Absolute Pose from One or Two Scaled and Oriented Features

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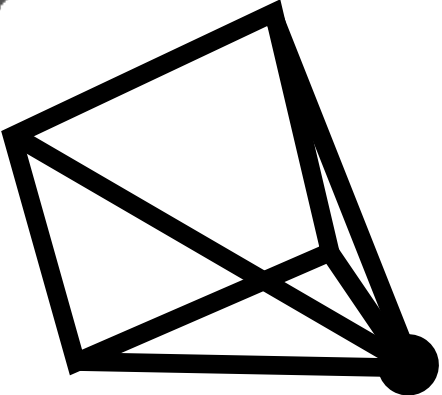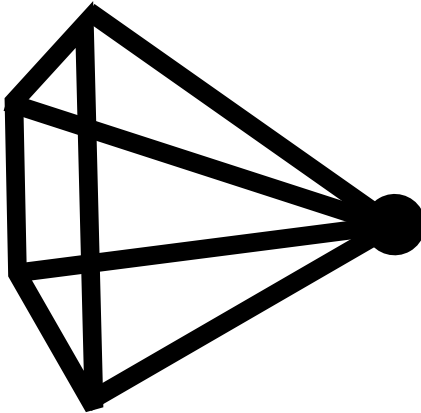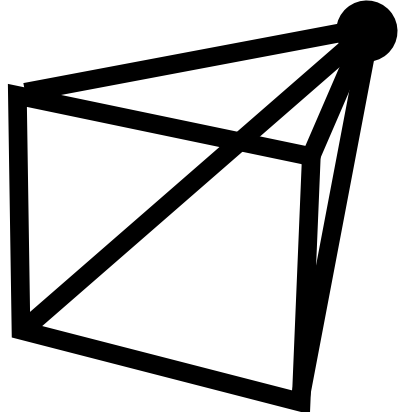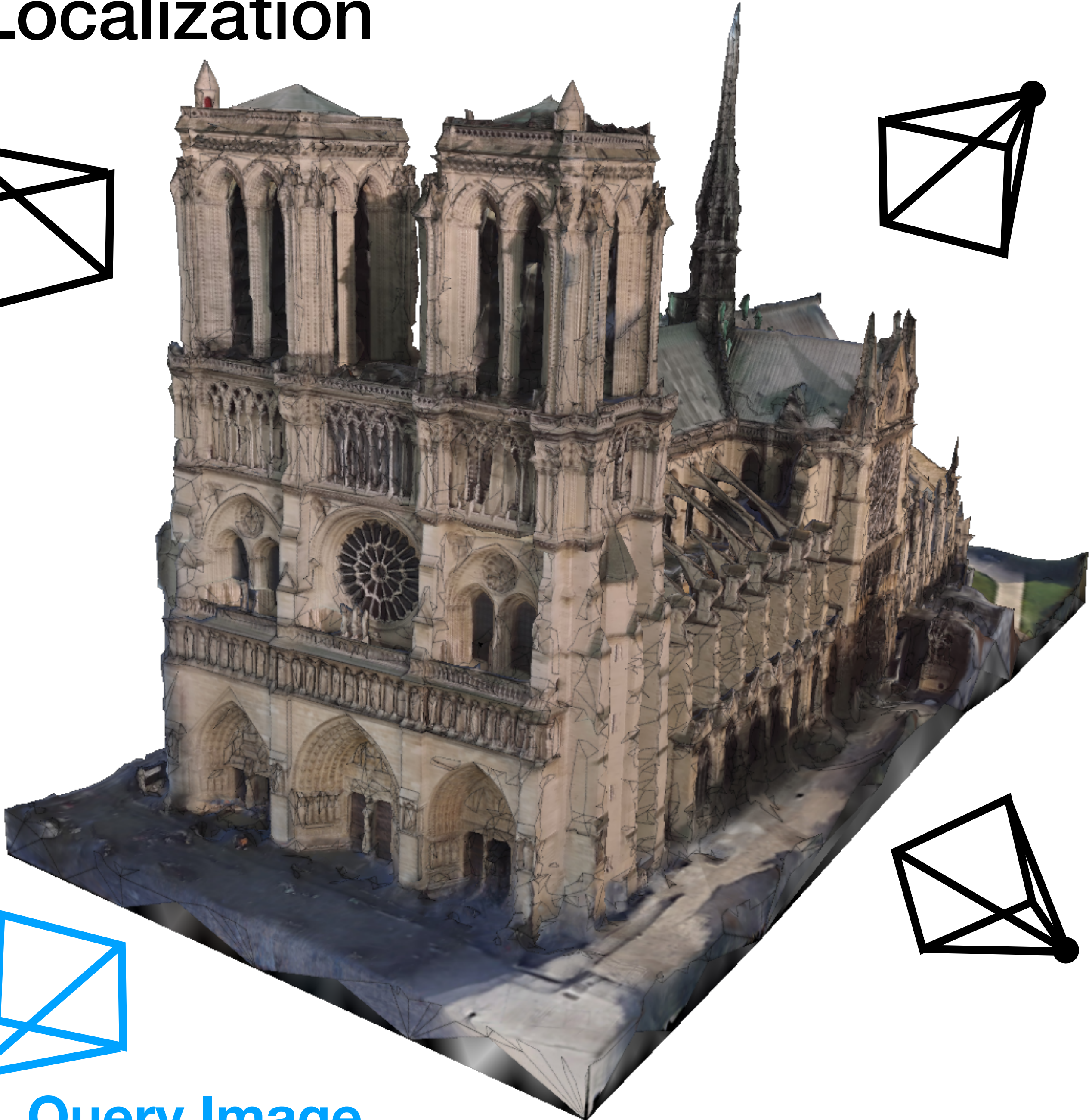[4]Computer Vision and Geometry Group, ETH Zürich

Image-based Localization

Reference Images
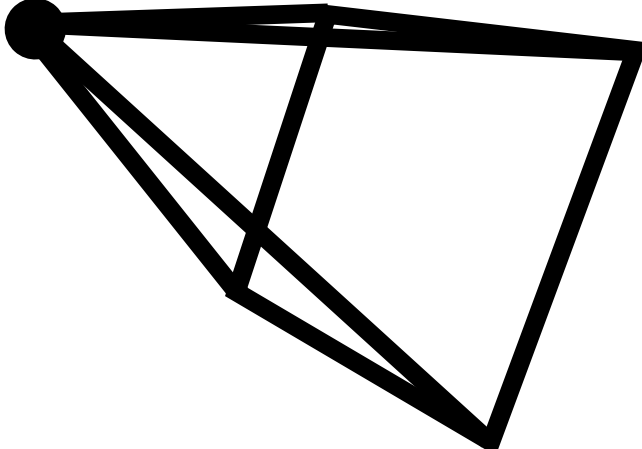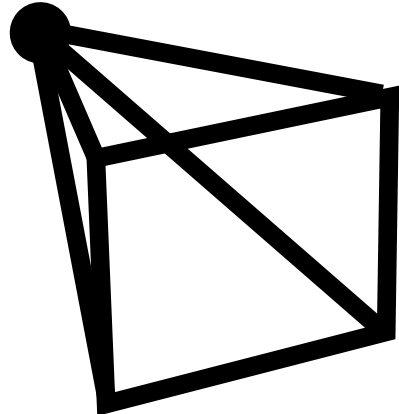
$[\mathbf{R} \,|\, \mathbf{t}]$?
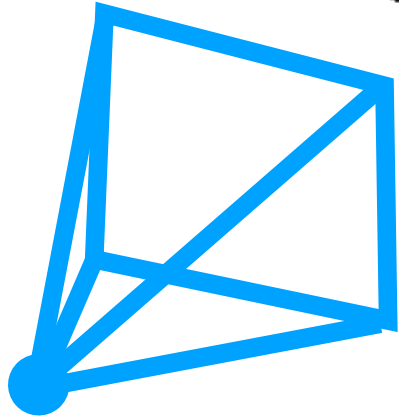
Query Image

P3P: Perspective three point solver

Solves for calibrated camera pose from three 2D observations of known 3D points

Thoroughly studied problem with long history (Haralick et al. 1994)

Solvers are widely used

Query image

Haralick et al. Review and analysis of solutions of the three point perspective pose estimation problem. IJCV 1994.

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Feature Scale and Orientation

Keypoint orientation estimation:
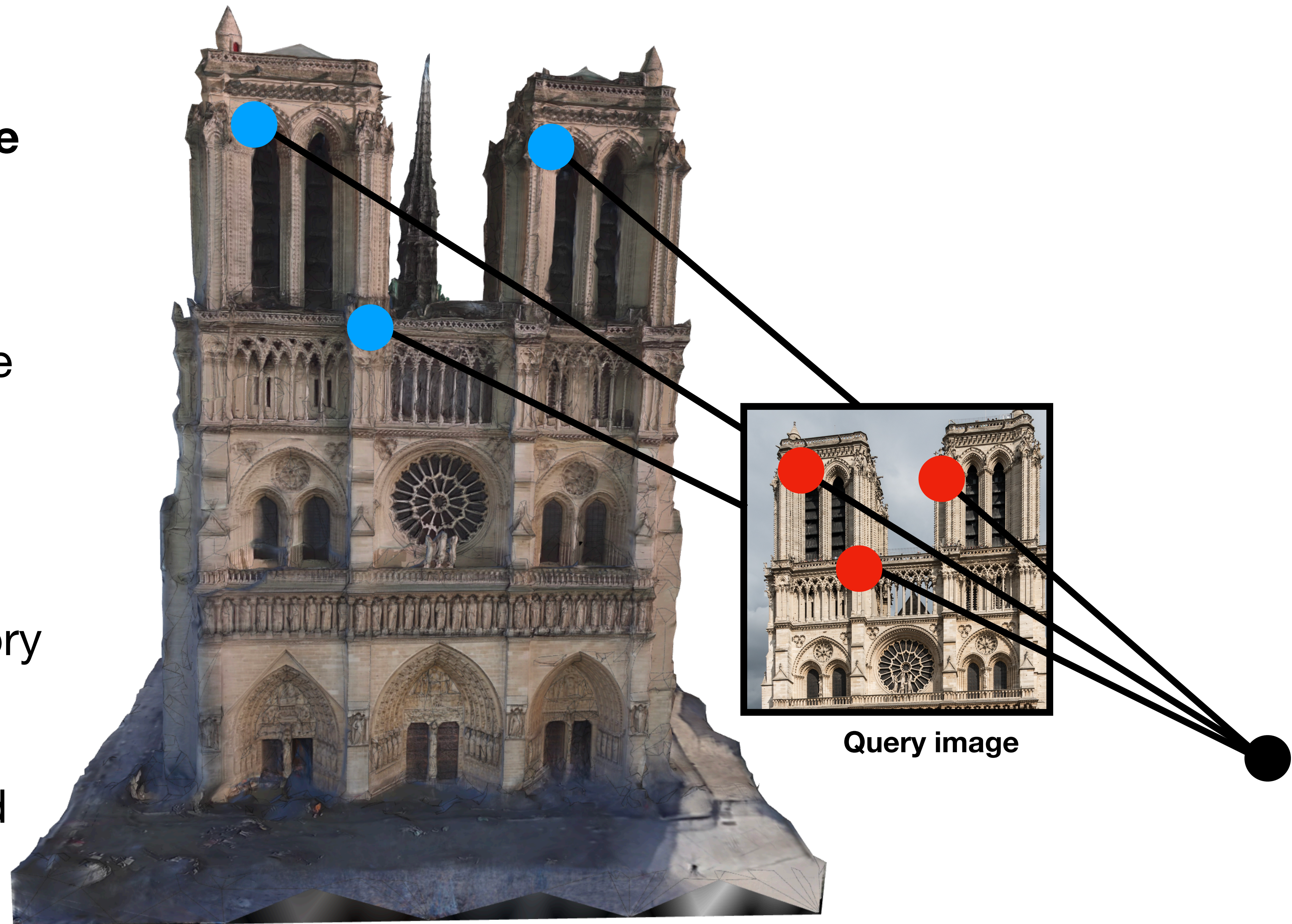 Histogram of gradients (Lowe 2004)
  Intensity centroid (Rosin 1999, Rublee et al. 2011)
  Supervised learning (Yi et al. 2016)
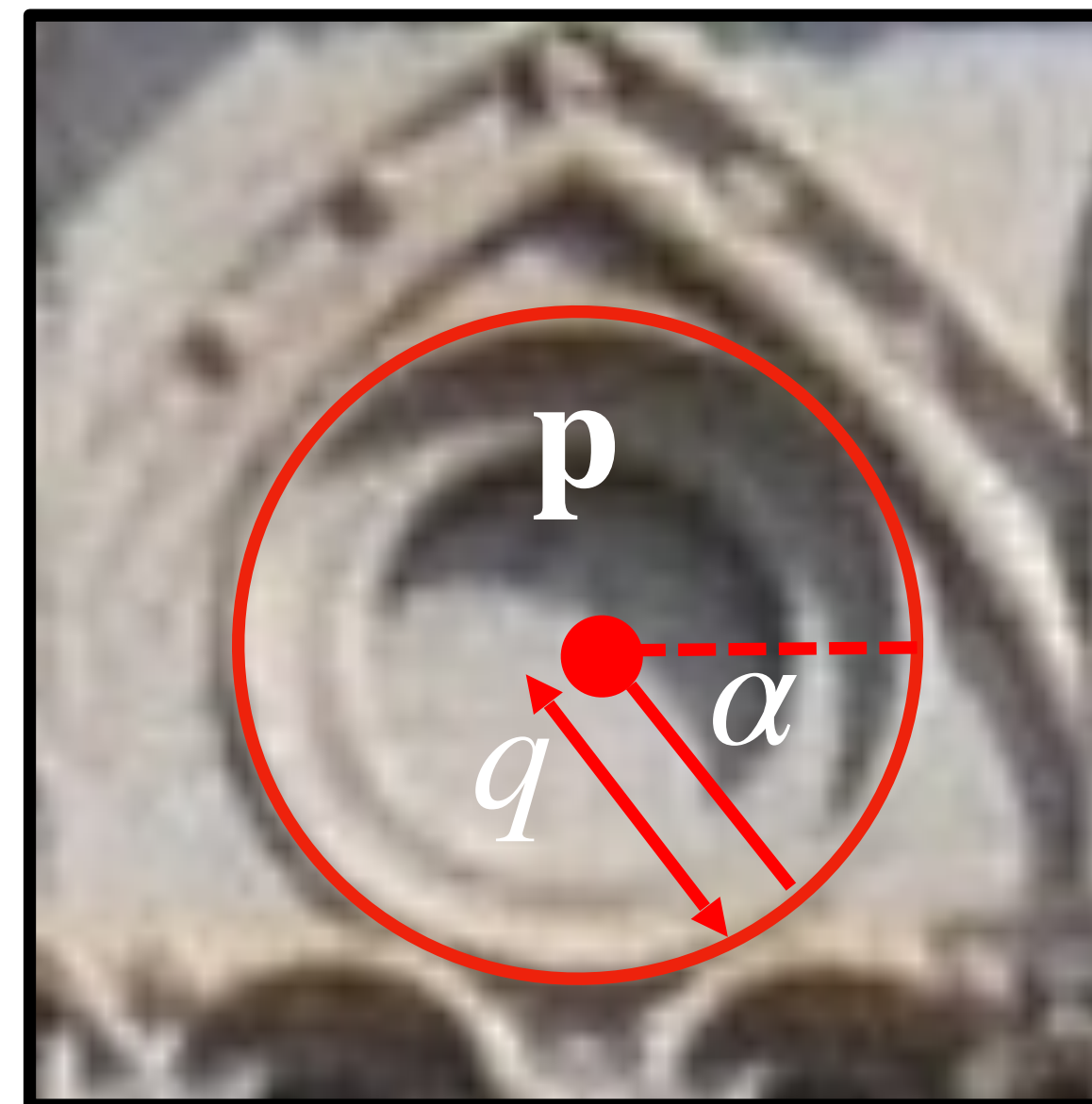 Unsupervised learning (Lee et al. 2021)

Keypoint scale estimation:
- Difference-of-Gaussian (DOG) detection (Lowe 2004)
- Harris-Laplace corner detector (Mikolajczyk and Schmid 2001)
- Learned features (Ono et al. 2018, Yi et al. 2016)
- Separately learned network (Lee et al. 2021)

Reference Image

Query Image
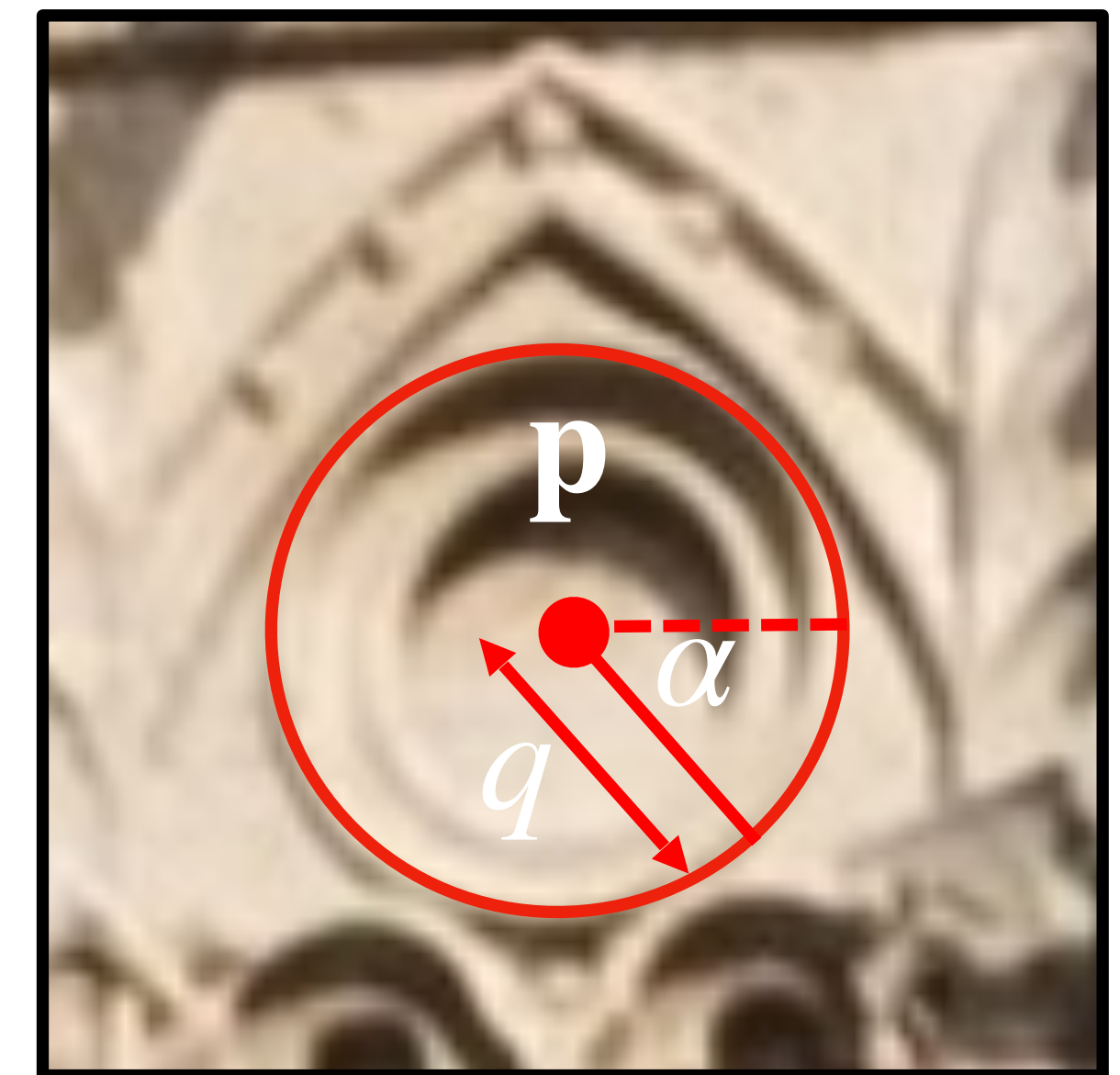
$\mathbf{p}$: feature location

α: feature orientation

q: feature scale

Problem definition

Compute absolute pose of query image given one or more scaled and oriented feature correspondences

Assume knowledge of 3D point and surface normal

Surface normal

d

Point depth

$\mathbf{n}$

$\mathbf{p}_{\text{ref}}$

$\mathbf{p}_{\text{query}}$

Query image

$[\mathbf{R}_{\text{query}} \,|\, \mathbf{t}_{\text{query}}]$

Reference image

$[\mathbf{R}_{\text{ref}} \,|\, \mathbf{t}_{\text{ref}}]$
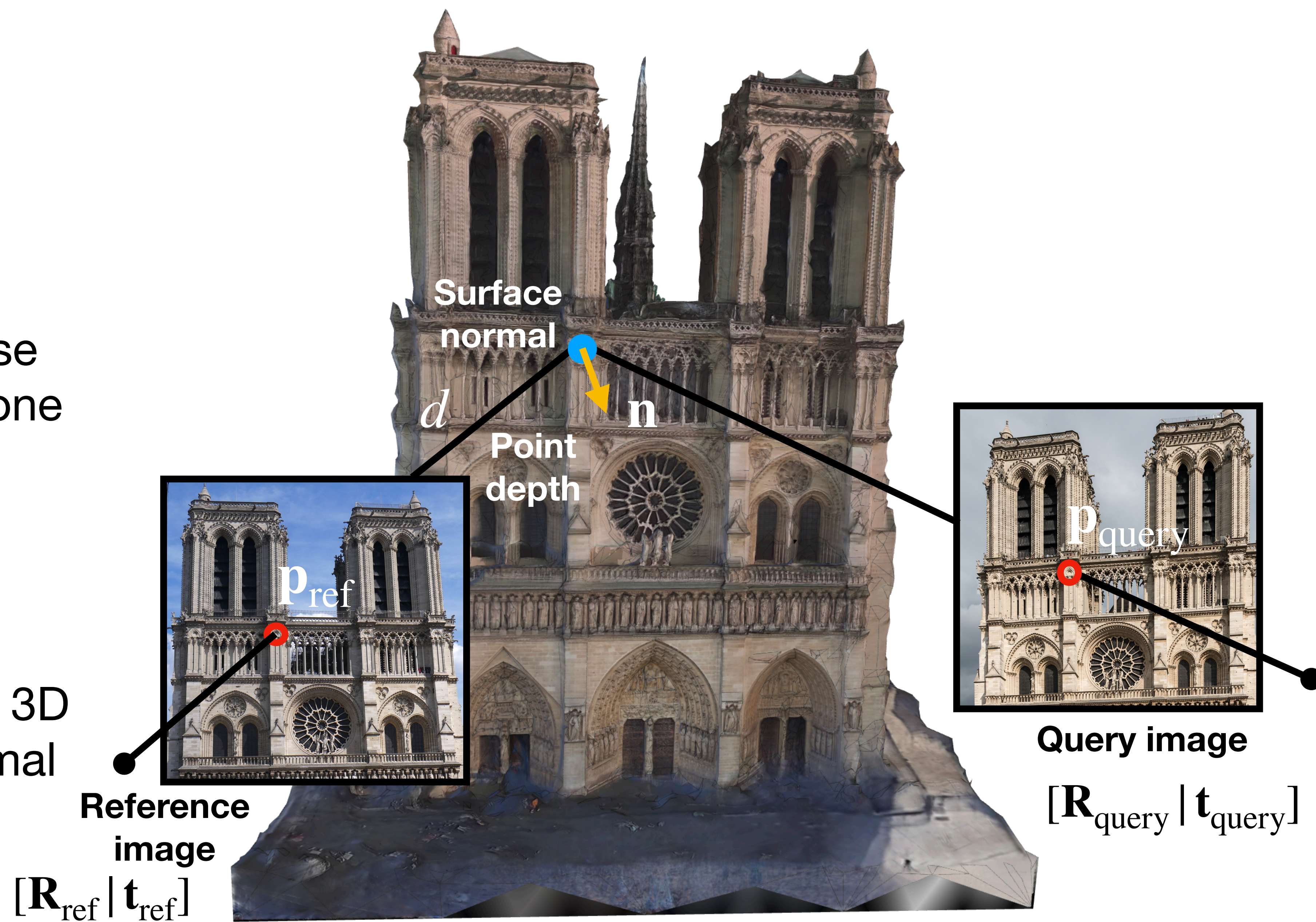
Our contributions

Develop novel constraints on absolute pose from scale-and-orientation features

Introduce two new minimal solvers for pose estimation from one or two scale-and-orientation features
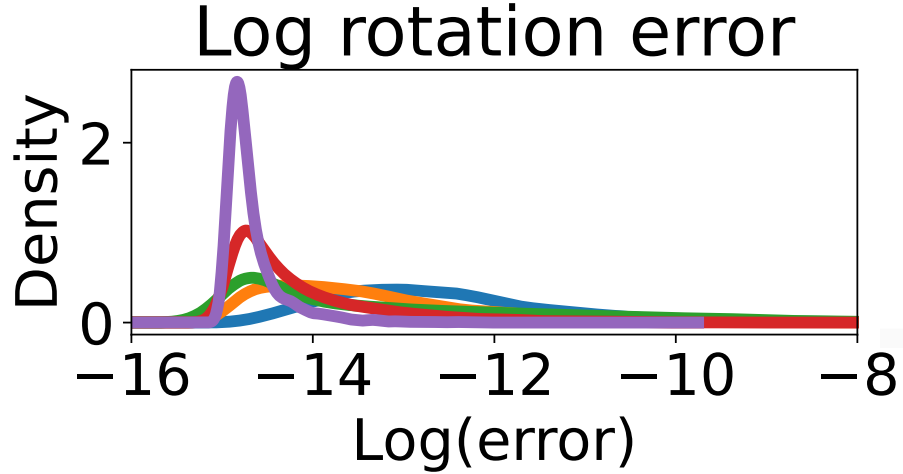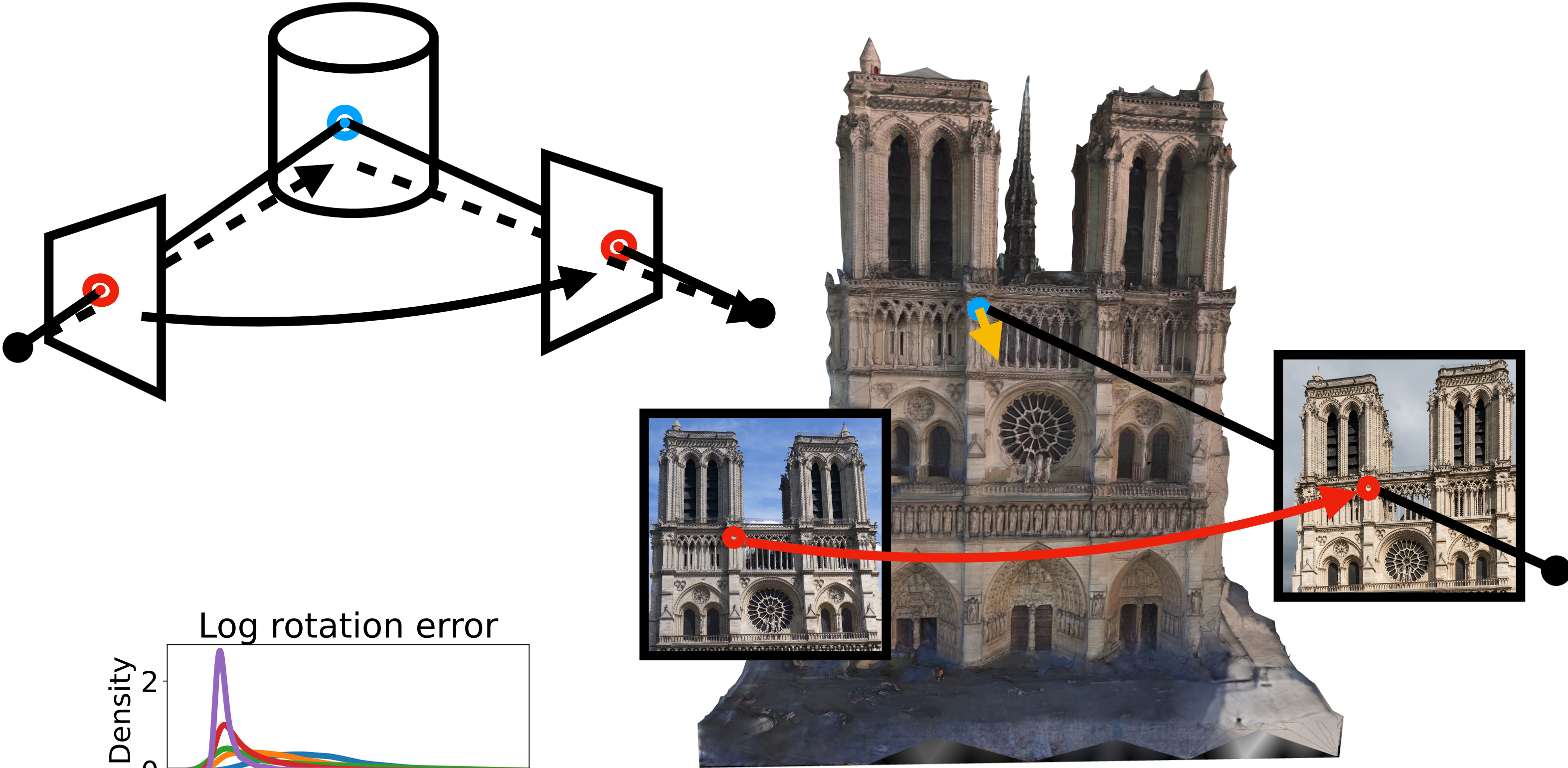
Experiments

Establish numerical stability and performance under noise

Show that our proposed methods improve recall and run-time in image-based localization

Log rotation error

Aachen Day-Night
(Sattler et al. 2018)

Affine Correspondence Constraint (Ventura et al. 2023)

Point depth

d

Reference image

$\mathbf{n}$
Surface normal

Query image

$\mathbf{y}$

$\mathbf{v}$

$\mathbf{x}$

$\mathbf{u}$

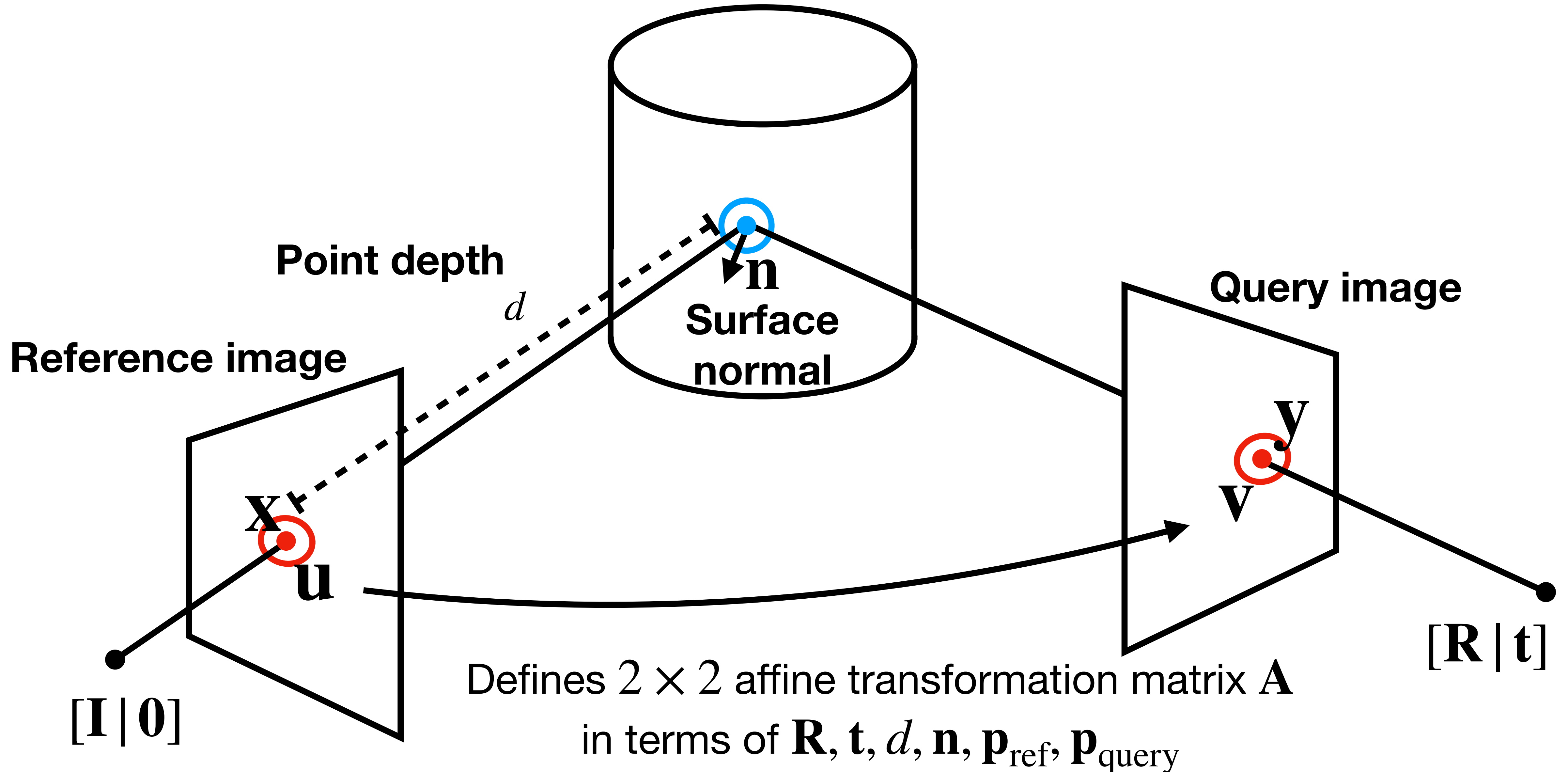$[\mathbf{R} \,|\, \mathbf{t}]$

$[\mathbf{I} \,|\, \mathbf{0}]$

Defines 2×2 affine transformation matrix $\mathbf{A}$
in terms of $\mathbf{R}, \mathbf{t}, d, \mathbf{n}, \mathbf{p}_{\text{ref}}, \mathbf{p}_{\text{query}}$

Ventura, Kukelova, Sattler and Baráth. P1AC: Revisiting absolute pose from a single affine correspondence. ICCV 2023.

Scale & Orientation Constraints

Two constraints relating $\mathbf{A}$, α_{ref}, q_{ref}, α_{query}, and q_{query}.

Orientation constraint

Derived from scale & orientation constraints.

One constraint relating $\mathbf{A}$, α_{ref}, and α_{query}.

Reference Image

Query Image

α_{ref}

q_{ref}

q_{query}

α_{query}

$\mathbf{A}$

Baráth and Kukelova. Relative pose from SIFT features. ECCV 2022.
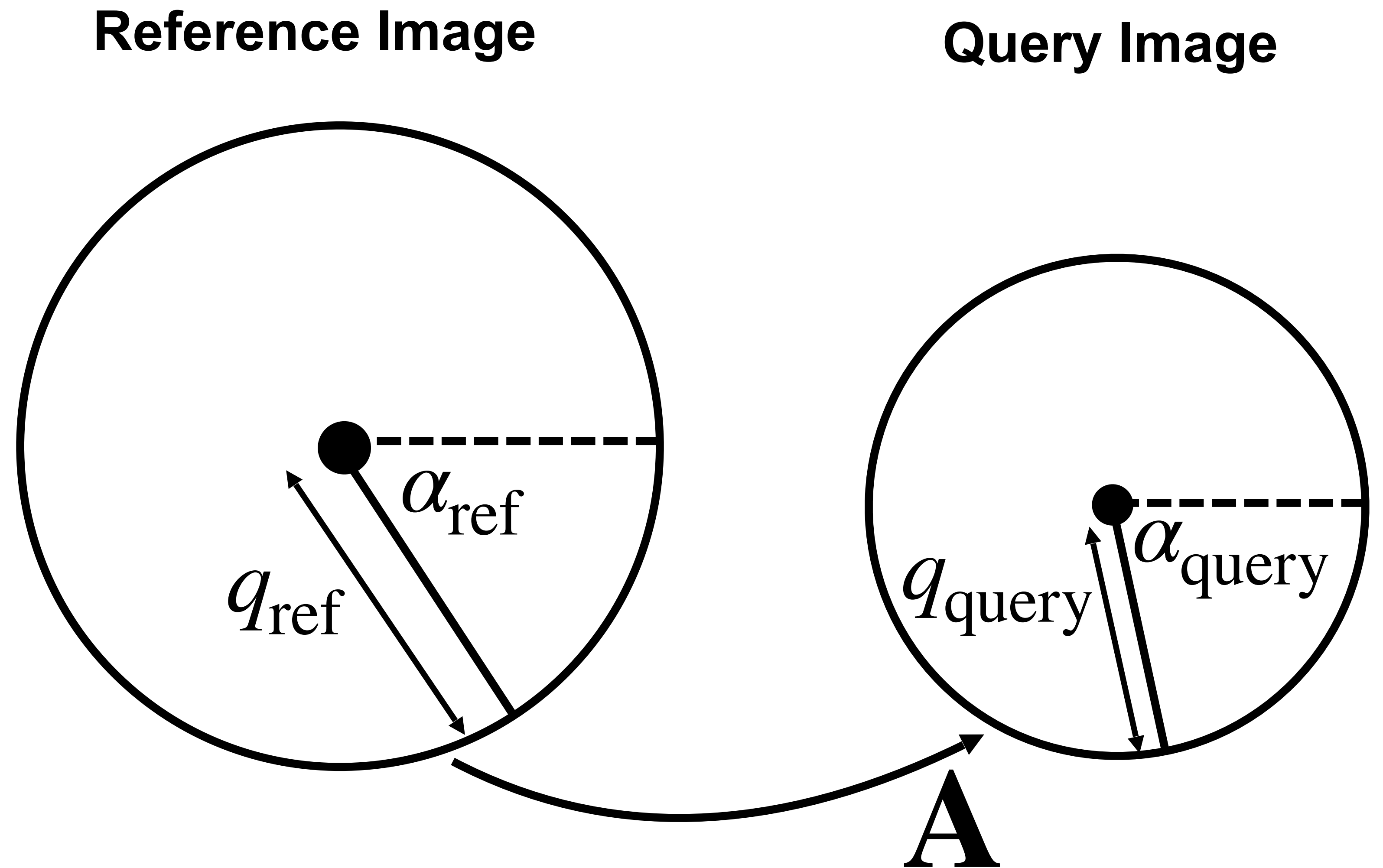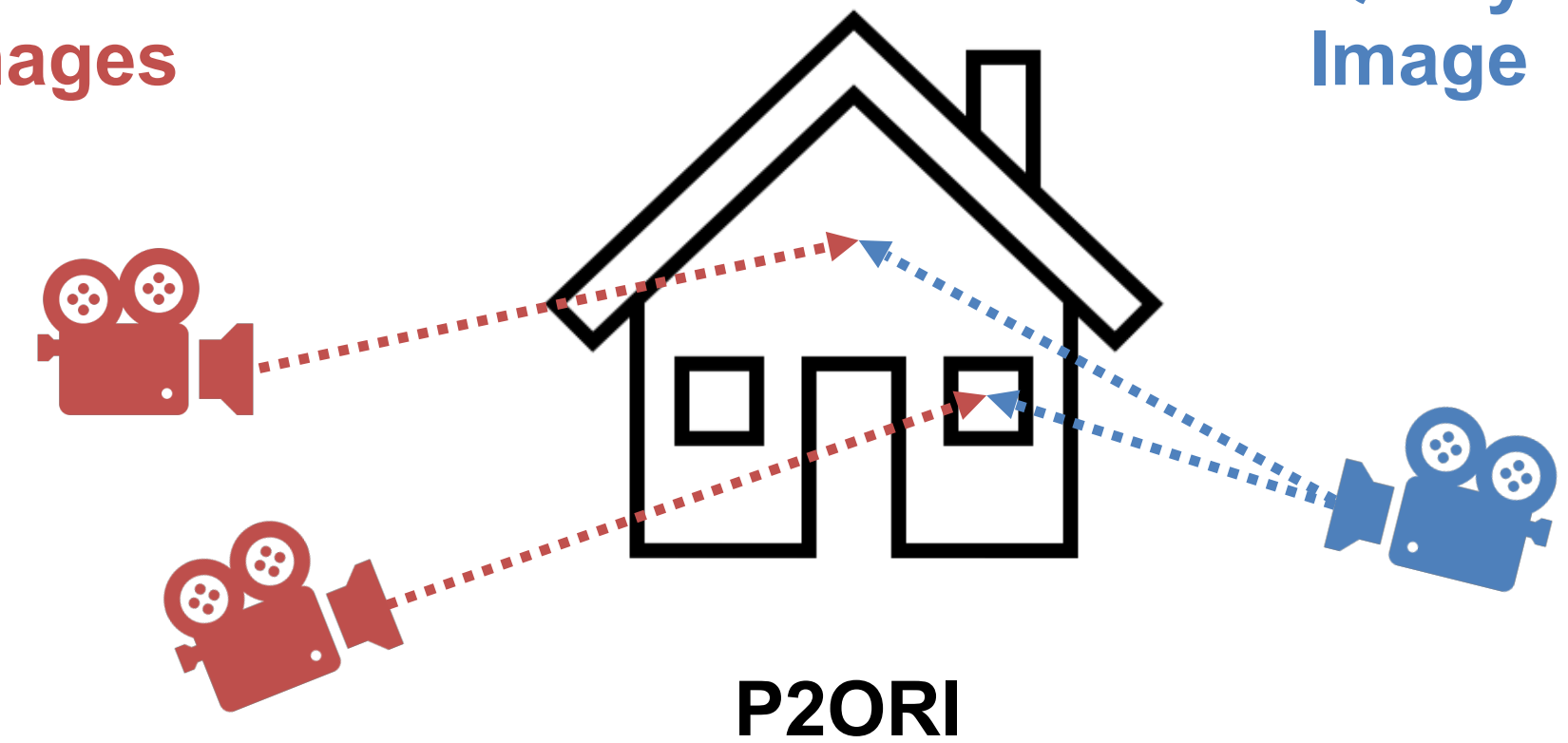
Novel Minimal Solvers

P2ORI: Pose from Two Oriented Observations

Point projections + orientation constraints = six equations.

After Gauss-Jordan elimination, apply Cayley parameterization to produce a 3Q3 problem (Kukelova et al. 2016).
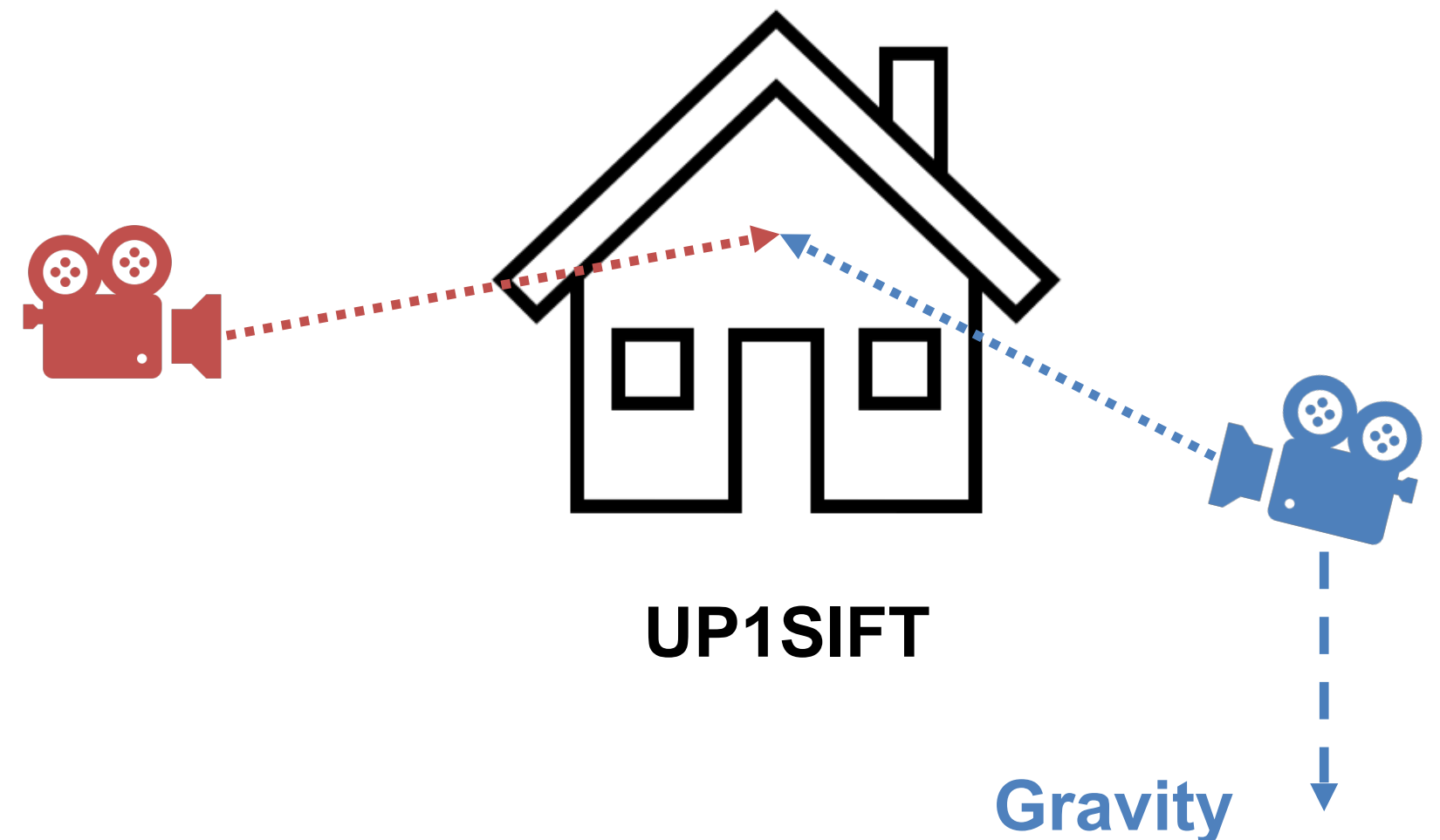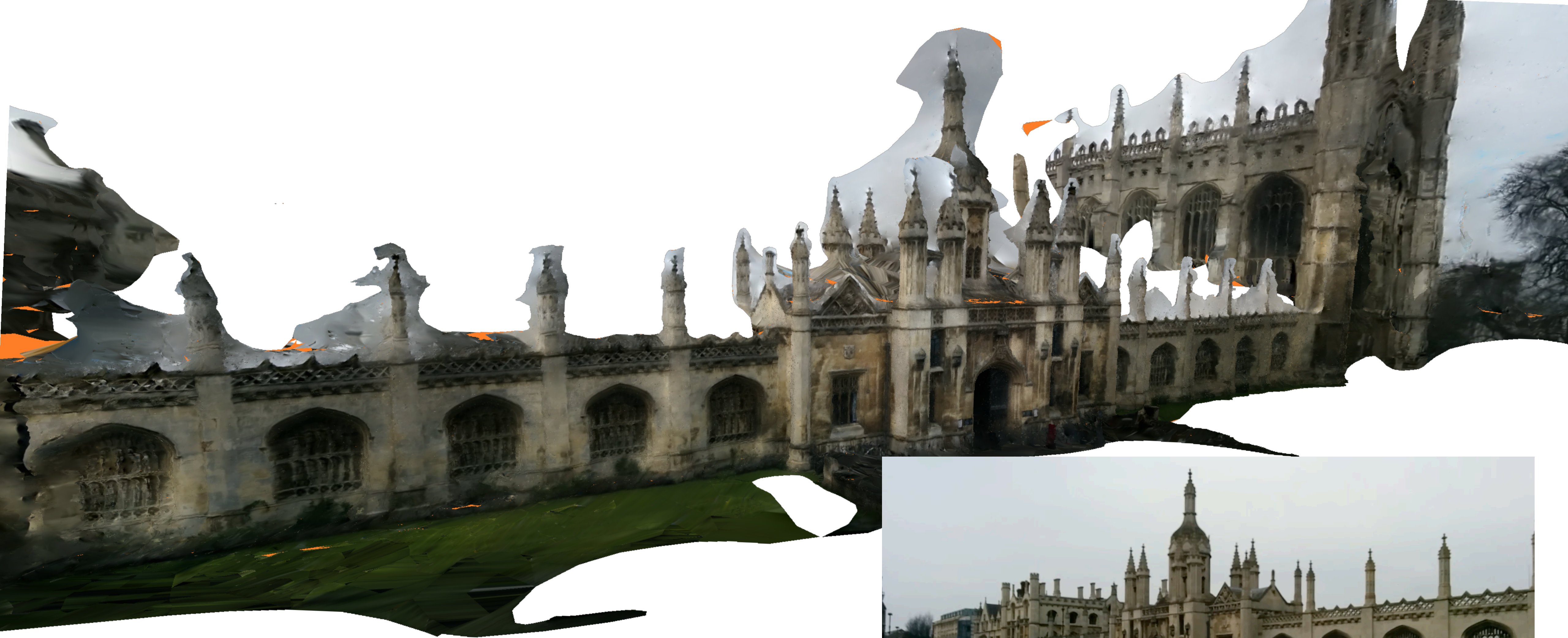
UP1SIFT: Upright Pose from One Scale+Ori Feature

Assume known gravity direction to remove two rotational degrees of freedom.
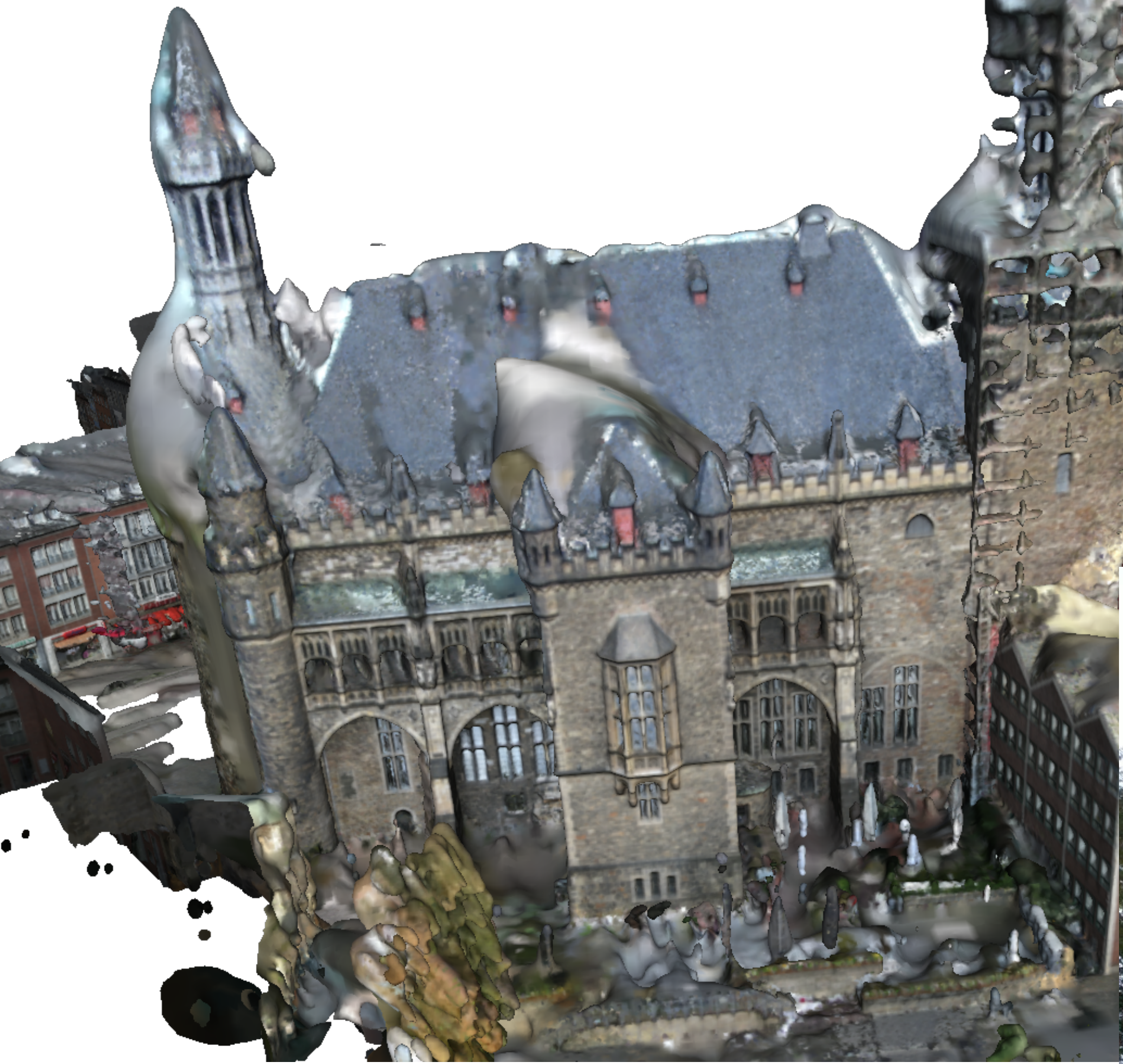
Point projection + scale&ori constraints = four equations.

After Gauss-Jordan elimination, apply half-angle parameterization to produce a single quadratic polynomial.

Reference Images

Query Image

P2ORI

UP1SIFT

Gravity

Z. Kukelova et al. Efficient intersection of three quadrics and applications in computer vision. CVPR 2016.

Cambridge Landmarks
(Kendall et al. 2015)

Kendall, Grimes and Cipolla. PoseNet: A convolutional neural network for real-time 6-DOF camera relocalization. ICCV 2015.

Day

Night

Aachen Day-Night
(Sattler et al. 2018)

Sattler et al. Benchmarking 6dof outdoor visual localization in changing conditions. CVPR 2018.
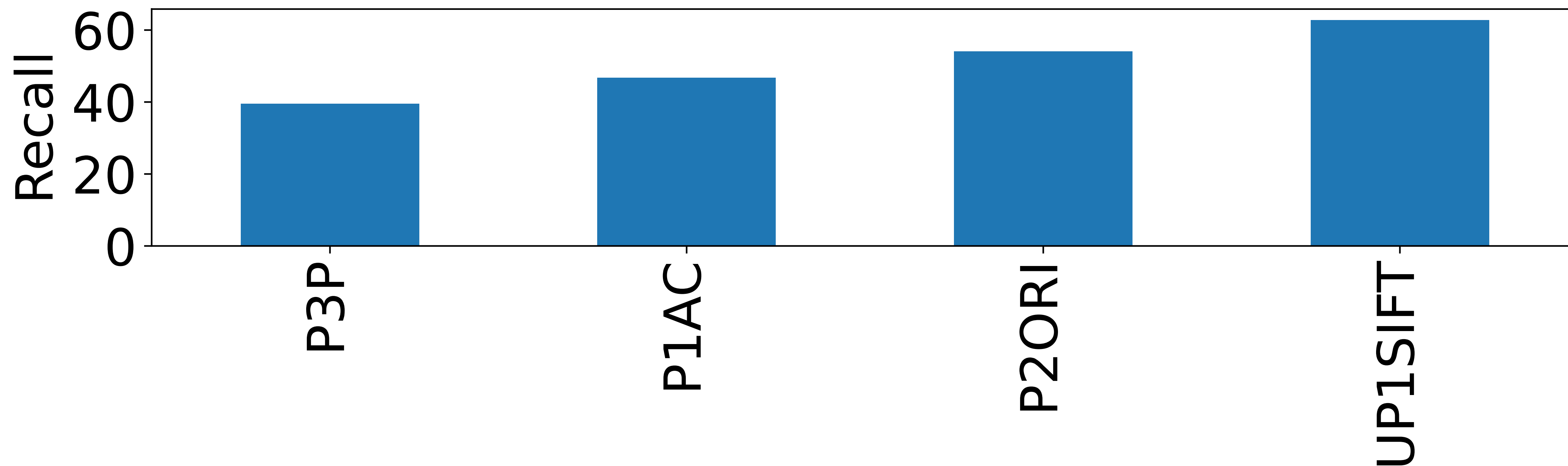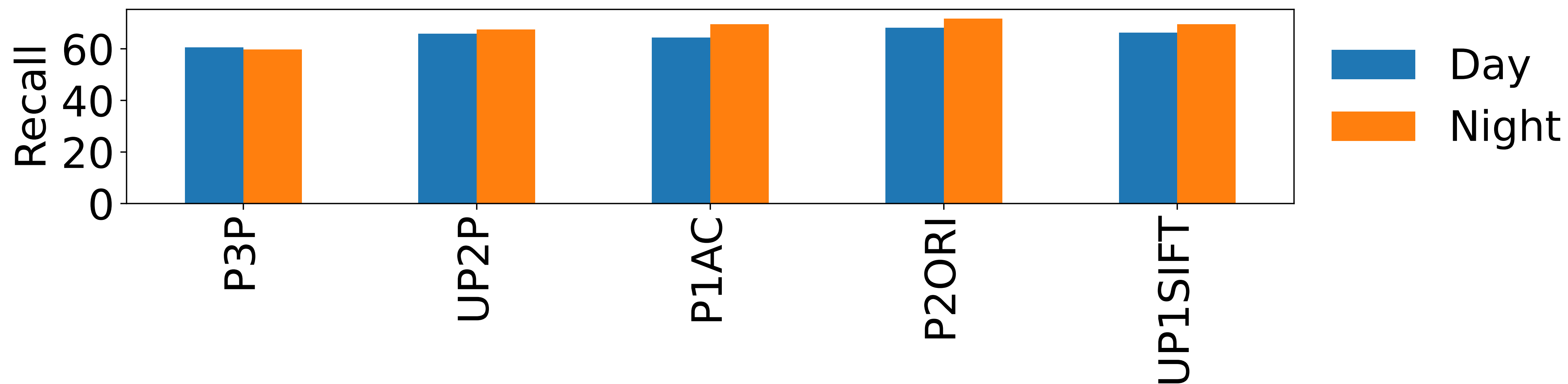
Cambridge Landmarks Recall @ 0.05m/1°

Persson and Nordberg. Lambda Twist: An accurate and fast robust perspective three point (P3P) solver. ECCV 2018.
Ventura, Kukelova, Sattler, and Baráth. P1AC: Revisiting absolute pose from a single affine correspondence. ICCV 2023.

Aachen Day/Night Recall @ 0.25m/2°

Persson and Nordberg. Lambda Twist: An accurate and fast robust perspective three point (P3P) solver. ECCV 2018.
Ventura, Kukelova, Sattler, and Baráth. P1AC: Revisiting absolute pose from a single affine correspondence. ICCV 2023.
Z. Kukelova et al. Closed-form solutions to minimal absolute pose problems with known vertical direction. ACCV 2010.

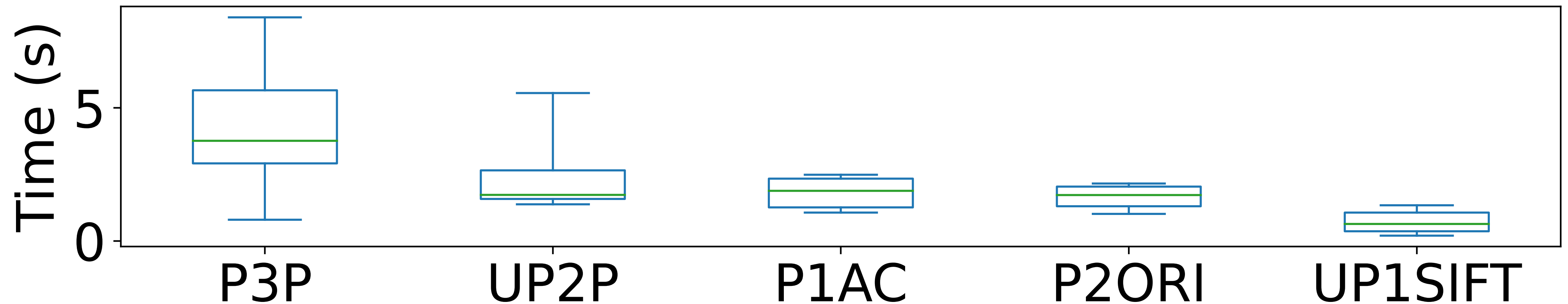# Average GC-RANSAC Timing (all datasets)

Persson and Nordberg. Lambda Twist: An accurate and fast robust perspective three point (P3P) solver. ECCV 2018.
Ventura, Kukelova, Sattler, and Baráth. P1AC: Revisiting absolute pose from a single affine correspondence. ICCV 2023.
Z. Kukelova et al. Closed-form solutions to minimal absolute pose problems with known vertical direction. ACCV 2010.

Conclusions and Future Work

- Derived novel constraints and minimal solvers for absolute pose from scaled and oriented features

- Achieved higher recall and faster query times on benchmark datasets compared to P3P and other baseline methods

- Future work includes exploring solvers for uncalibrated, generalized, and non-minimal problems and integrating our methods into SfM and SLAM systems

- Code available: https://github.com/danini/absolute-pose-from-oriented-and-scaled-features