IWMV 2014

GPS Refinement and Camera Orientation Estimation from a Single Image and a 2D Map

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Outline

- Introduction
- Approach
- Experimental Results
- Conclusions

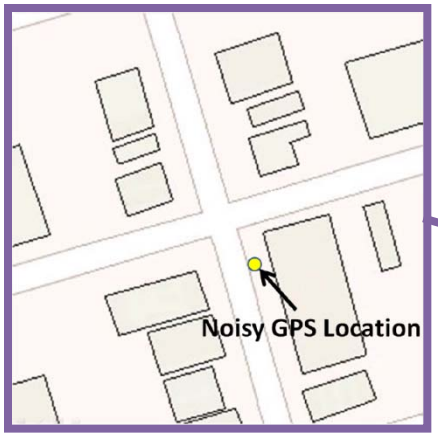
Motivation

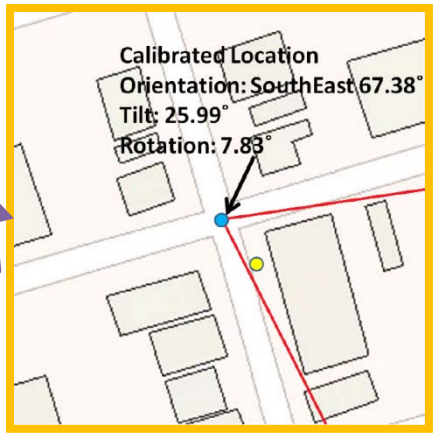
1. Minimal Image Analysis
2. “Refine” Location

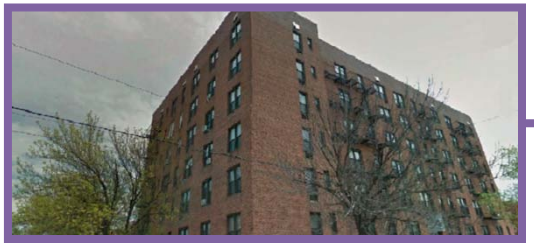
Lightweight but intelligent way of combining GPS & image

[Zandbergen et al. JoN11]

Introduction







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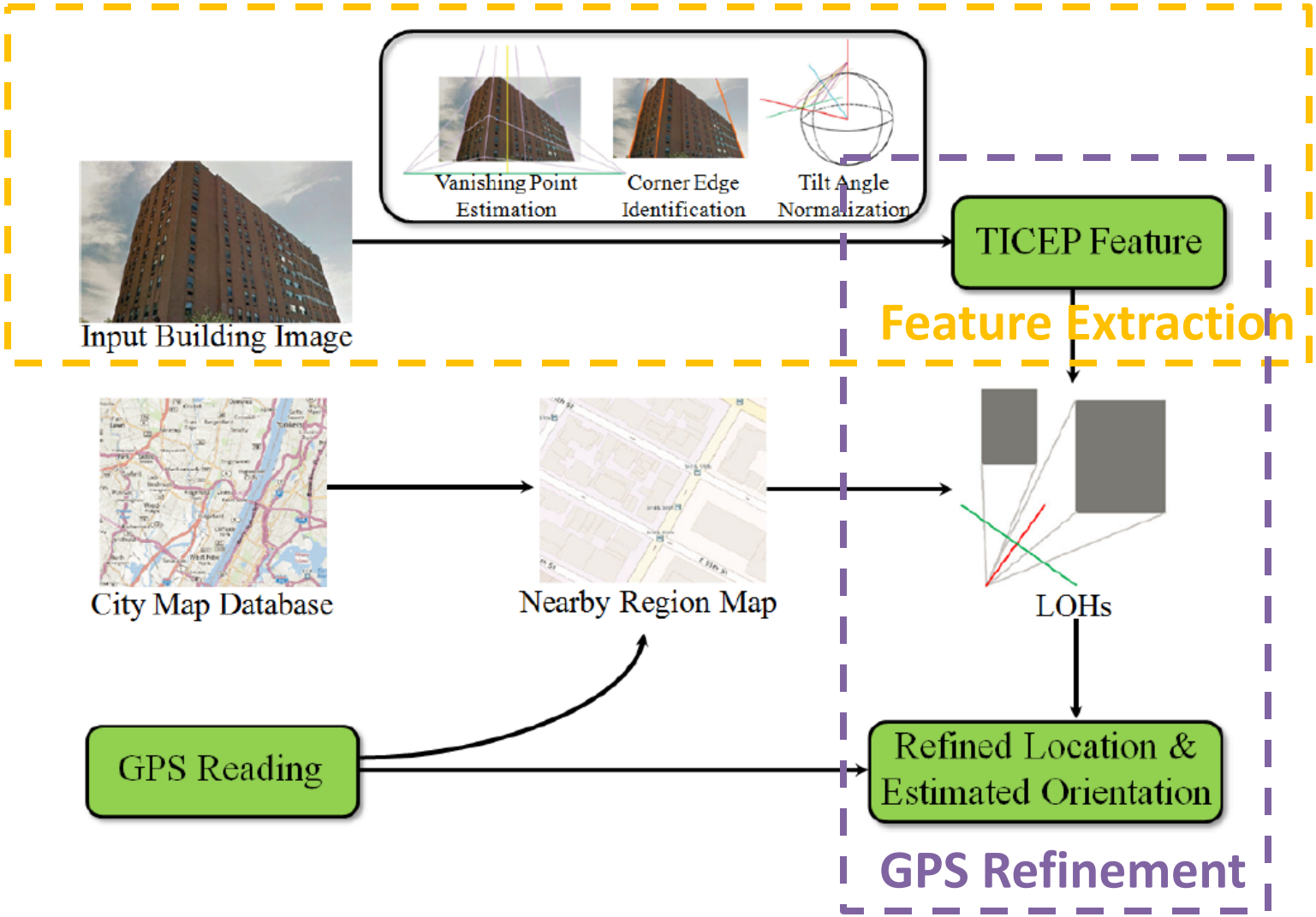
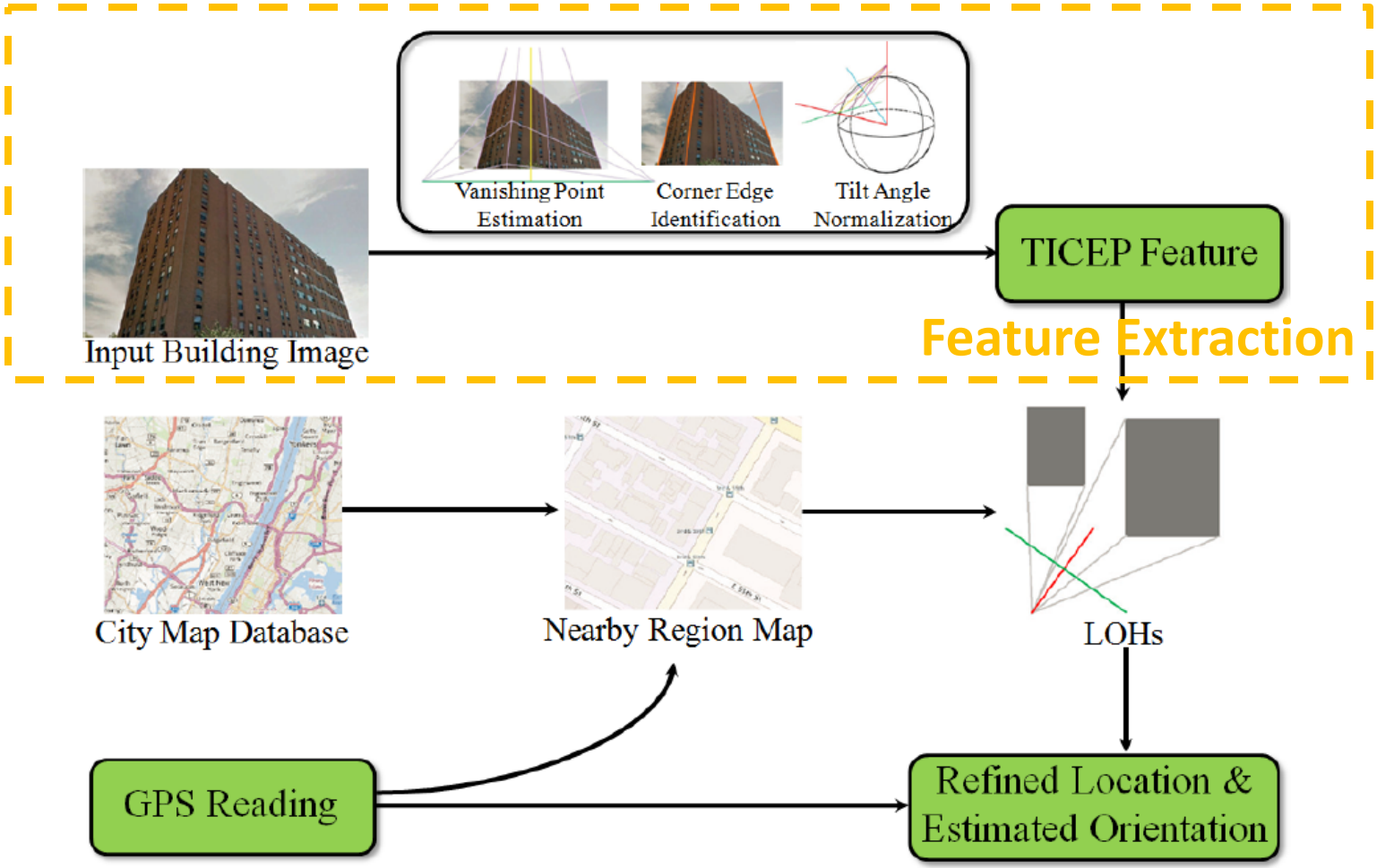
Approach


Vanishing Point Estimation
Corner Edge Identification
Tilt Angle Normalization
Input Building Image
TICEP Feature
Feature Extraction
City Map Database
Nearby Region Map
LOHs
GPS Reading
Refined Location & Estimated Orientation
GPS Refinement

Approach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Feature Extraction

1. Estimate vanishing points from line segments of the segmented image.

[Gioi et al. PAMI10] [Tardif et al. ICCV09]

Feature Extraction

2. Identify vertical building boundary/intersecting corner edges.

Boundary:

$$Scr_{BCE}(j) = Scr_c(j) + Scr_p(j) + Scr_l(j)$$

- Horizontal Color Gradient
- Segment Vertical Steepness
- Adjacent Horizontal Line Condition

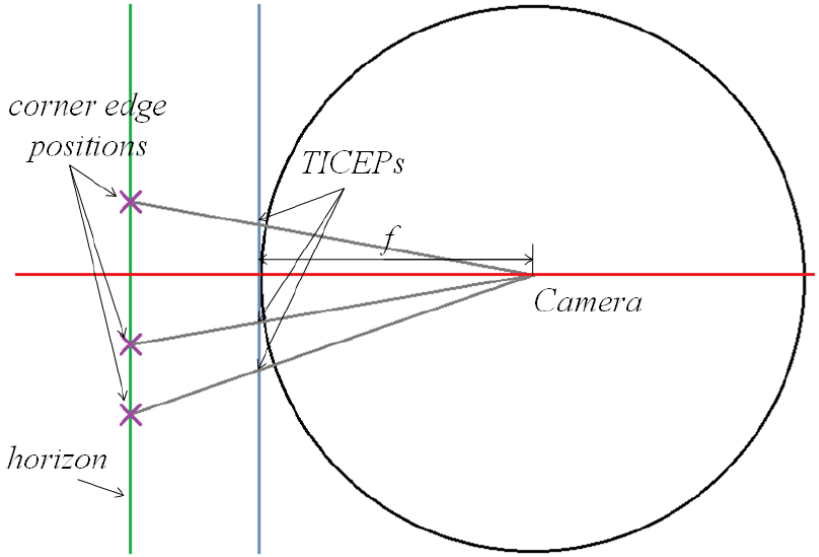
Intersecting:

Longest vertical line segment where lines from different horizontal *vps* meet.

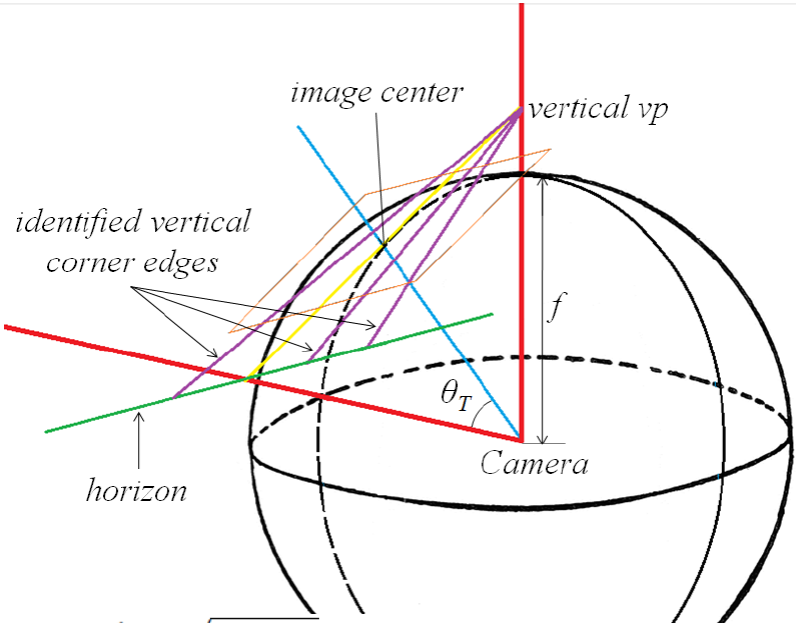
85.73% Accuracy

Feature Extraction

3. Compute Tilt-Invariant Corner Edge Position by normalizing the tilt angle.



$$TICEP_i = p_{ix}\cos(\theta_T)$$

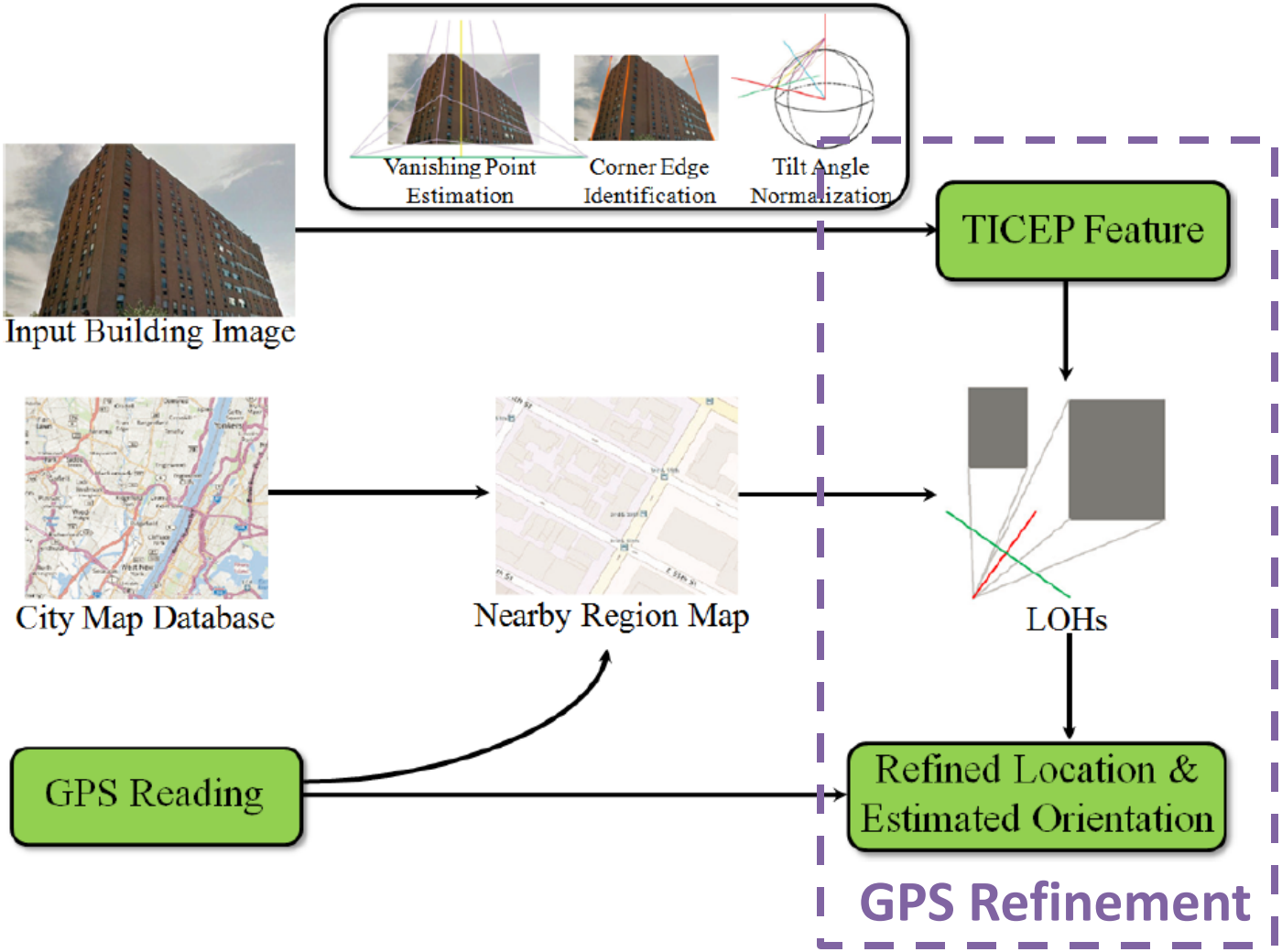


$$tan(\theta_T) = \begin{cases} \frac{h-\sqrt{h^2-4f^2}}{2f} & \text{when } |v_{vy}| > |v_{1y}| \\ \frac{h+\sqrt{h^2-4f^2}}{2f} & \text{when } |v_{vy}| \leq |v_{1y}| \\ 0 & \text{when } v_{vy} = -\infty \end{cases}$$

$$f = \sqrt{-v_{vy}v_{1y}}$$

$$h = |v_{vy}| + |v_{1y}|$$

Approach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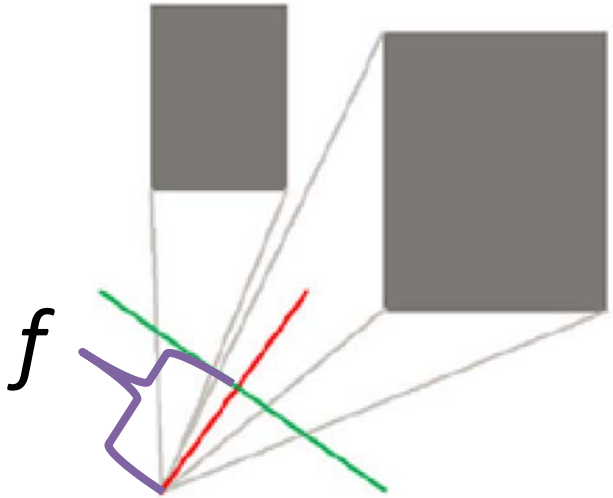
GPS Refinement

GPS Refinement

Given a set of corner edge positions, and a set of locations on the map, a Location-Orientation Hypothesis can be computed.



$$(\boldsymbol{x}_{LOH}, \boldsymbol{n}_{LOH}) = \underset{(\boldsymbol{x},\boldsymbol{n})}{\arg\min} \sum_{1 \le i \le N_p} ||\boldsymbol{q}_i - \boldsymbol{inter}_i||^2$$

$$\boldsymbol{inter}_i = (\boldsymbol{x} \times \boldsymbol{c}_{hi}) \times (\boldsymbol{q}_1 \times \boldsymbol{q}_2)$$

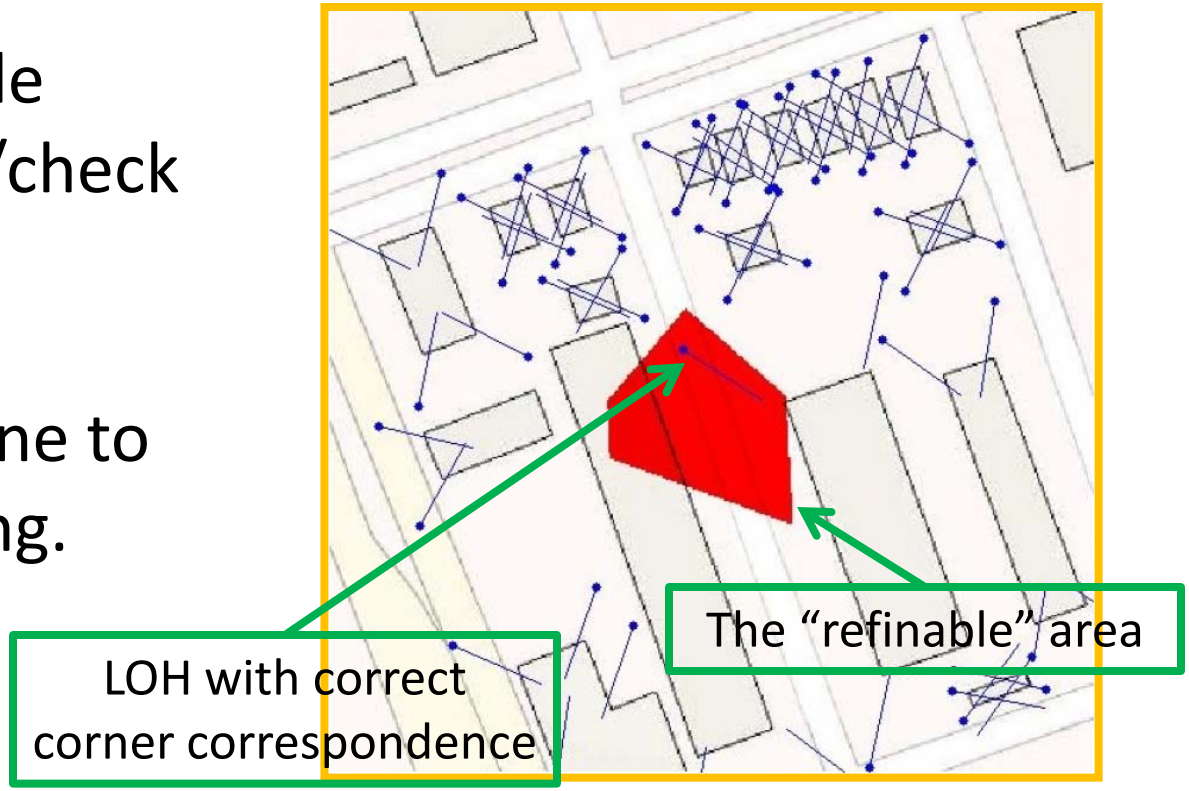
$$\boldsymbol{q}_i = \boldsymbol{x} + f\boldsymbol{n} + TICEP_i\boldsymbol{n}_\perp$$

GPS Refinement

Compute a Location-Orientation Hypothesis for every possible corner correspondence on the map.

Discard unreasonable hypotheses (indoor/check visibility).

Select the nearest one to the noisy GPS reading.



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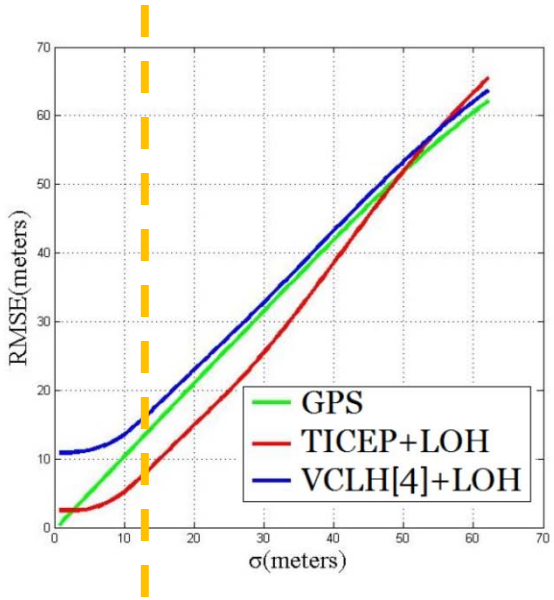
Experimental Results

RMSE of location and orientation of the Location-Orientation Hypothesis that has correct map correspondence.

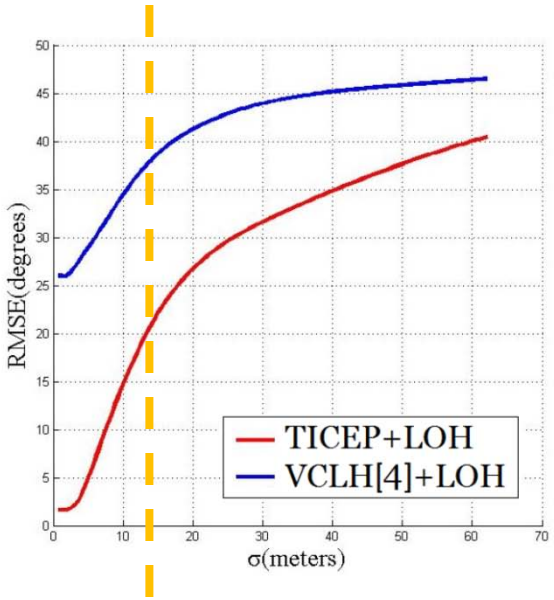
	Proposed Method	Using VCLH in [4]
Location	$2.48m$	$18.68m$
Orientation	$1.6°$	$5.9°$

[Cham et al. CVPR10]

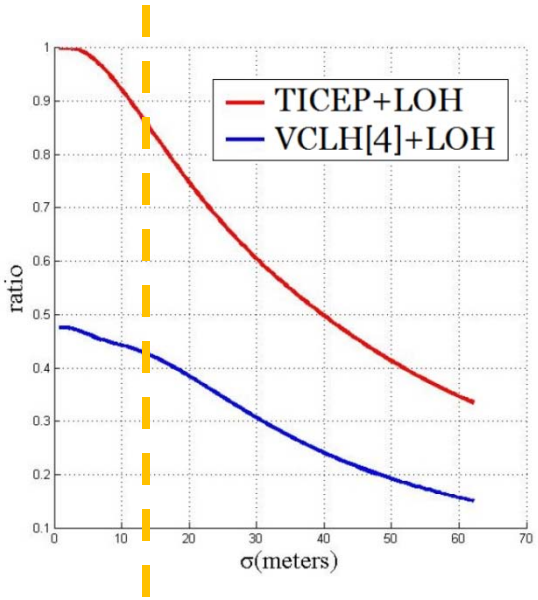
Experimental Results



Location Error



Orientation Error

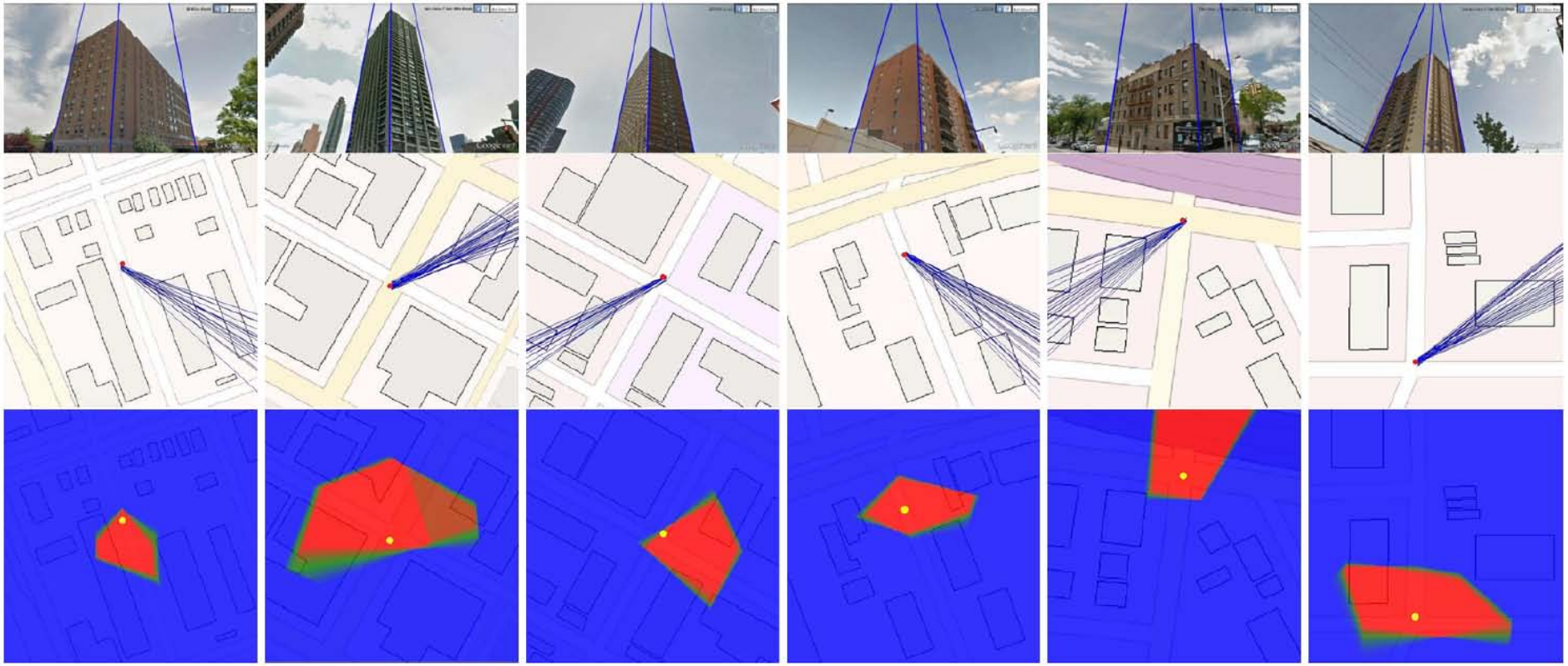


% of Correct LOH Selected

12.5m GPS → 6.89m, 17.96°

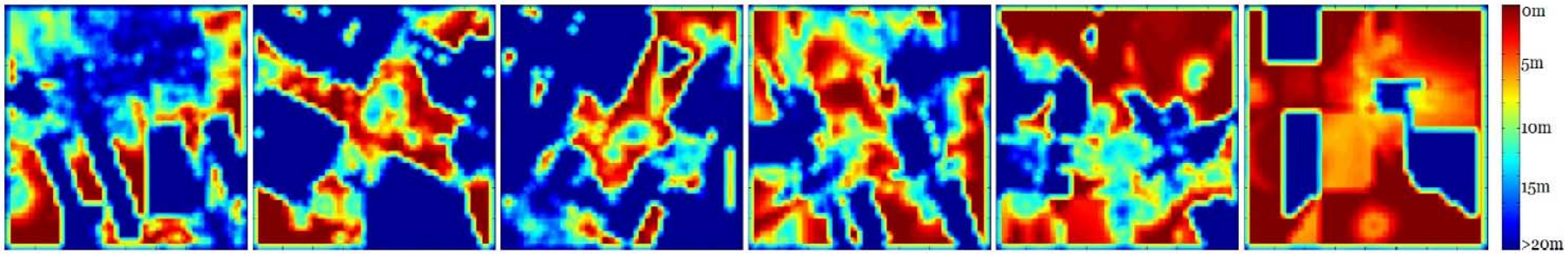
[Cham et al. CVPR10]

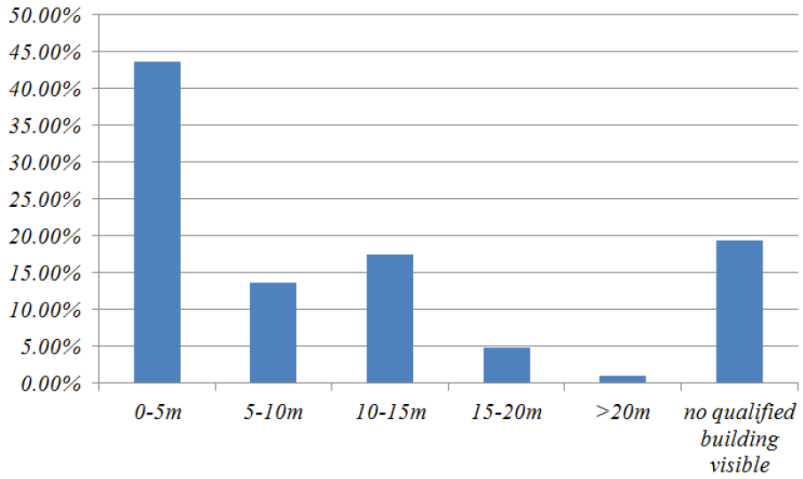
Experimental Results



Some results and “refinable areas”.

Experimental Results





Upper bound our refining method can achieve.

Mean: 6.70m

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Conclusions

- We present a framework for refining a noisy GPS location and estimating the camera orientation using a building image, and a 2D map.
- We propose to use Tilt-Invariant Corner Edge Positions as a better feature for representing building structures.
- We propose to use Location-Orientation Hypotheses to describe the interaction between extracted features and the map.

Conclusions

- A lightweight but intelligent way of combining GPS and image information
  - Minimal Image Analysis
  - Refine GPS Location

Thank you