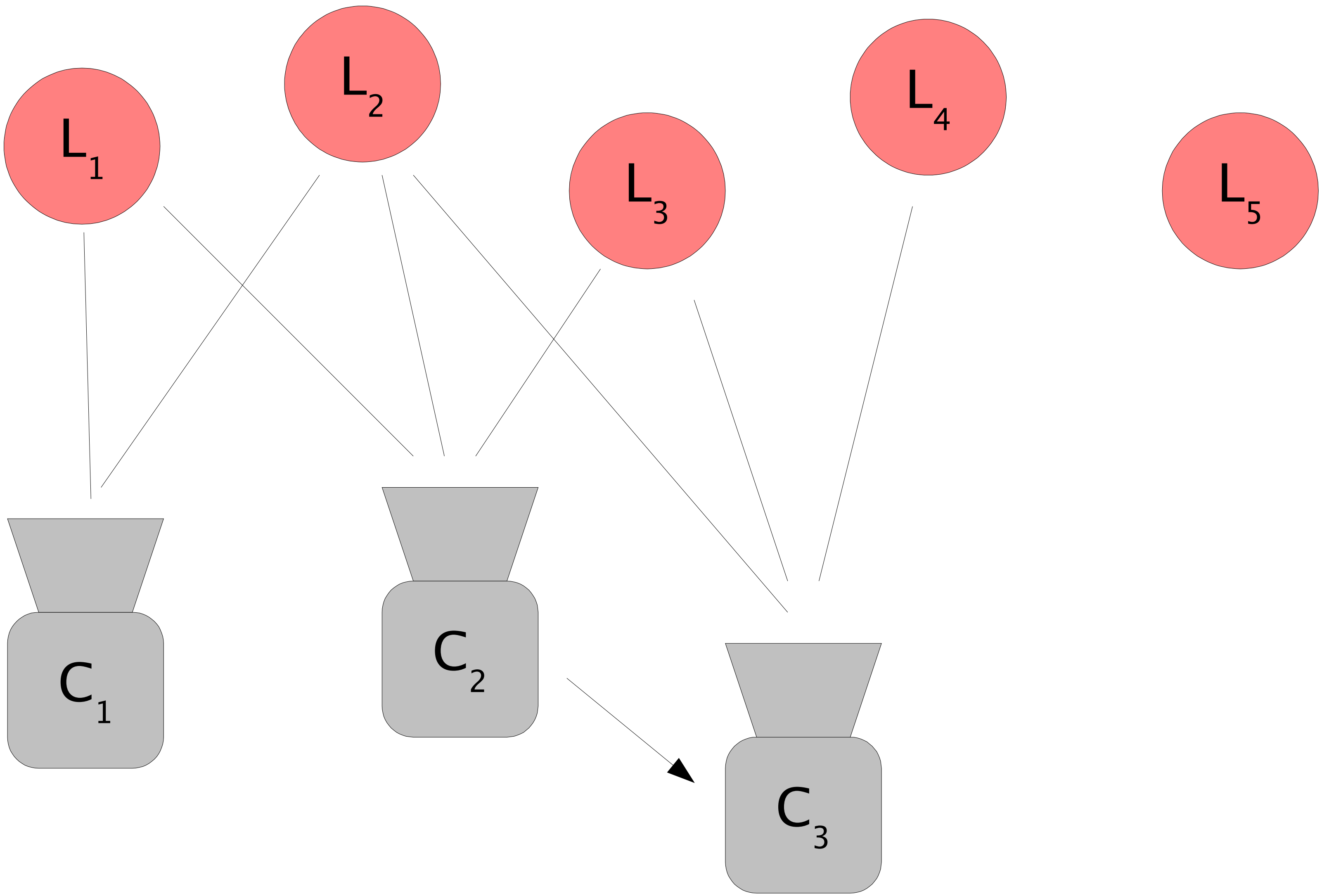


Landmark Dependence



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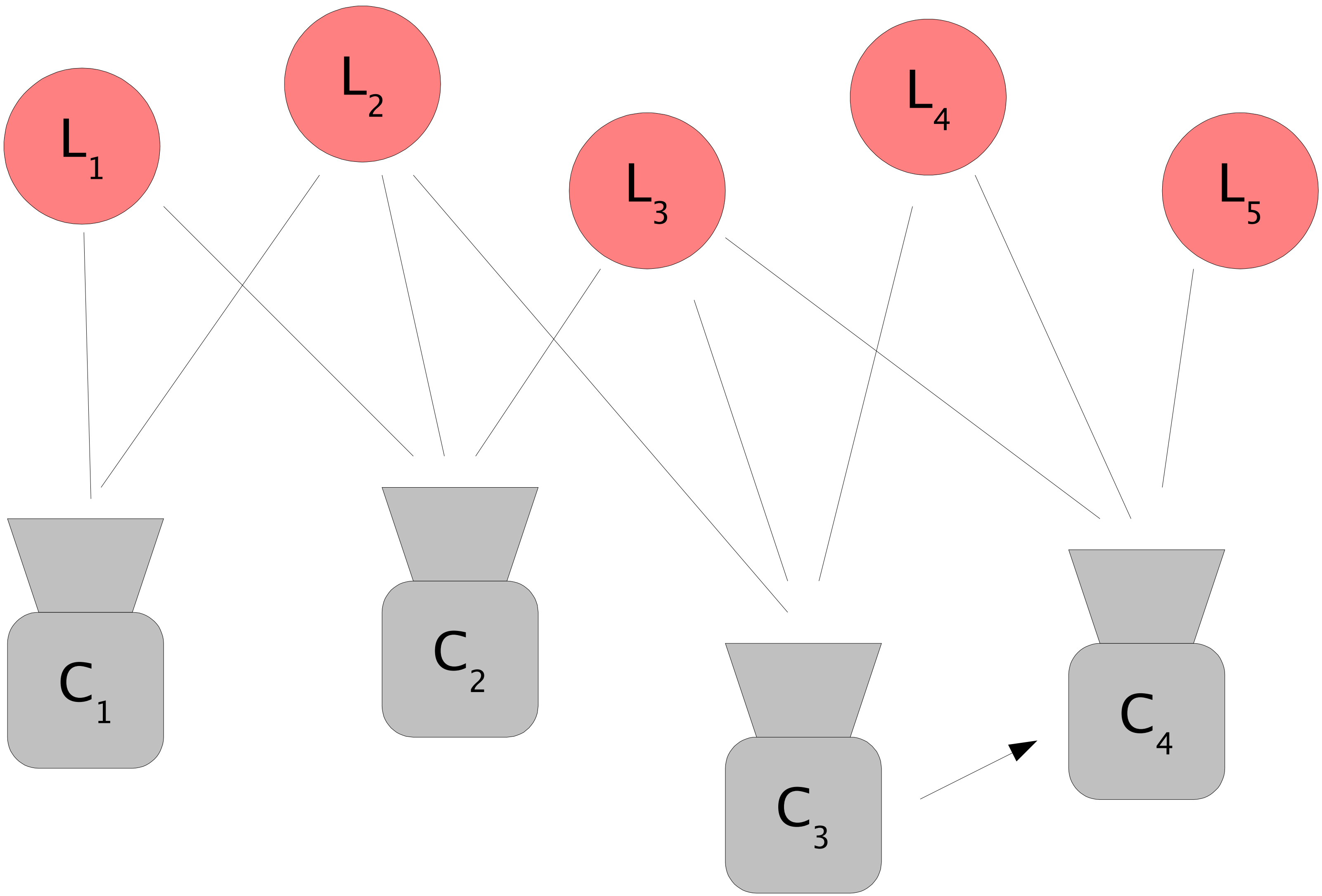

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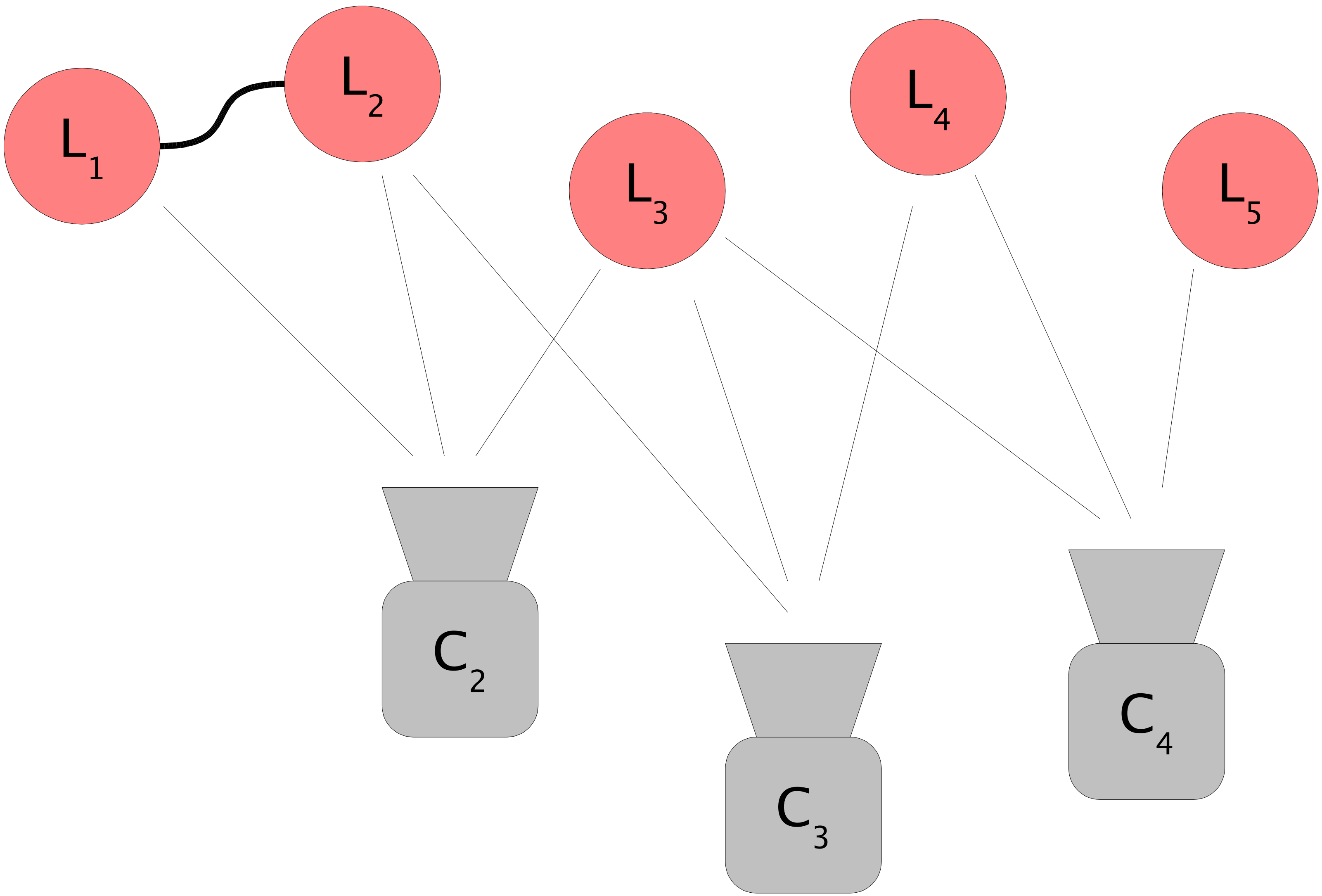

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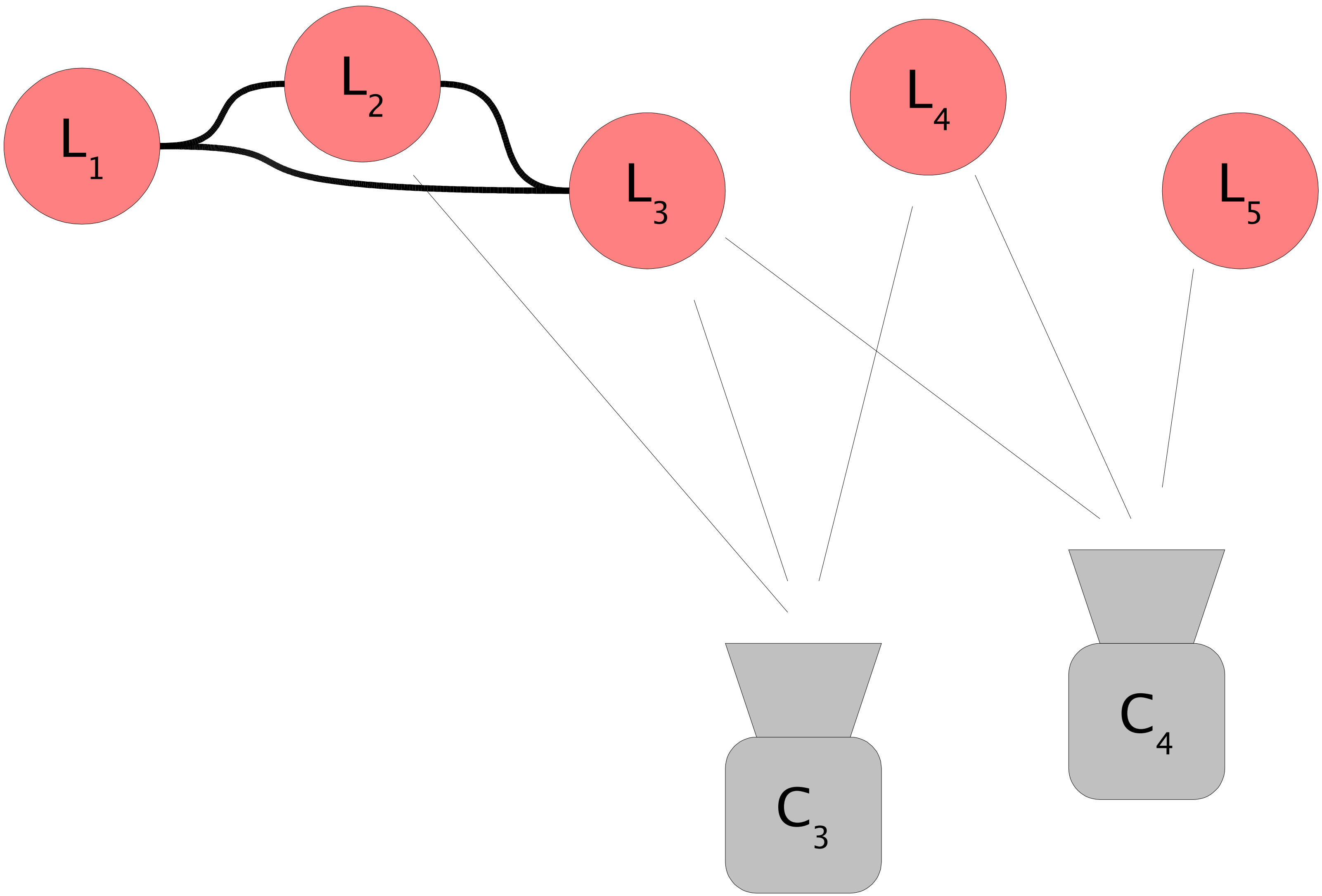

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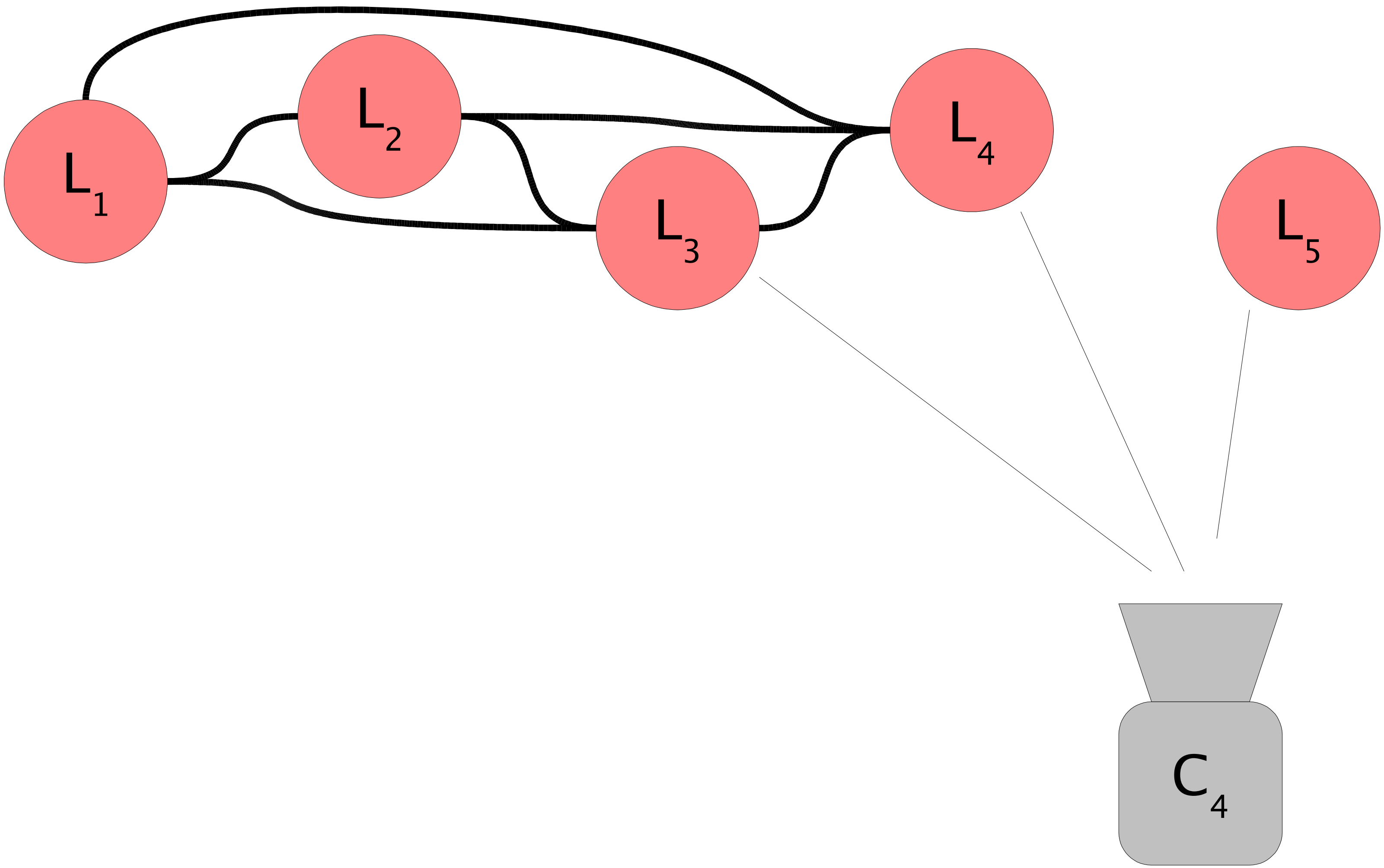

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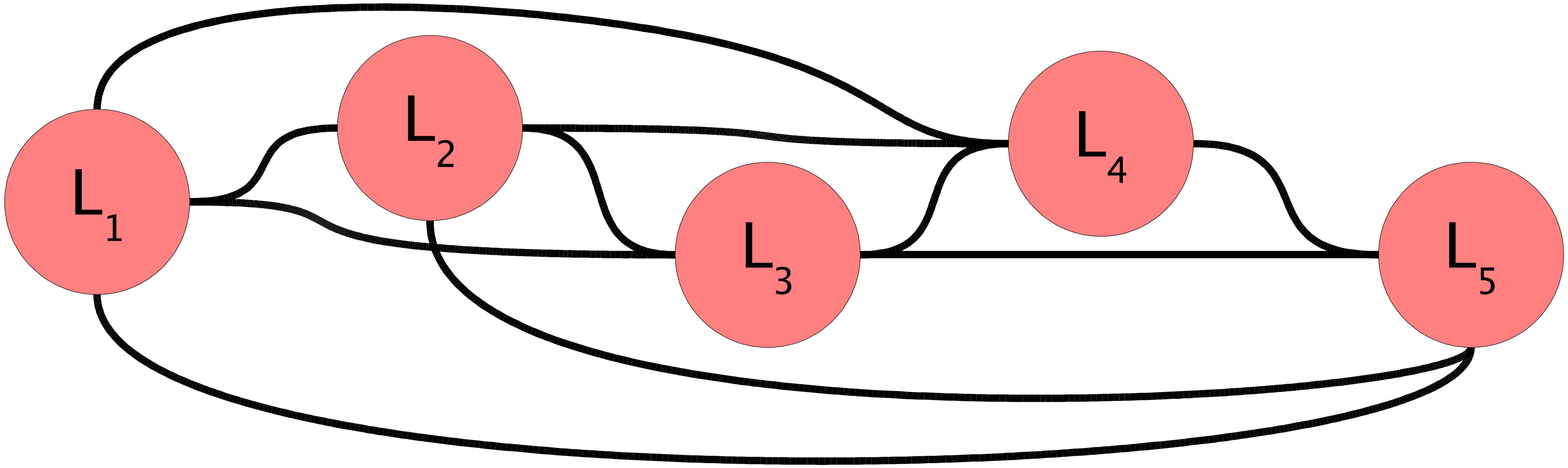
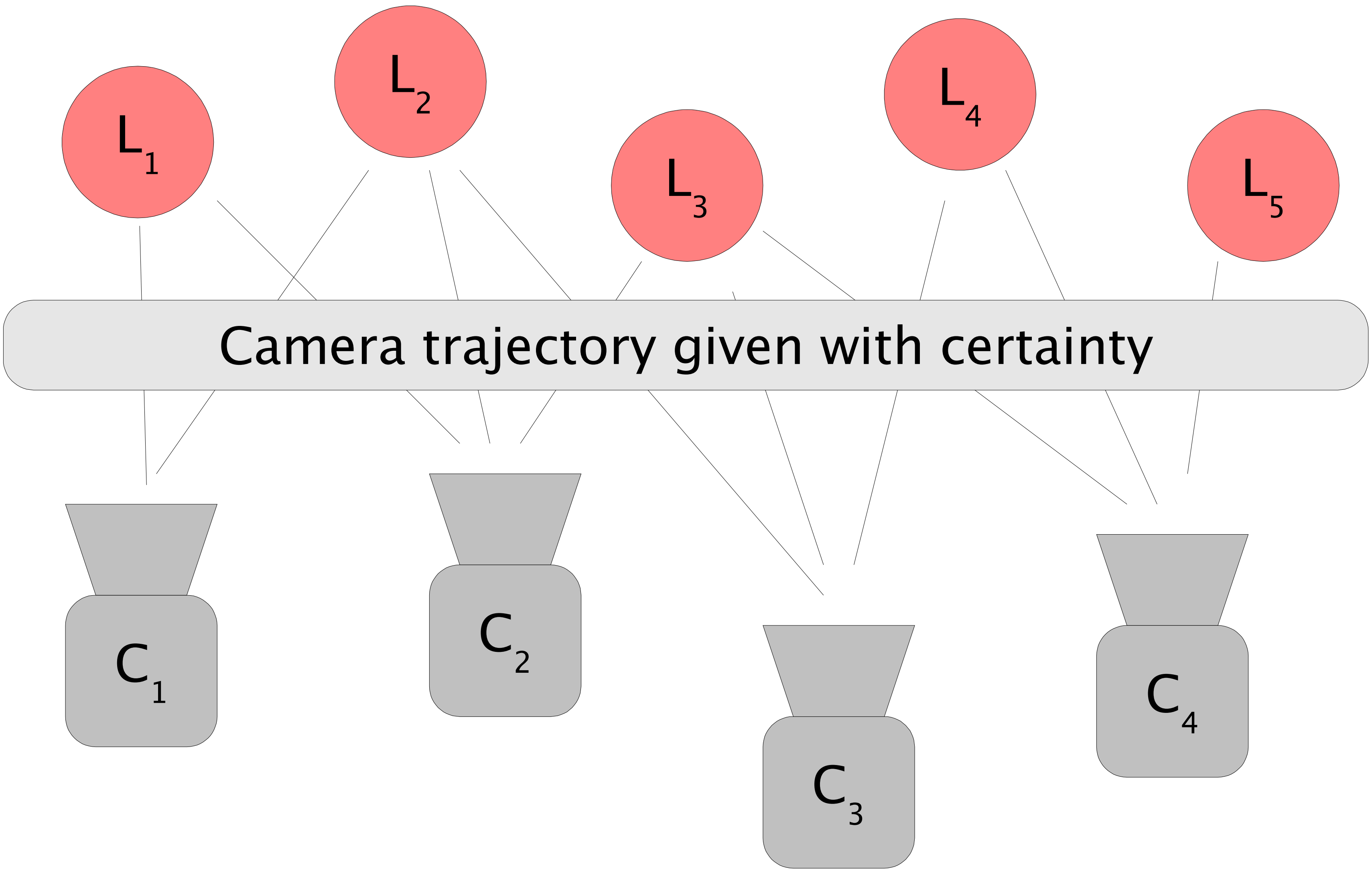


Landmarks are dependent when
the camera trajectory is marginalized out

FastSLAM: Conditional Independence

[Montemerlo et al.]



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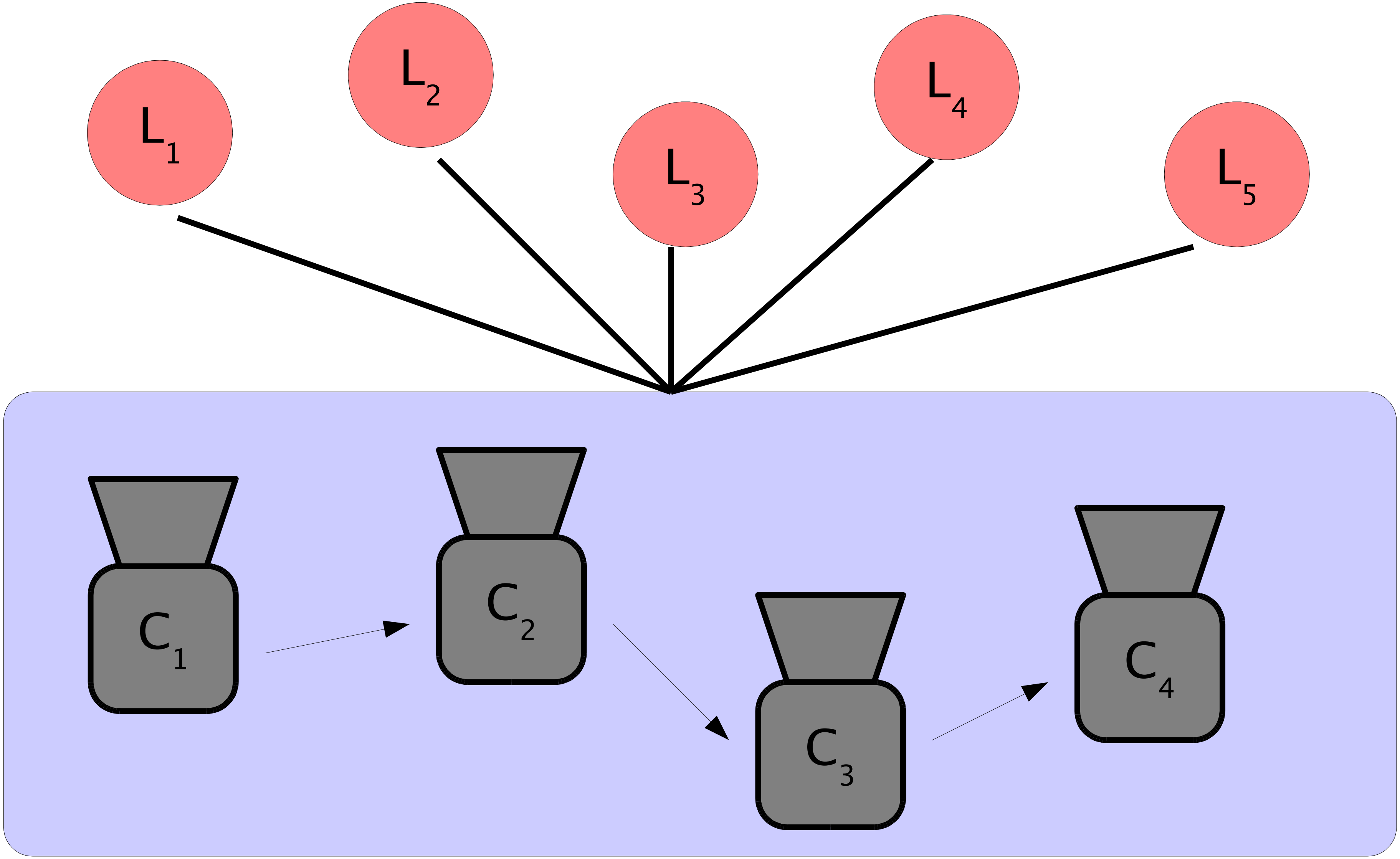


FastSLAM

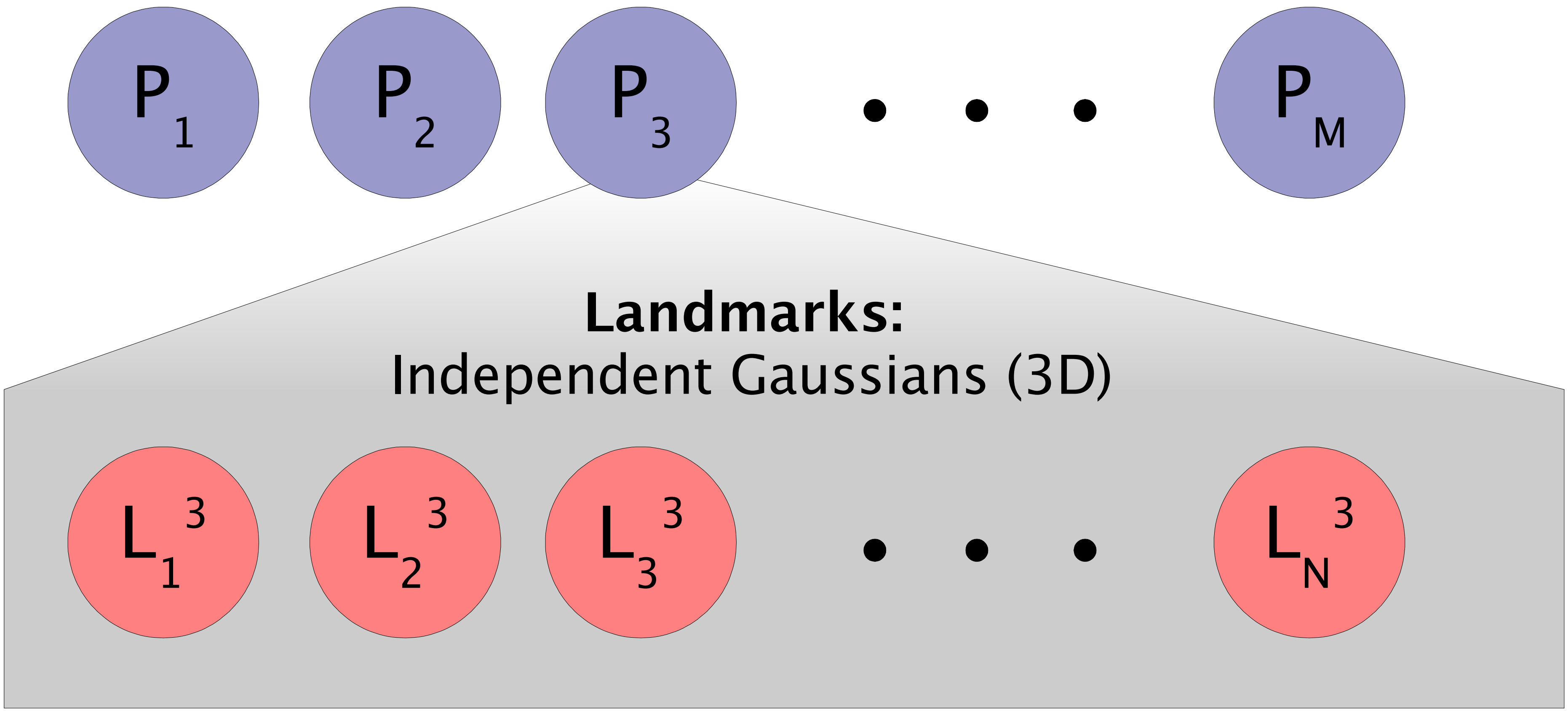
[Montemerlo et al.]

State Estimate	Filter Update
M sampled trajectories	Sample M new trajectories
Independent Gaussians for N landmarks, for each trajectory	Update **only** observed landmarks
O(MN) space	**O(M) time/observation**

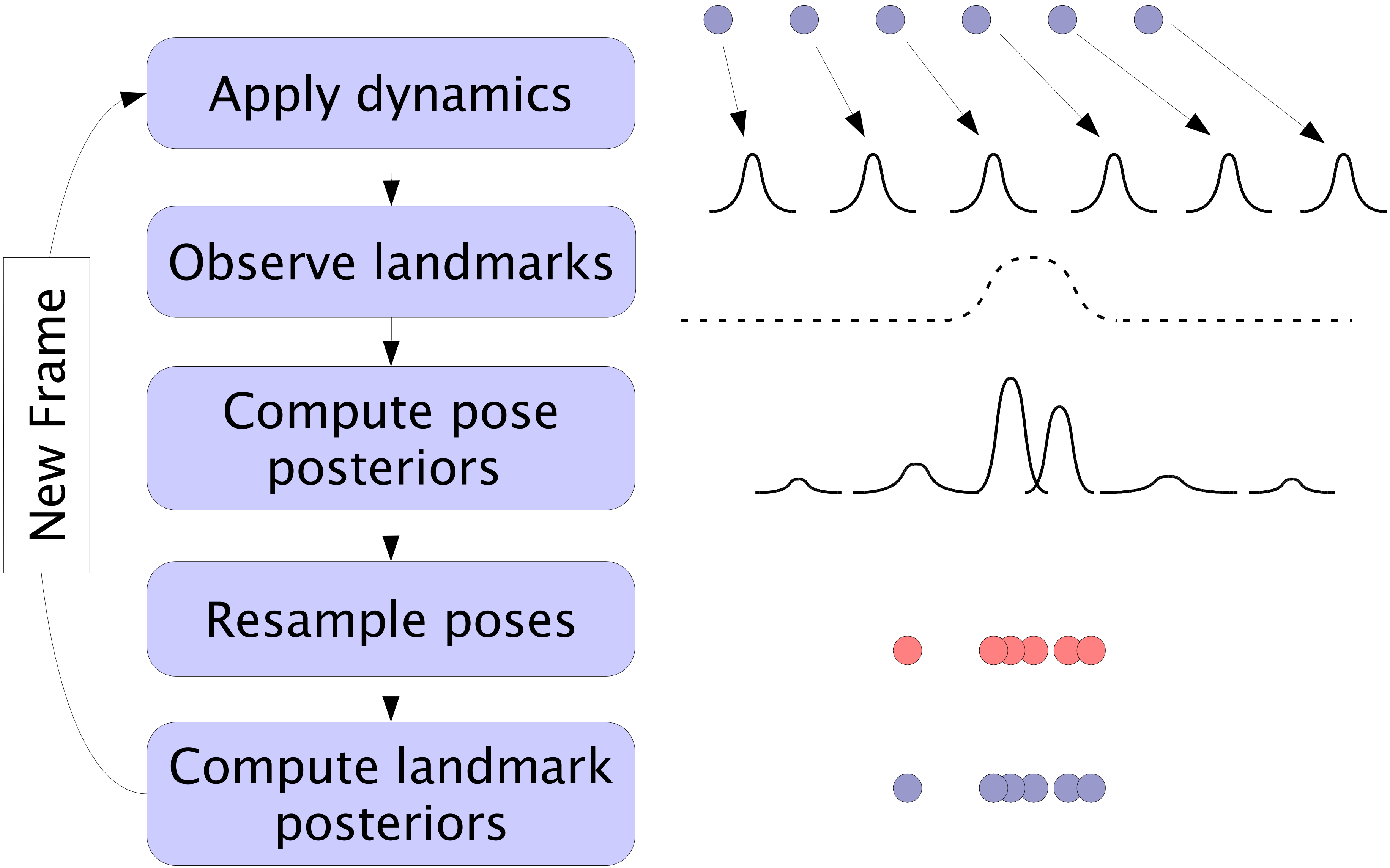
Rao-Blackwellized Particle Filter:
particles for poses,
independent Gaussians for landmarks

State Representation

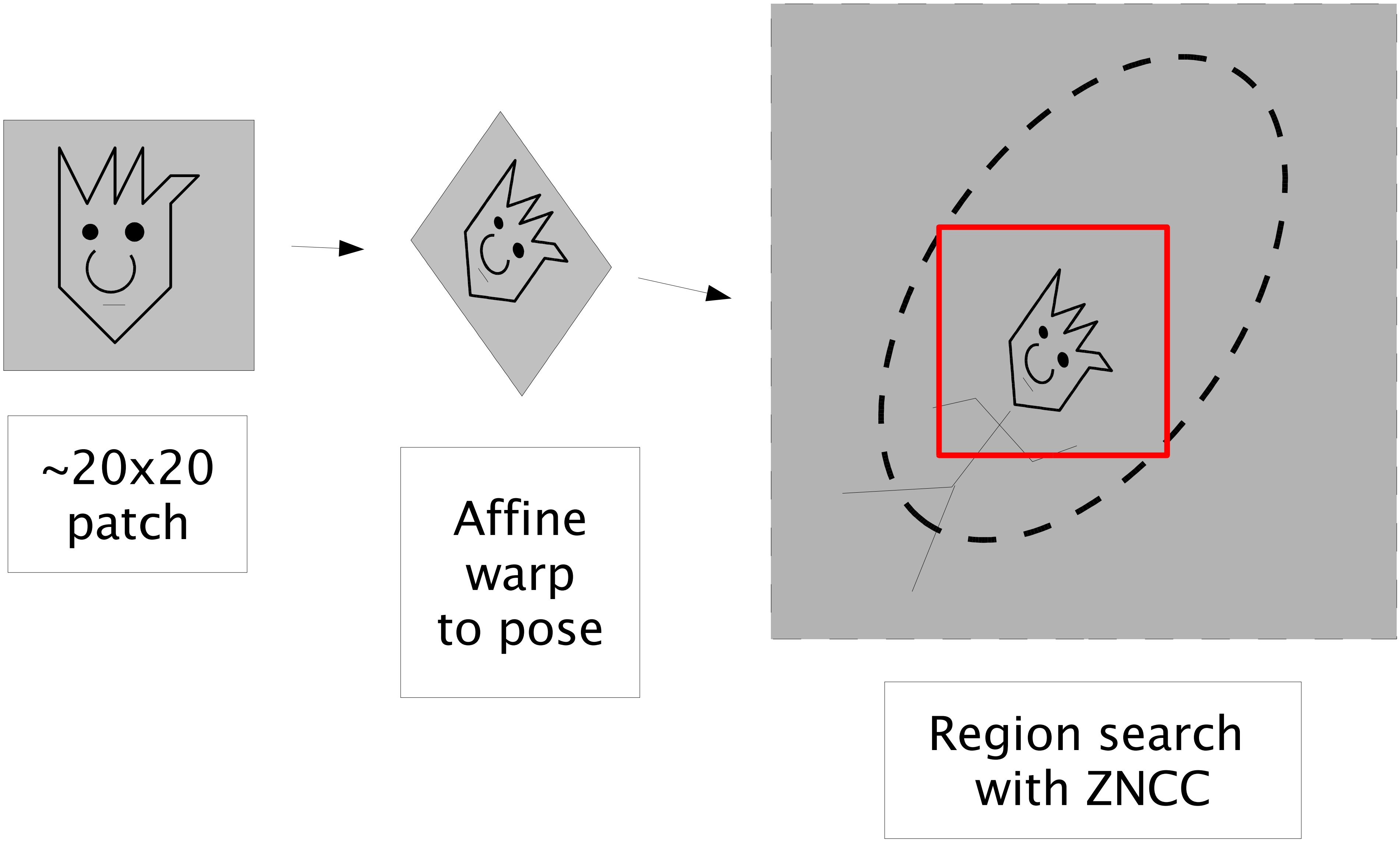
Particles:
Pose sample (6D) + conditional landmark estimates



Particle Filter Vision SLAM



Observing Landmarks



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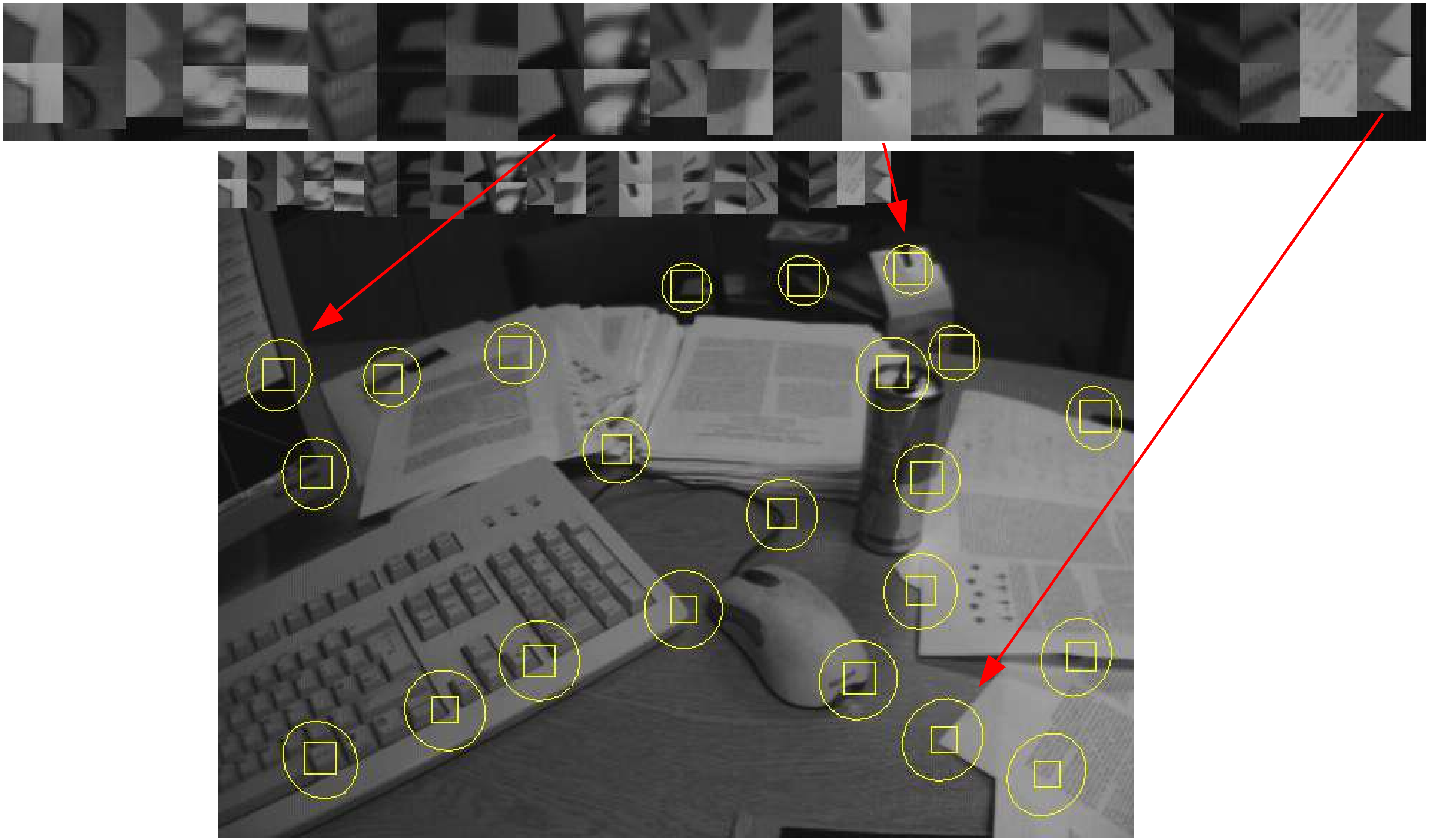
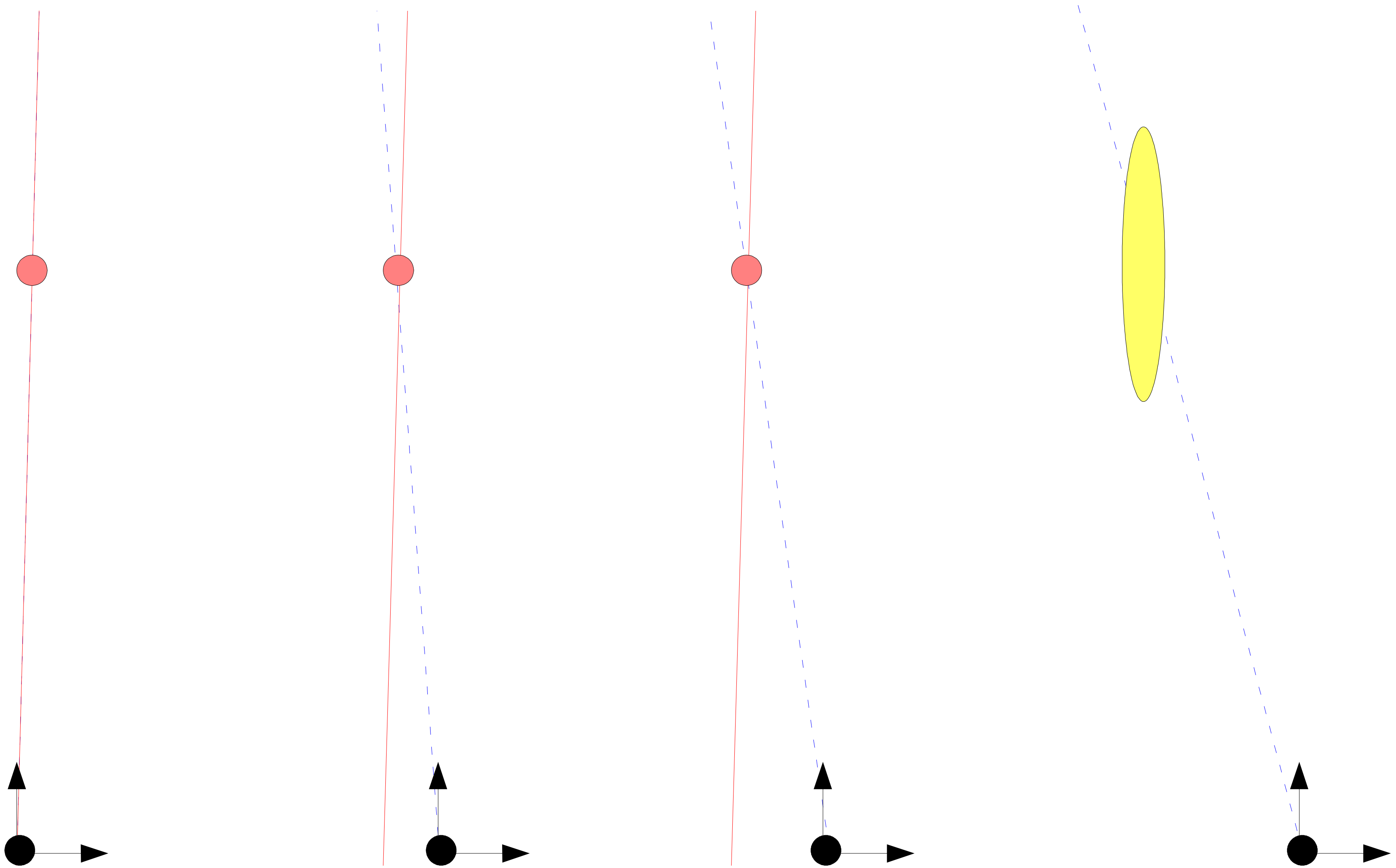


Partially Initialized Landmarks



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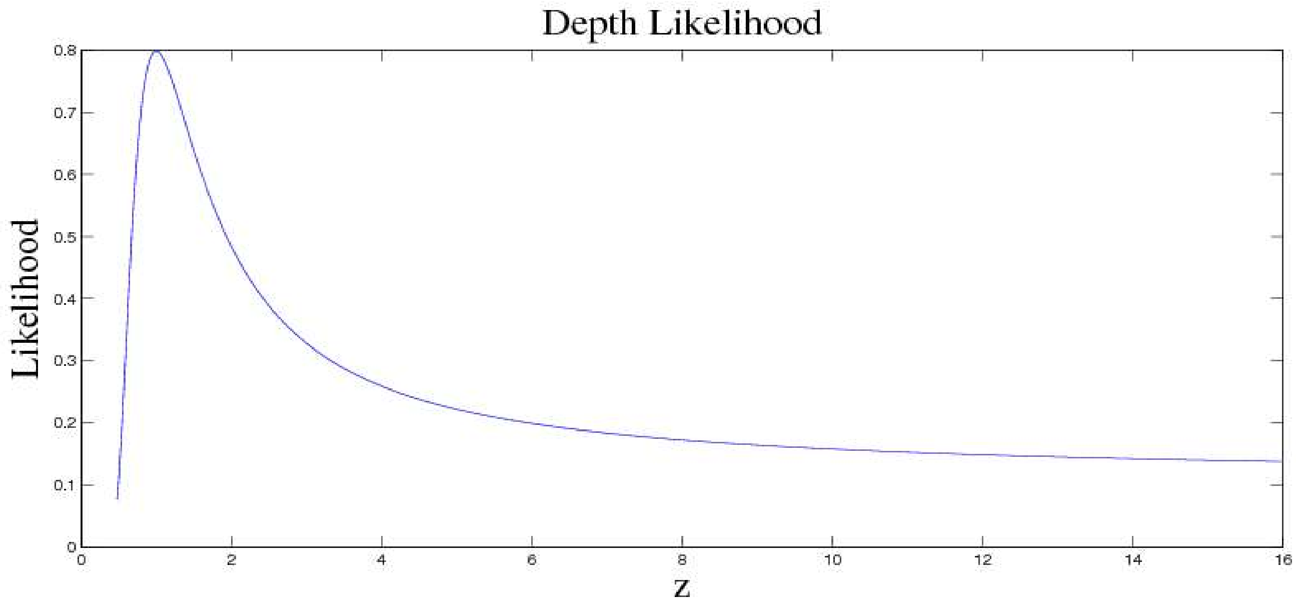
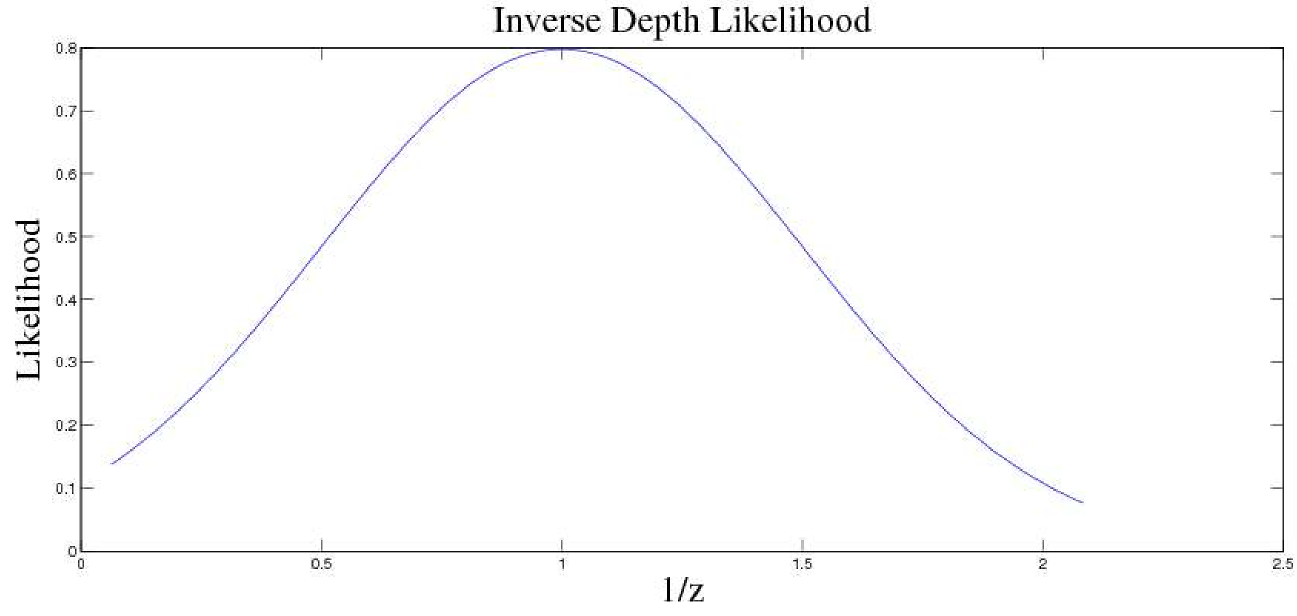




Partially Initialized Landmarks

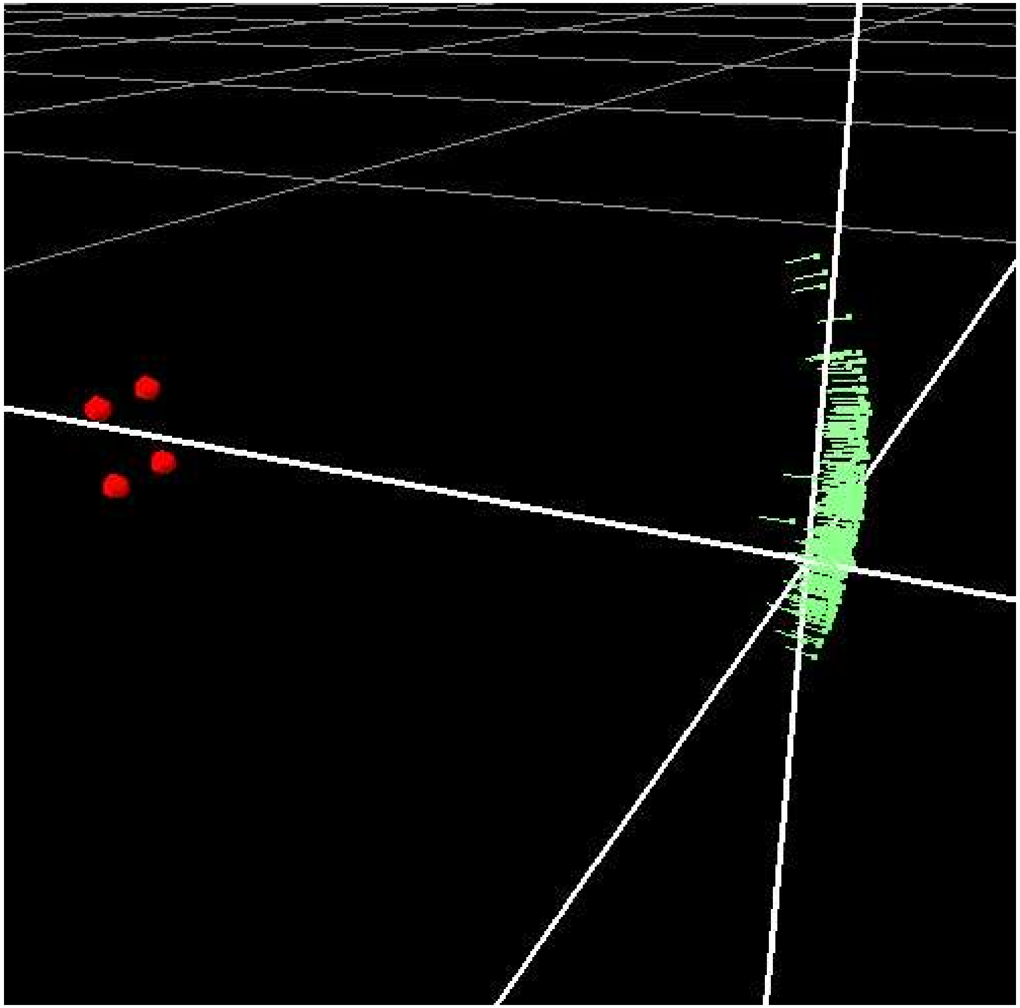
Conventionally, only fully initialized landmarks are used to estimate motion.

However, observations of partially initialized landmarks have two dimensions:

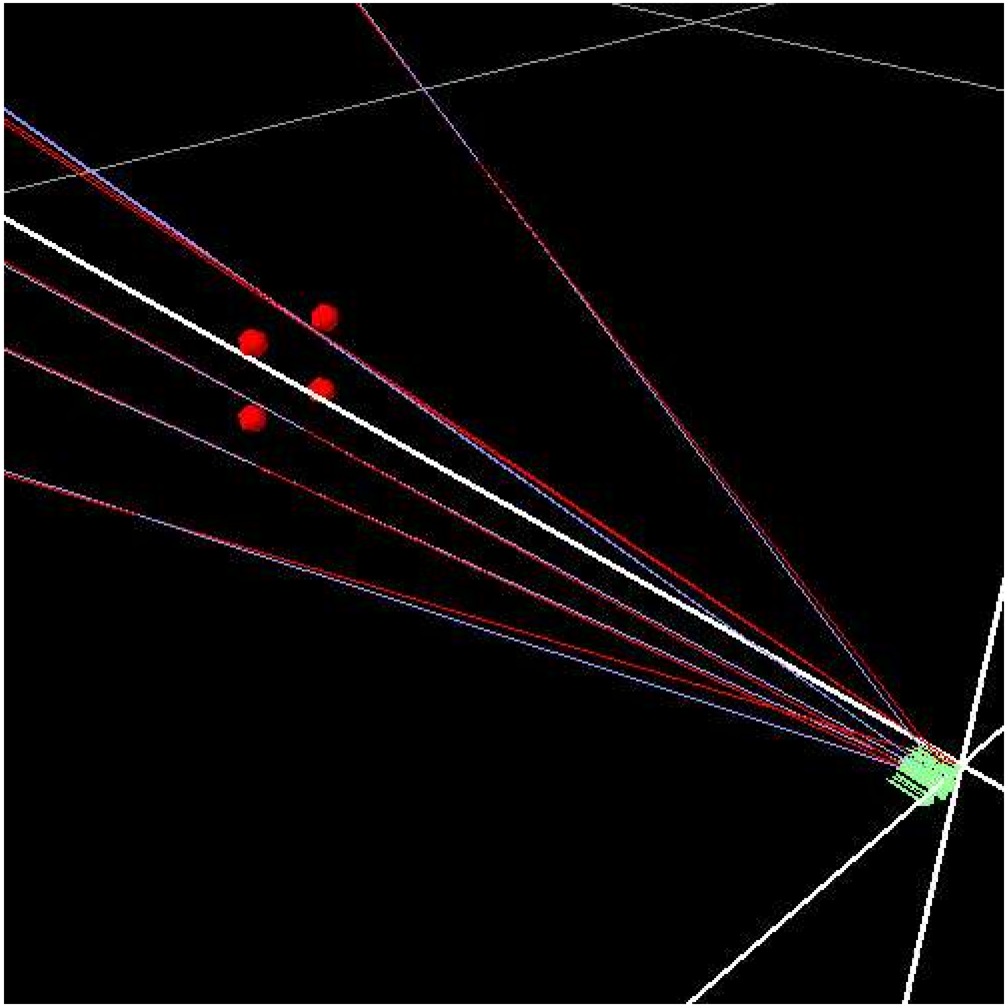
- One gives ***depth*** information
- The other helps constrain camera pose through the ***epipolar constraint***

We don't need to discard this information!

Partially Initialized Landmarks

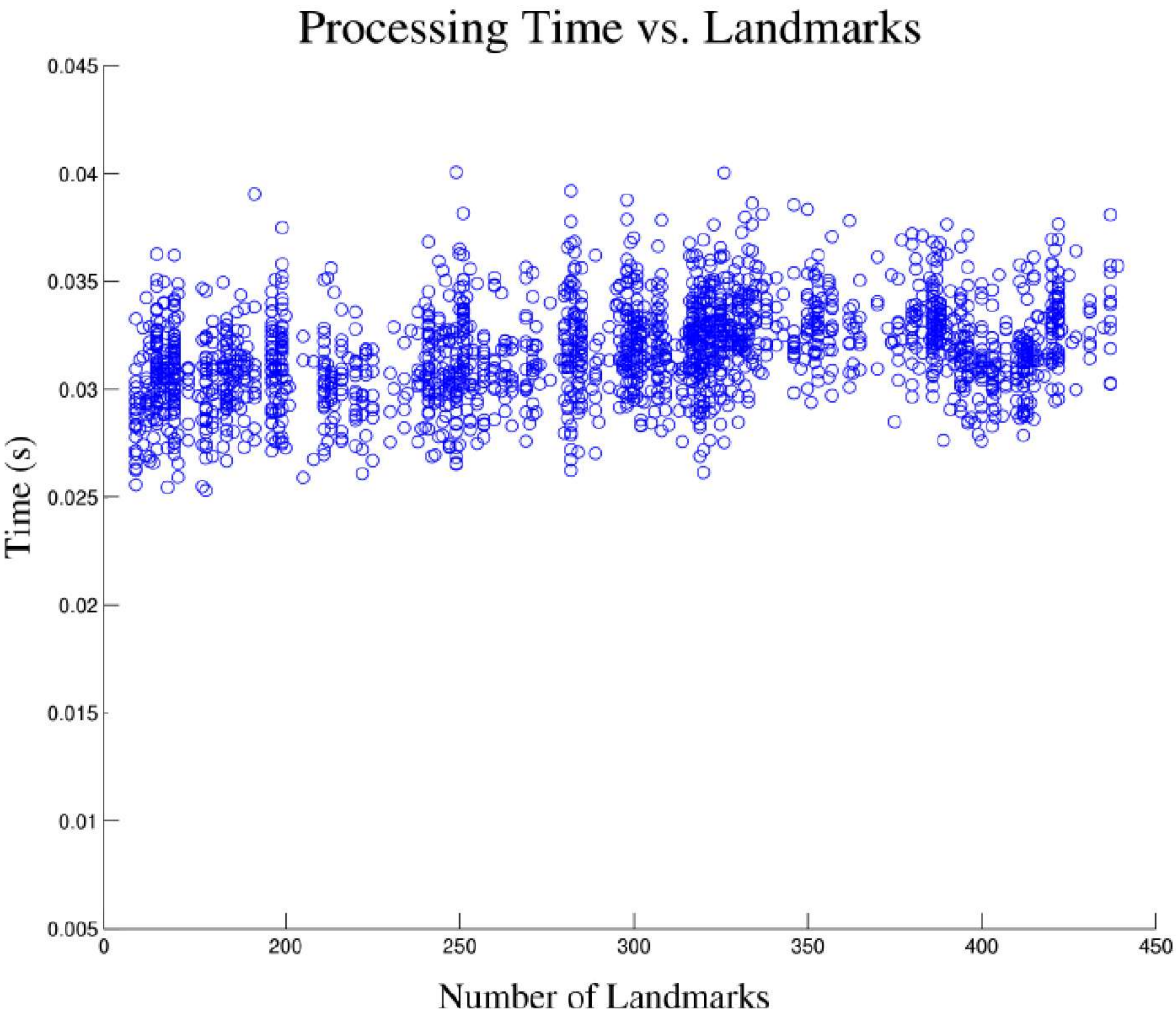


4 fully initialized



4 fully + 5 partially initialized

Results: 400+ landmarks



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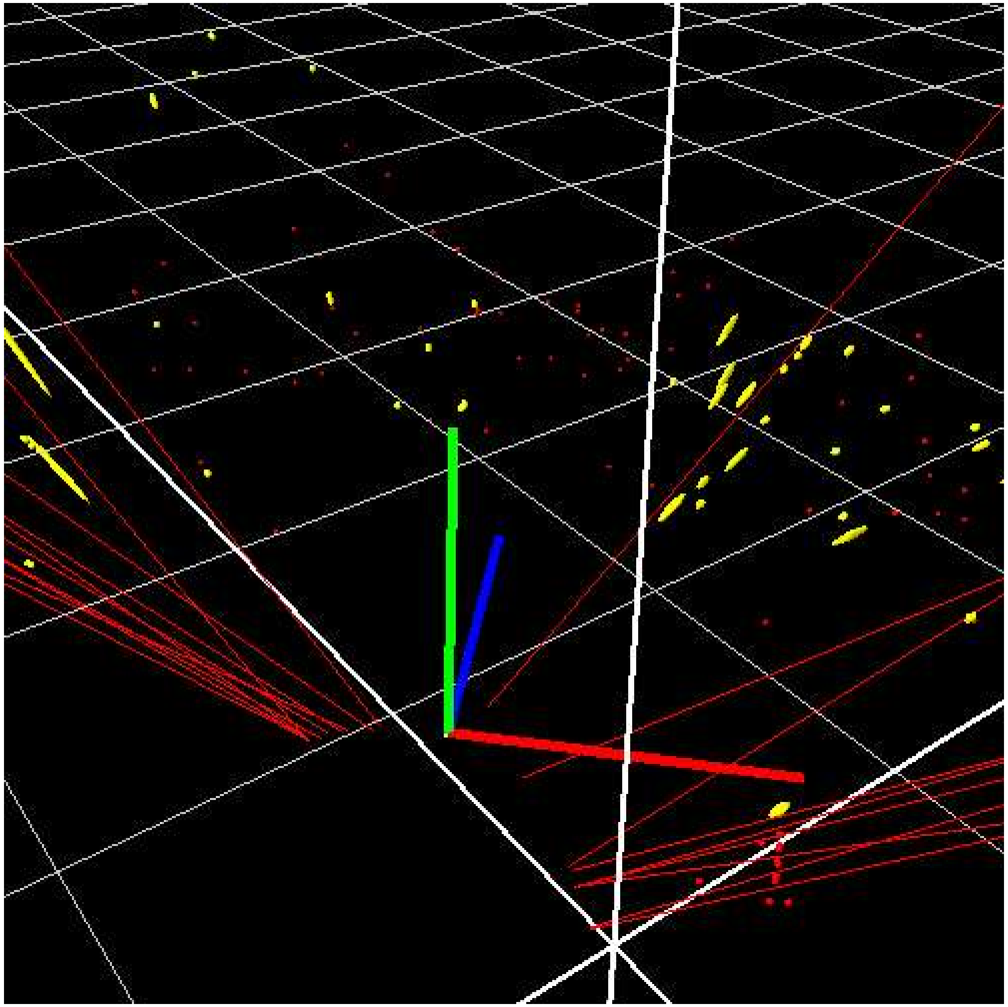
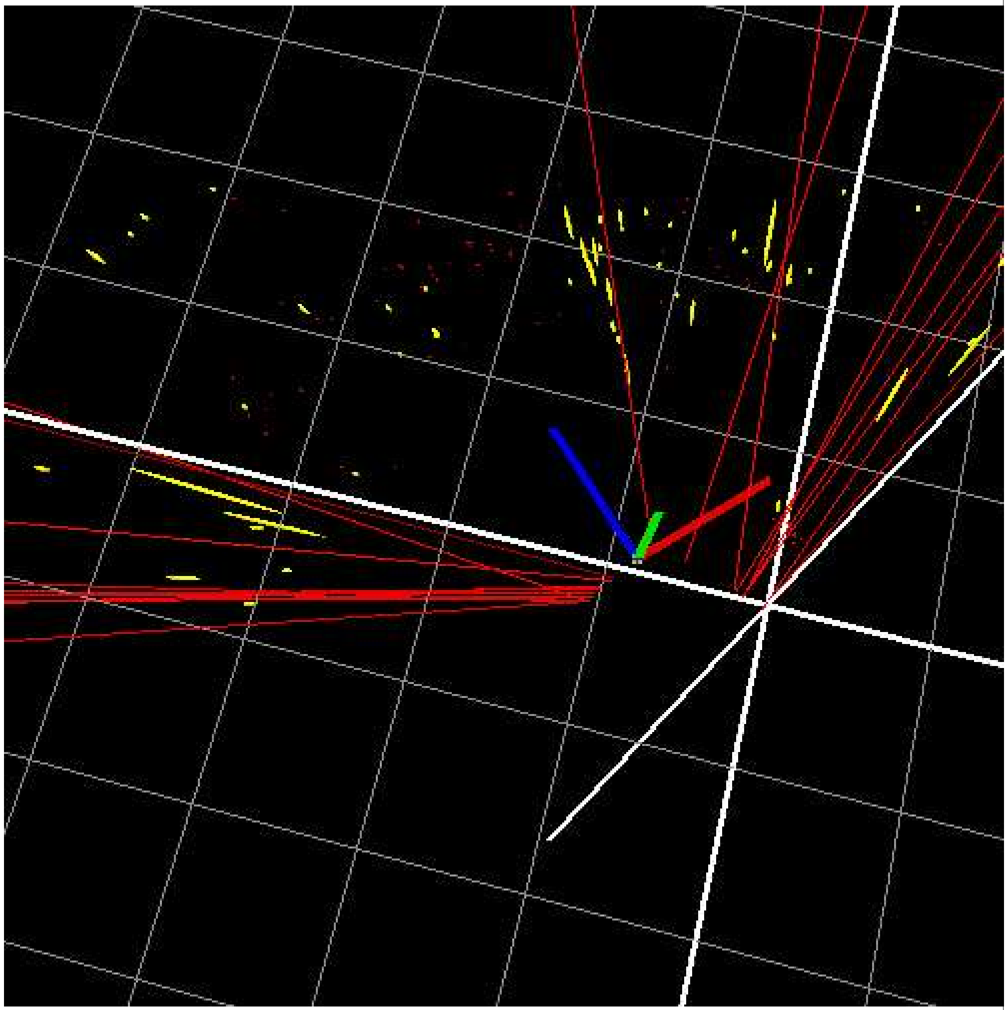
Results





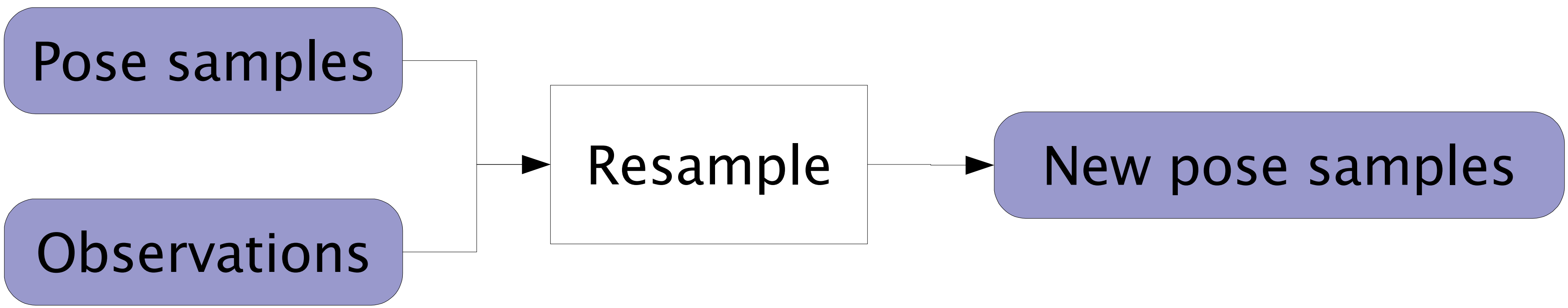
Models

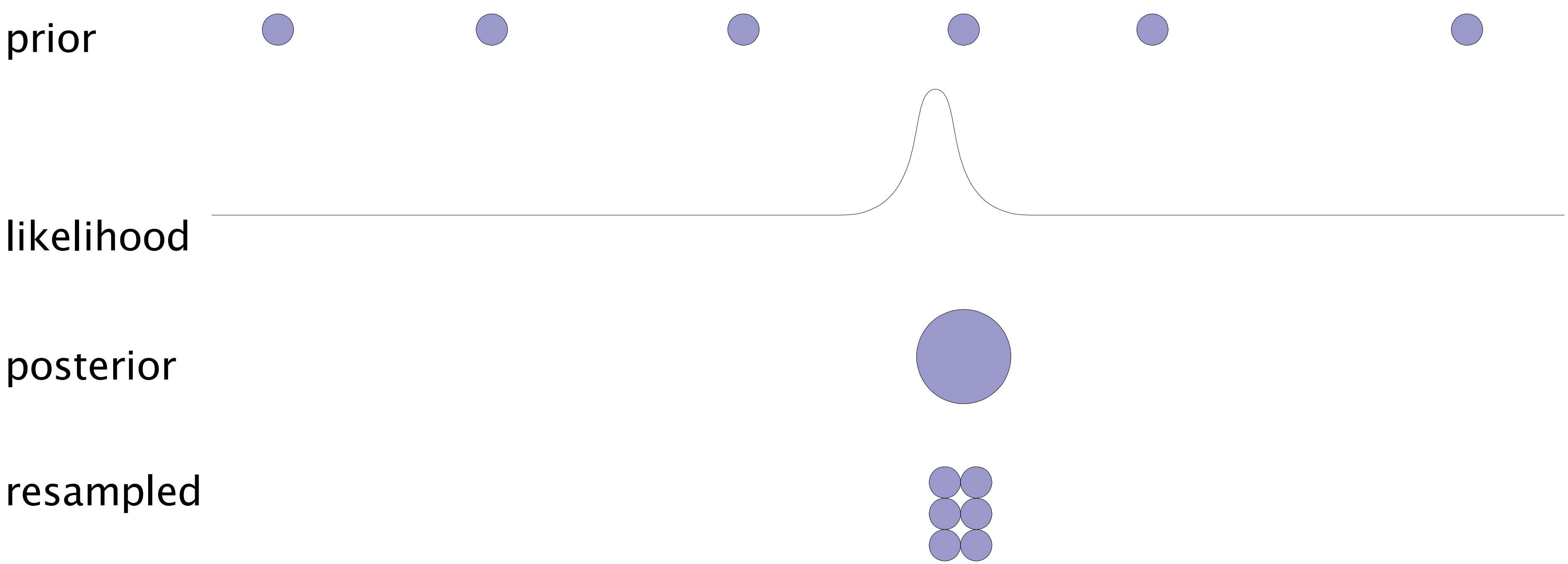
- Pose as element of SE(3)
- Constant velocity model in camera frame:
  $\boldsymbol{C}_{new} = \exp(\mathbf{v}) * \boldsymbol{C}$
- Measurements in camera plane:
  $\mathbf{p} = \text{project}(\boldsymbol{C} * \mathbf{x}) = \text{project}(\mathbf{Rx} + \mathbf{t})$
- Calibrated camera with quintic radial distortion model

Problems

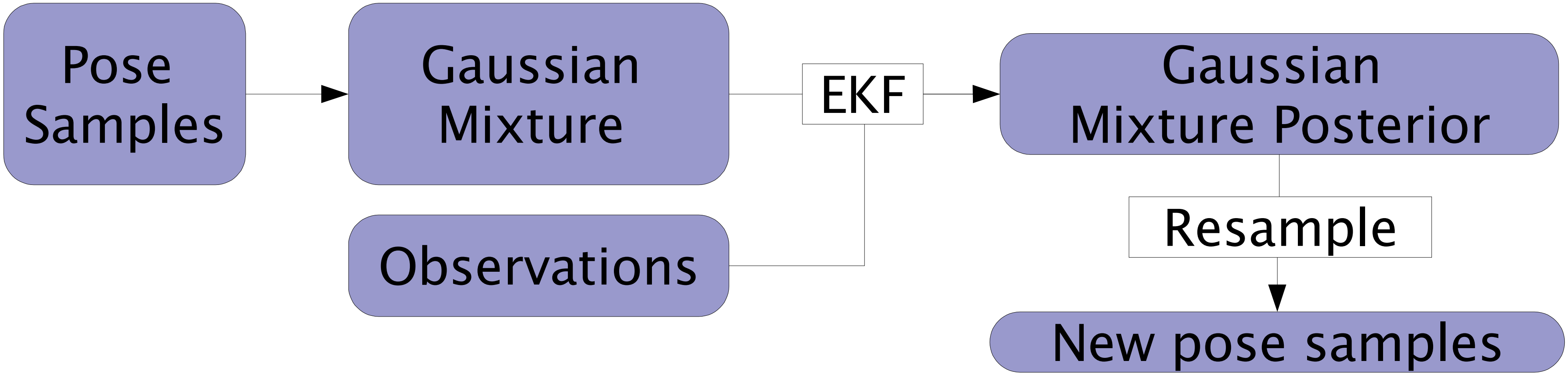
- Because FastSLAM encodes landmark correlations in the particle cloud, a small number of particles may be insufficient to close loops.
- Without any direct measurement of scale after initialization, maps can accrue local scale error.
- Very large scale mapping will require active loop closing.

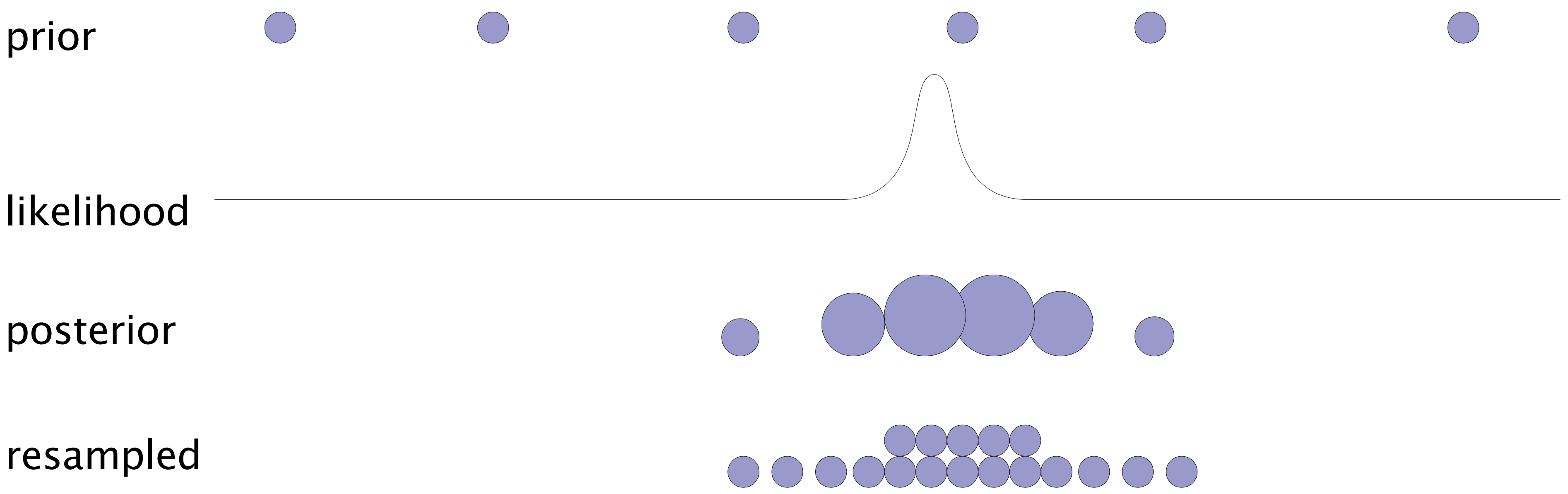
Updating the Pose Distribution



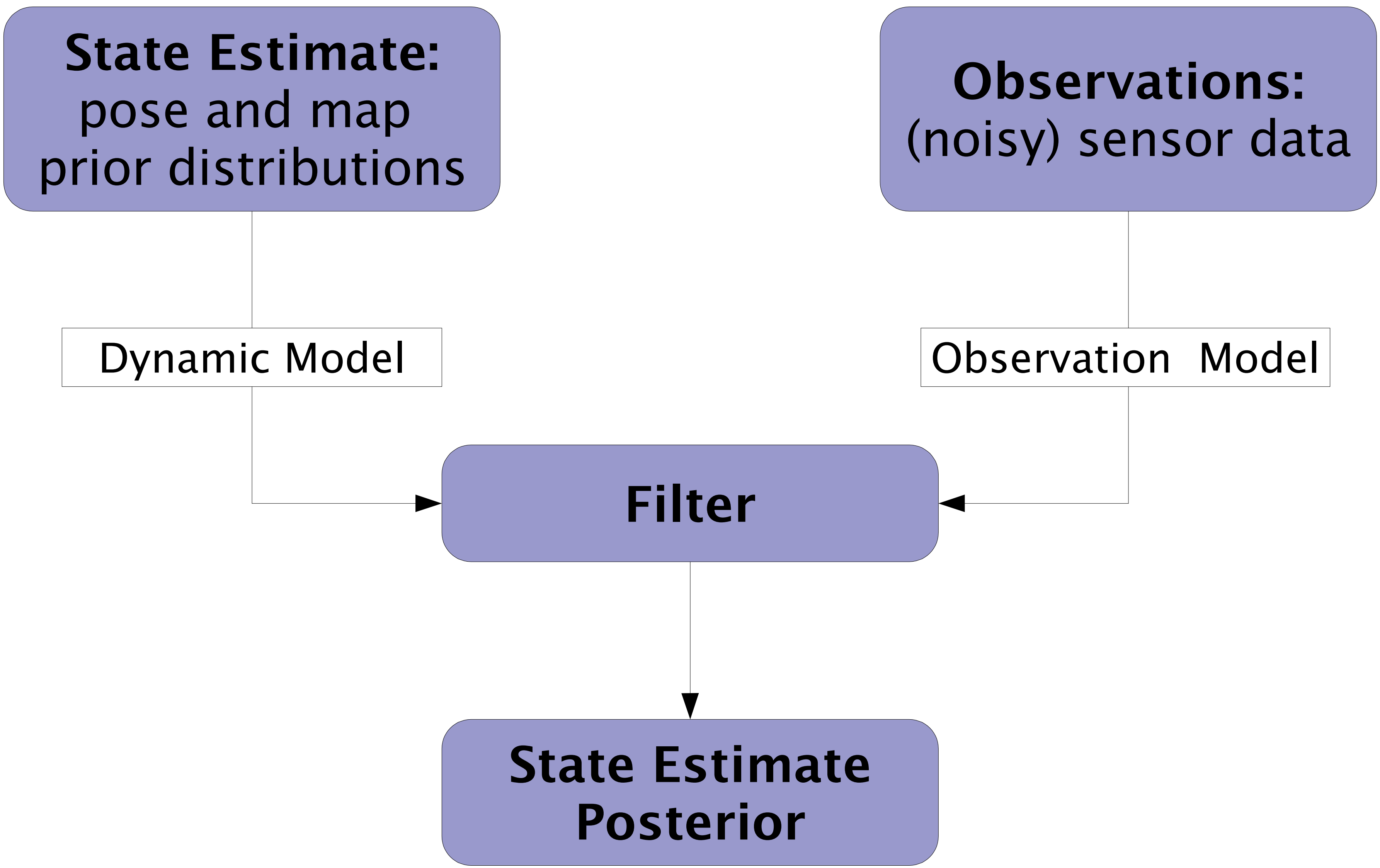


Optimizing the Poses





Probabilistic SLAM



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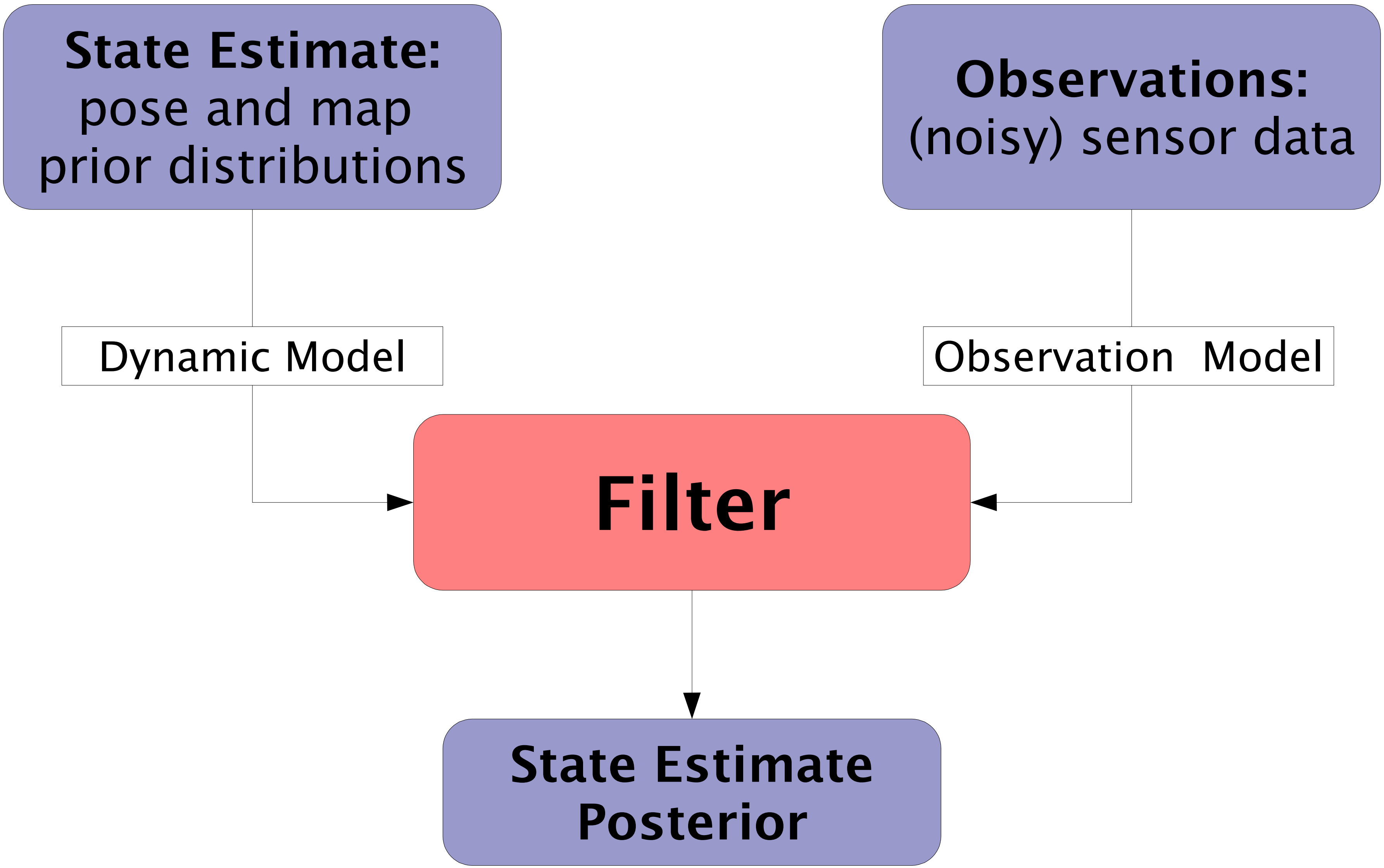

FAST Corners

Ed Rosten, Tom Drummond

Rosten and Drummond.
Fusing points and lines for high performance tracking.
ICCV '05.

Rosten and Drummond.
Machine learning for high-speed corner detection.
ECCV '06.

Find this man.