



Tackling the Scale Factor Issue in a Monocular Visual Odometry Using a 3D City Model

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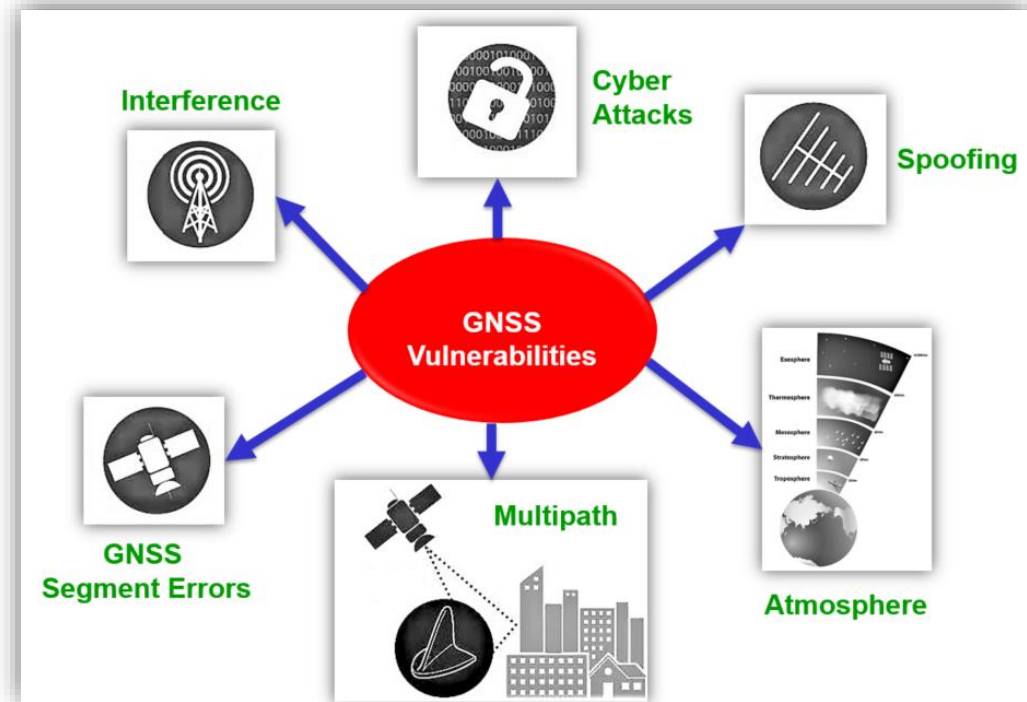
Introduction

- In open sky environment with good satellite visibility, GNSS provide seamless and accurate solutions

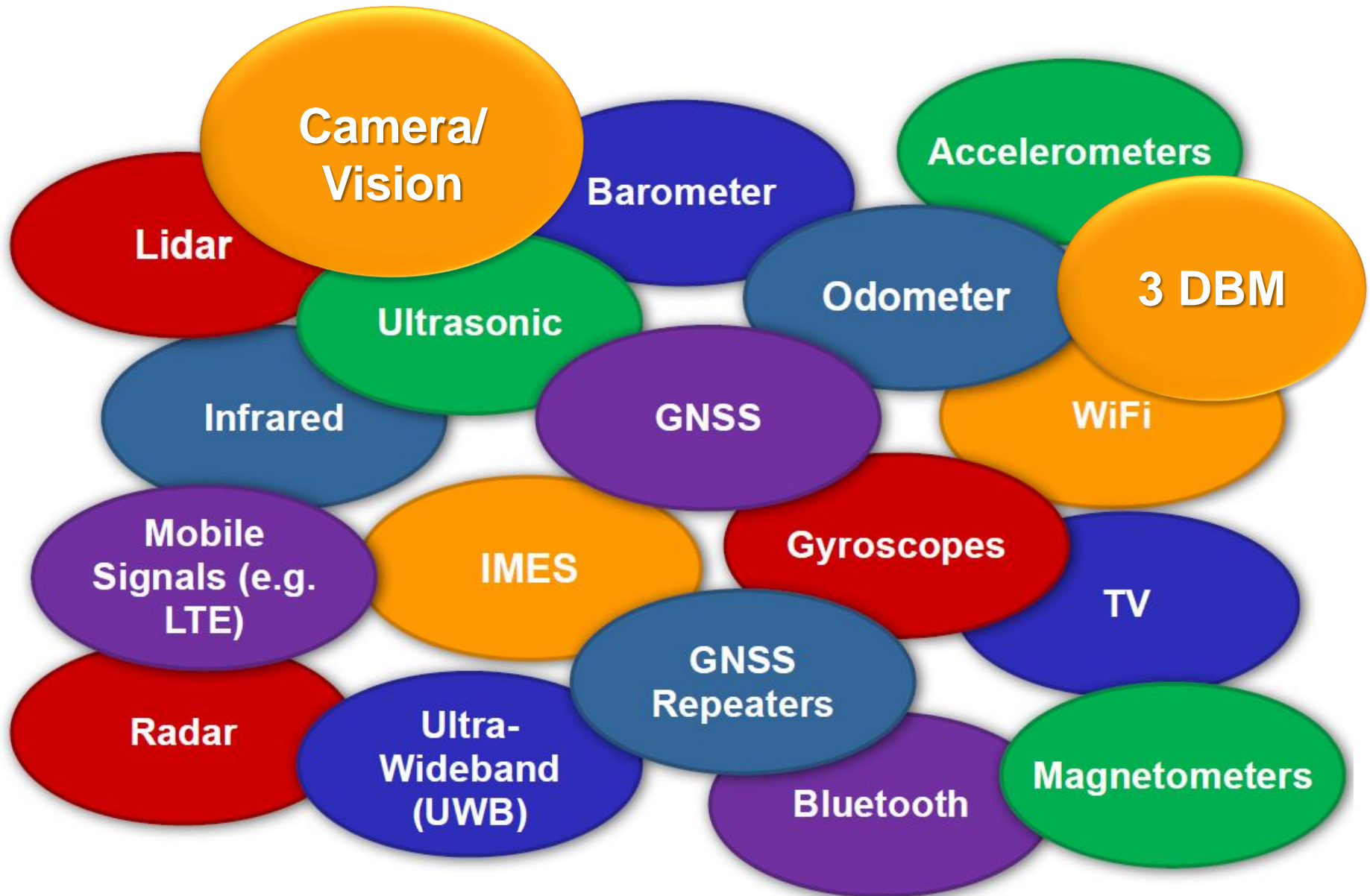
- However, in urban canyons
 - poor GNSS availability
 - corrupted GNSS signals

- In such areas, signals are classified in three groups

- Direct
- Shadowed
- **Blocked**

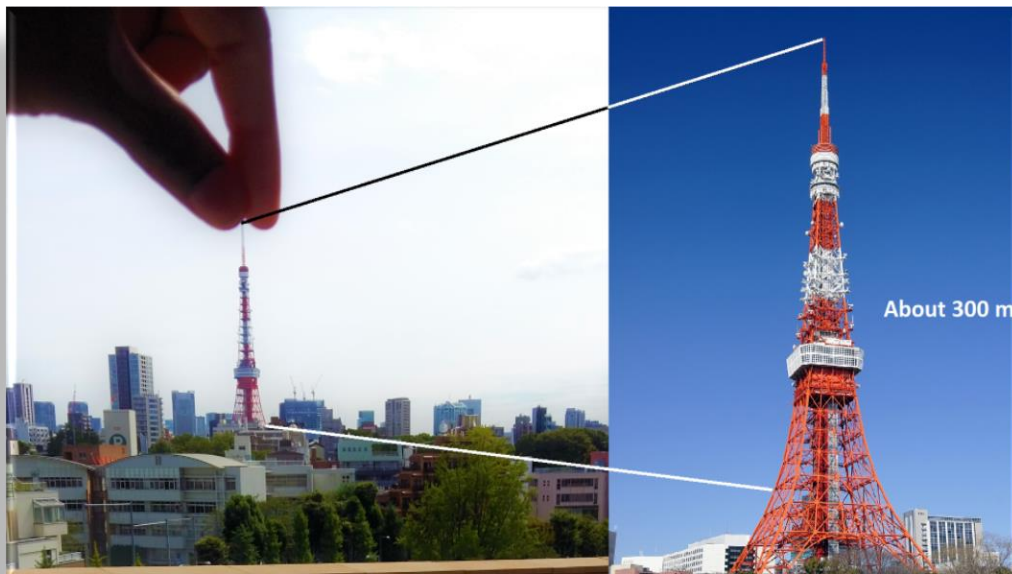


Various Existing Methods



Scale Factor (SF) Ambiguity – 1/2

A

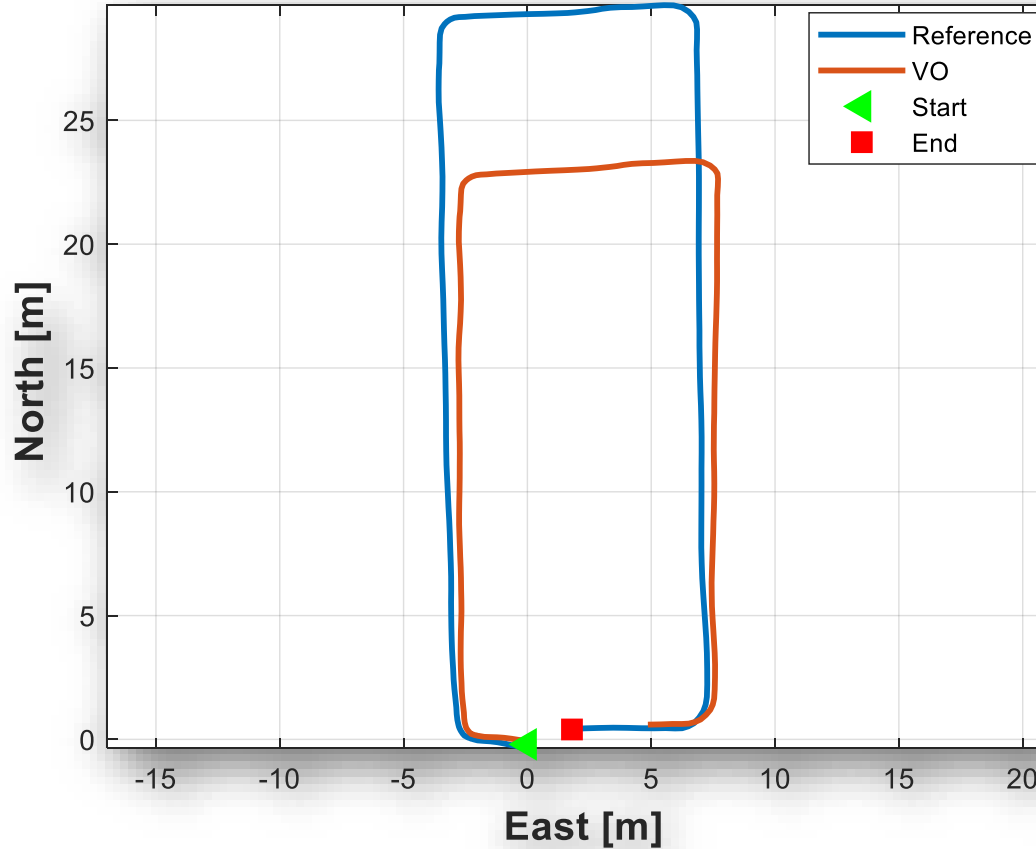


B



With a monocular system, overall scale cannot be directly measured

Scale Factor (SF) Ambiguity – 2/2



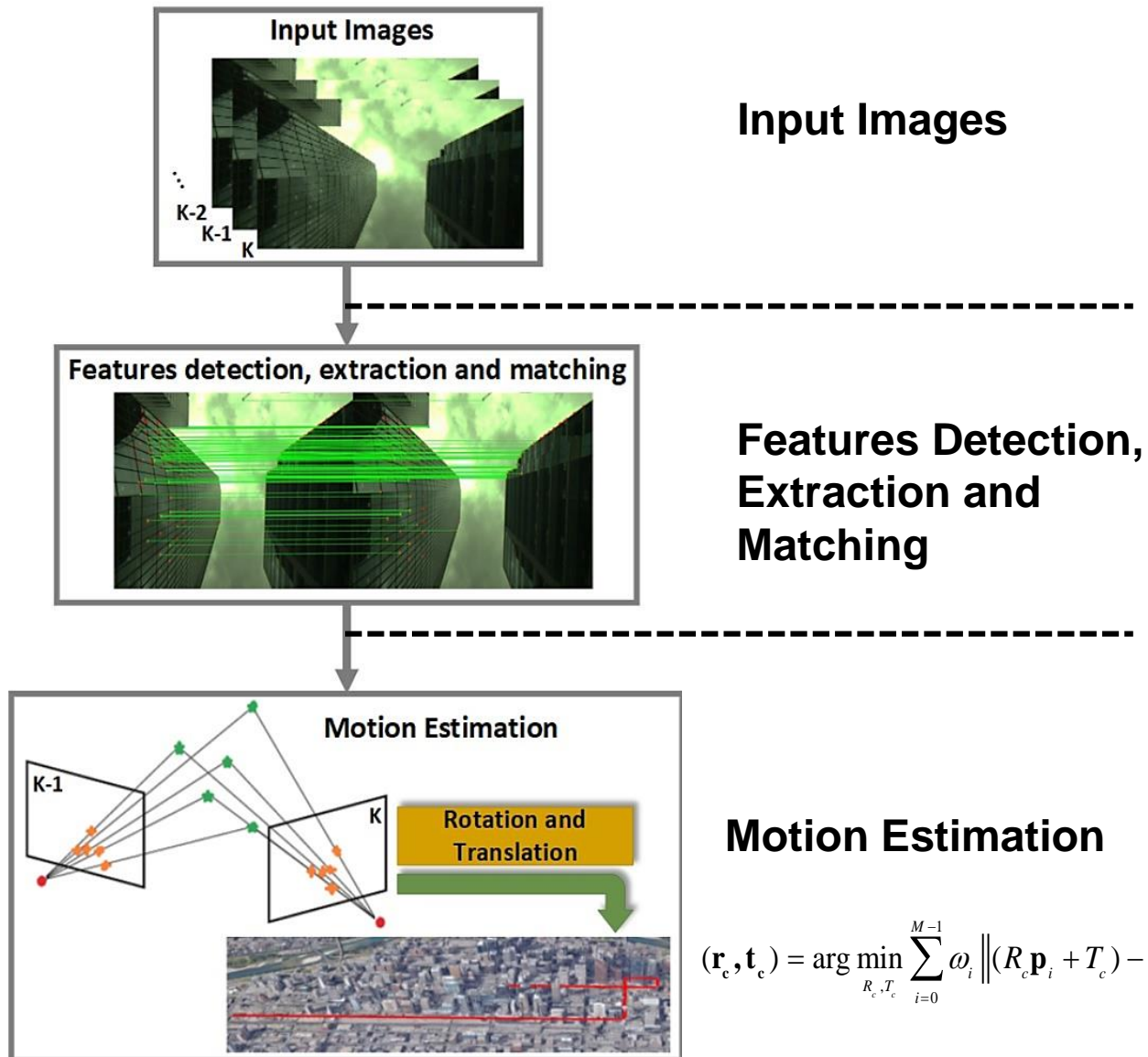
Solutions to the SF Ambiguity

- **INS can help to obtain scale, but INS error will lead to scale error, which leads to error in aiding INS, which leads to scale error**
- **There must be some absolute knowledge of scale somewhere in the system in order to avoid scale uncertainty**
 - **Baseline between stereo cameras**
 - **Feature locations/relative separations are known**
 - **Depth from defocus/coded apertures**
 - **In an aircraft, knowing altitude and ground height**

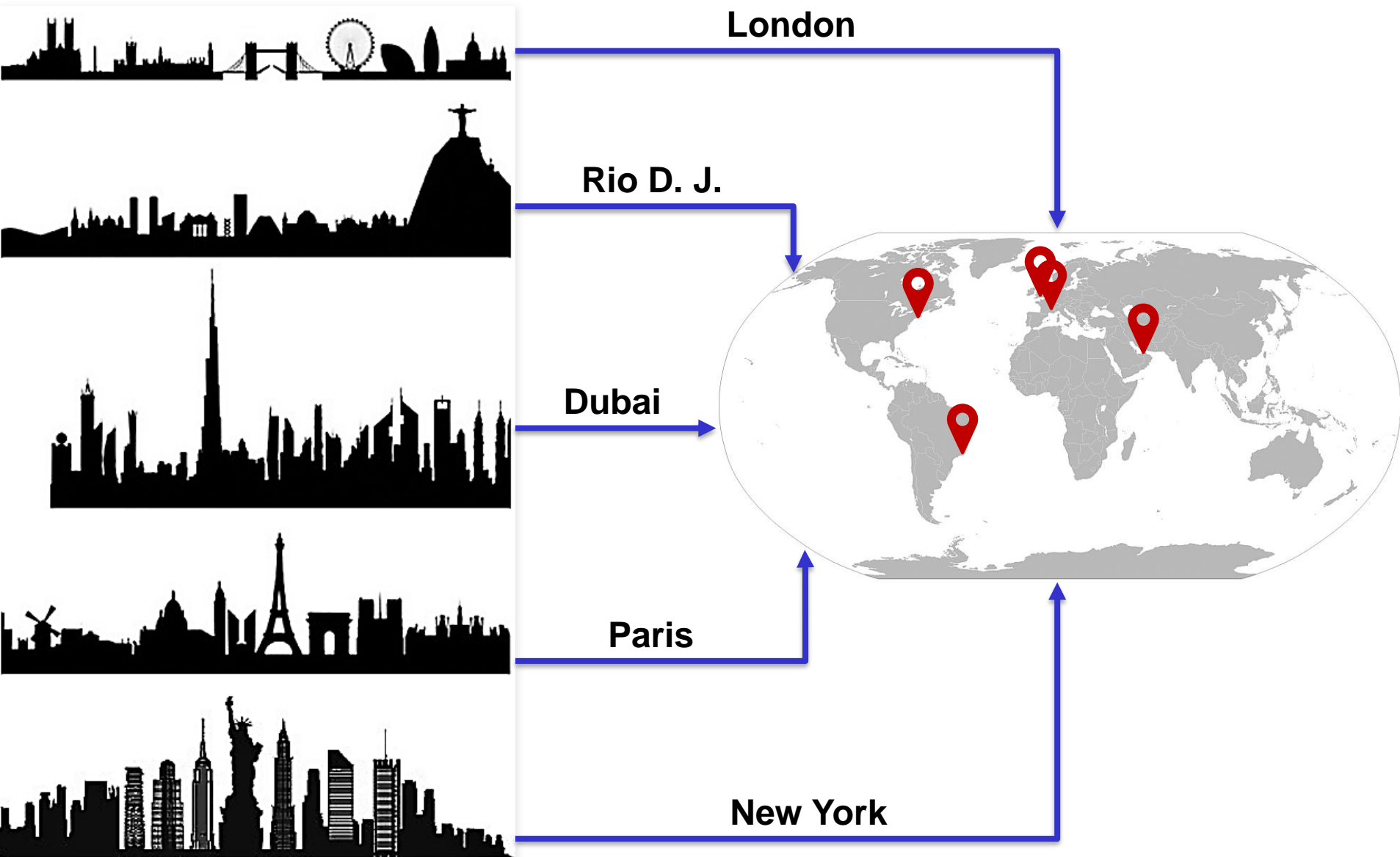
Objectives of the Research

- **Overcome the scale factor issue observed in a monocular VO**
 - **Combine the information obtained from a 3DBM by matching synthesized 3DBM images and camera images and also with VO**
 - **Calculate the scale factor from the 3DBM to increase the translation magnitude accuracy for monocular VO**

Methodology – 1/3

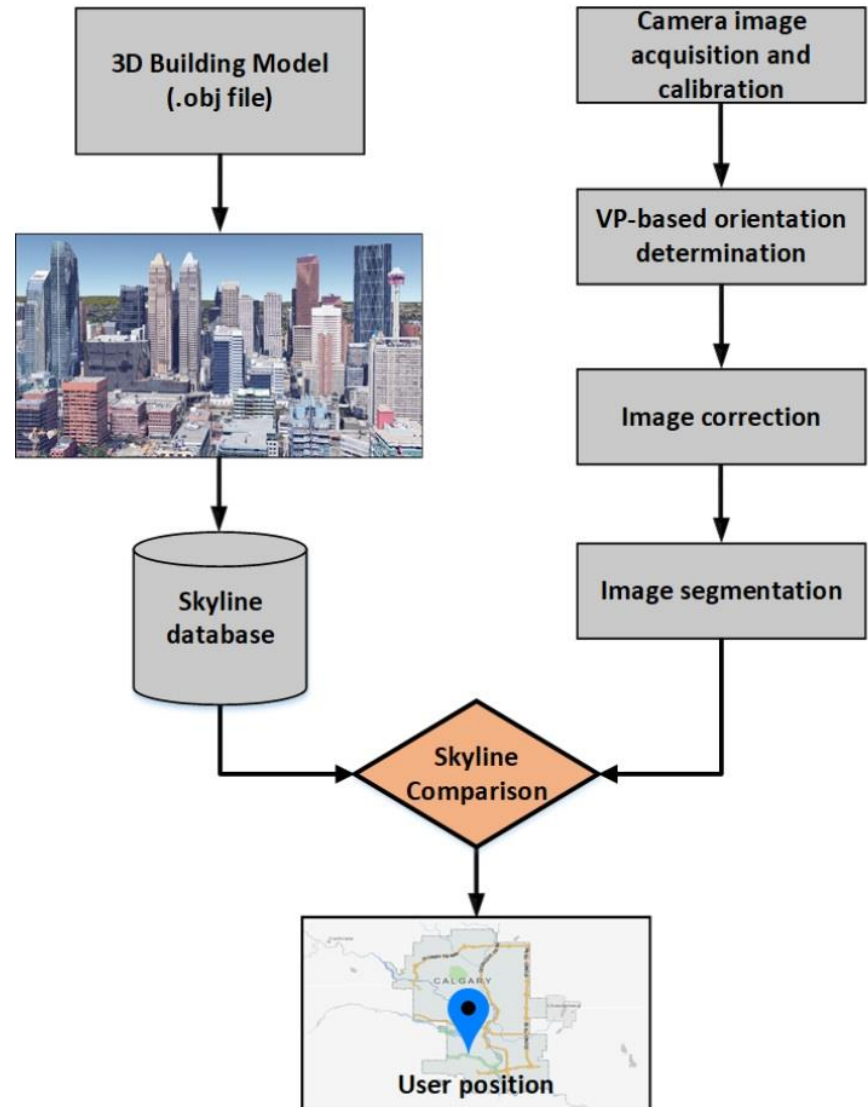


Methodology – 2/3



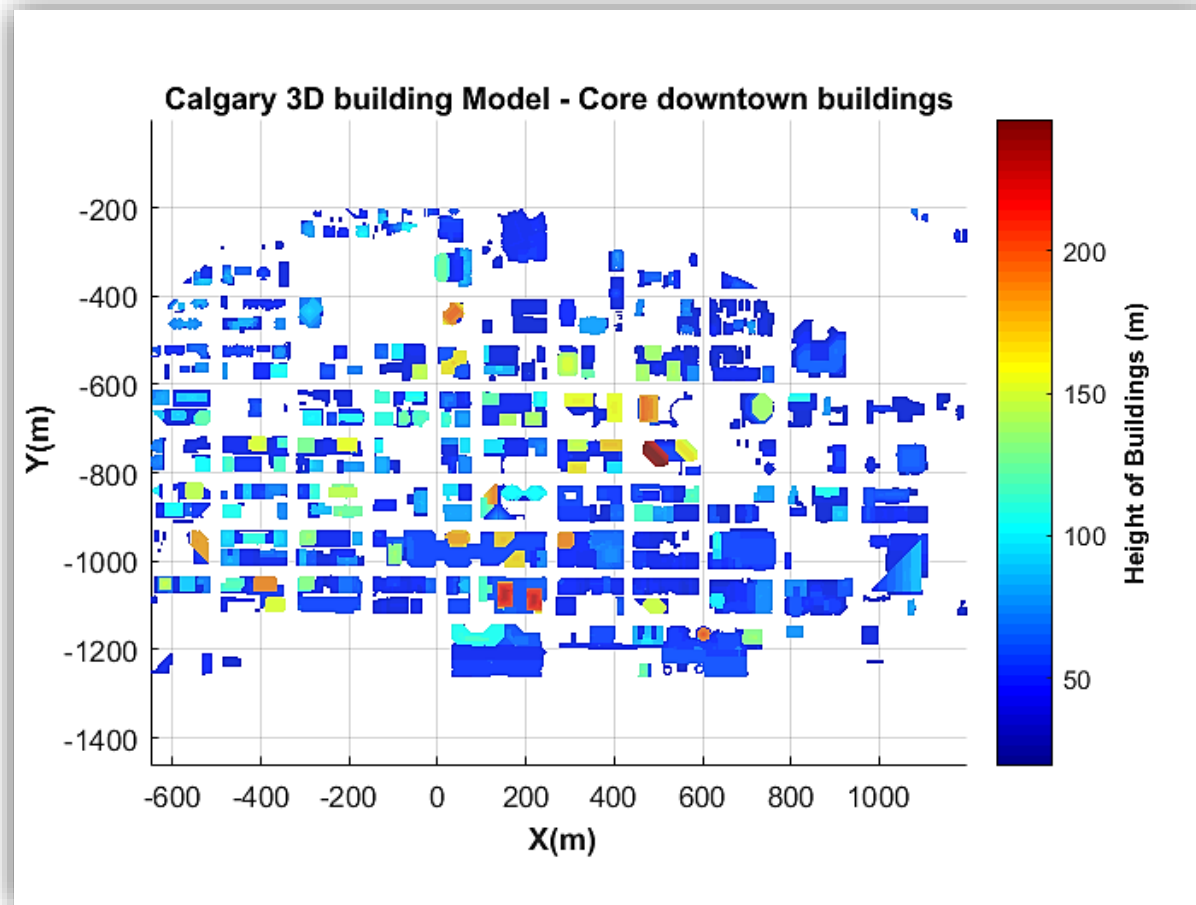
Methodology – 3/3

- Extract “ideal” skylines from a 3DBM
- Obtain “observed” skyline images from an upward facing camera
- Rectify and segment the observed images
- Match the segmented “observed” and “ideal” skylines



Skyline-based positioning – 1/2

- Ideal skylines (georeferenced images) generated from a 3D city model at any location of the user



Skyline-based positioning – 2/2

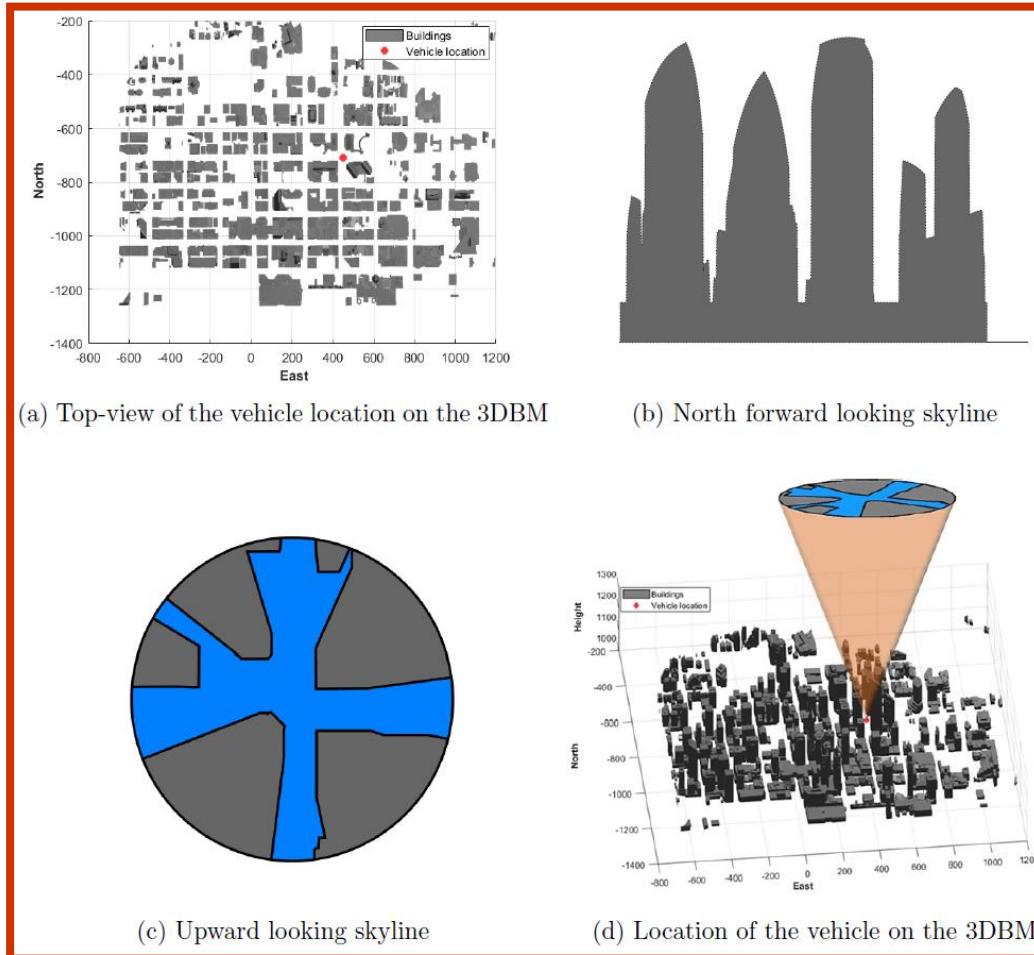
- Skyline parametrized as function of azimuth. For each azimuth, the highest elevation angle amongst all the obstructing surfaces was recorded with the corresponding height

$$\zeta_p = \left\{ \left(\boldsymbol{\varepsilon}_{p,j}, \mathbf{h}_{p,j} \right) \right\}, j = 0..N - 1$$

- ζ_p is the ideal DB used for comparison with the observed images

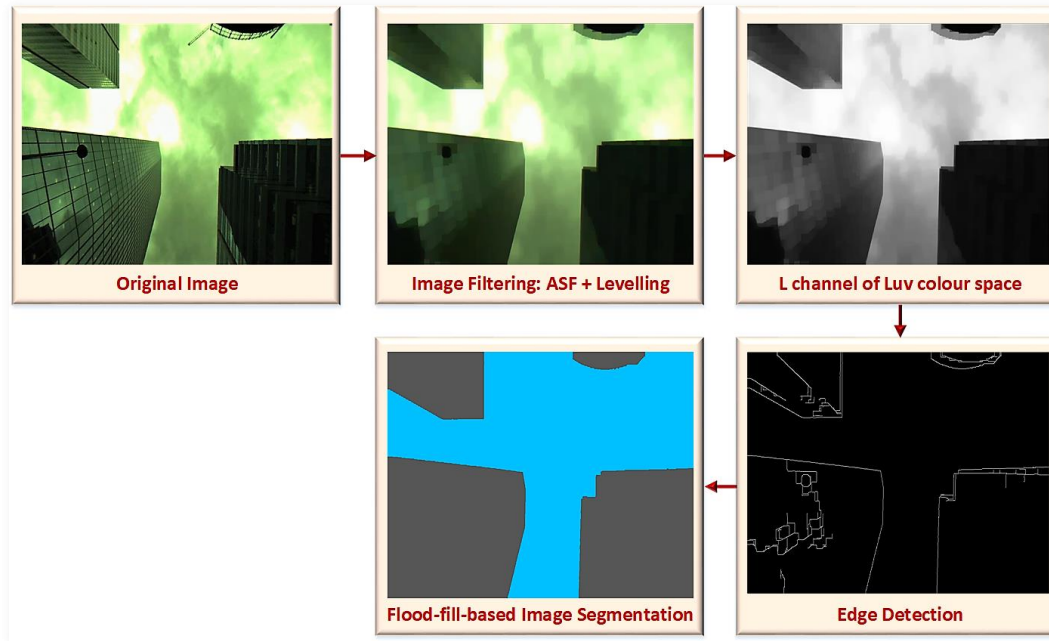
Concept Detail

- Example of a 3DBM-based synthesized image at a given location:

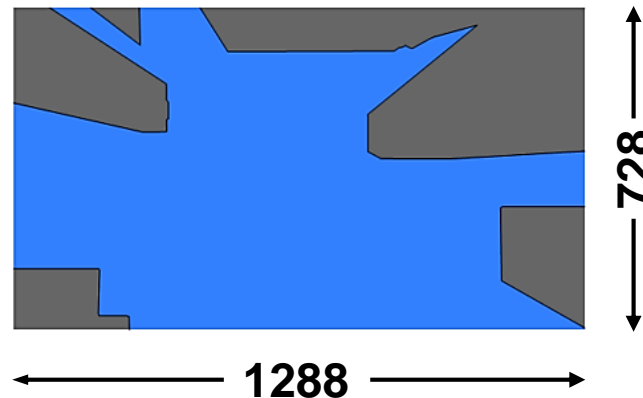


Skyline-based positioning – 2/2

Observed
Camera Image



3DBM
Synthesized Image



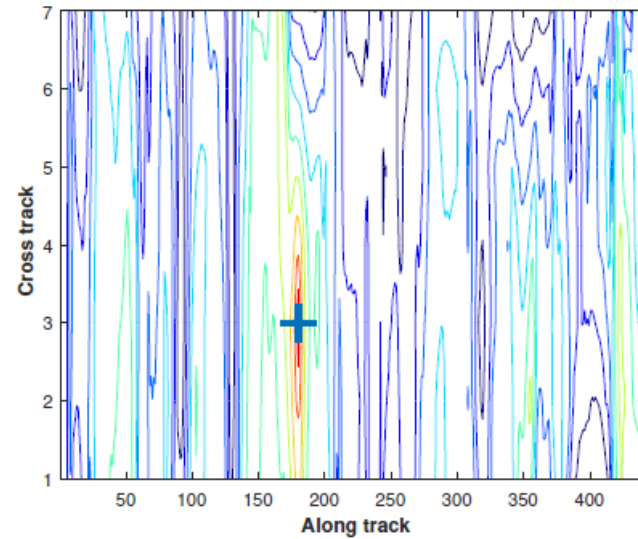
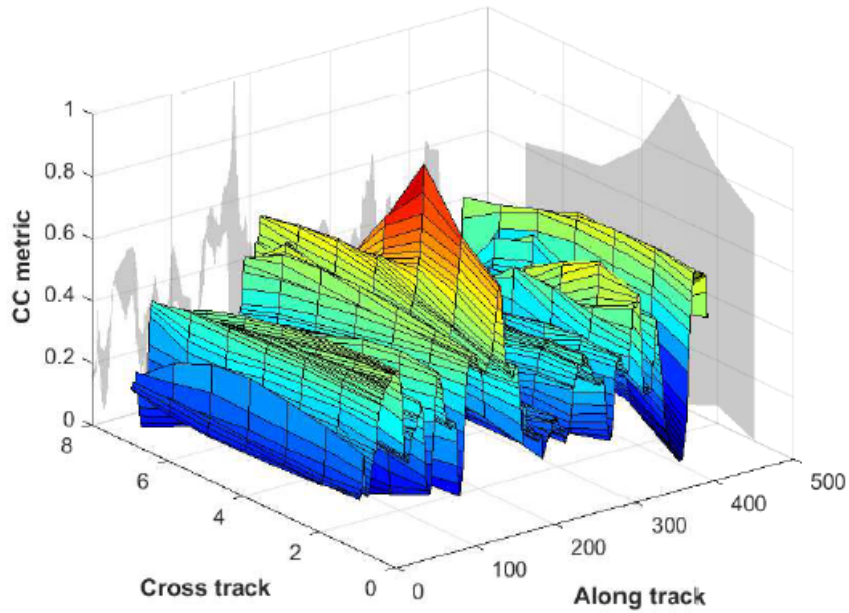
Skyline Matching

- **At this stage we have 2 types of binary images: from the 3DBM and the observed image**
- **Similarity metric used is the cross-correlation coefficient**

$$CC_{\mathbf{I}_{b(p)}}(u, v) = \frac{1}{n} \sum_{u, v} \left([\mathbf{I}_b]_{cam}(u, v) \circ [\mathbf{I}_b]_{3D(p)}(u, v) \right)$$

- **User position : position in the DB corresponding to the best match**

Similarity Metric



Scale Factor Computation

- After the system initialization, the scale factor can be computed:

$$\hat{s}_k = \sqrt{(\hat{x}_k - \hat{x}_{k-1})^2 + (\hat{y}_k - \hat{y}_{k-1})^2 + (\hat{z}_k - \hat{z}_{k-1})^2}$$

- When the 3DBM solution is available:

$$s_g = \frac{d_s}{\|P_{3DMB} - P_{VO}\|}$$

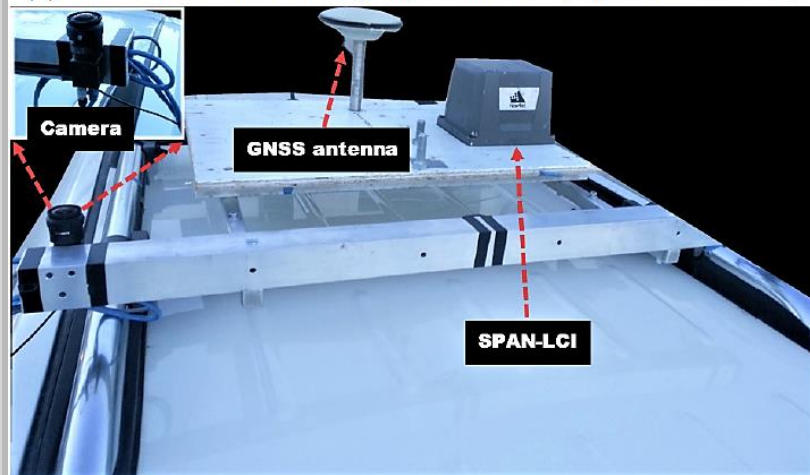
Where the slant distance is defined as: $d_s = \frac{h}{\sin \epsilon}$

Experiment and Results – 1/3

- Experiment conducted in downtown Calgary

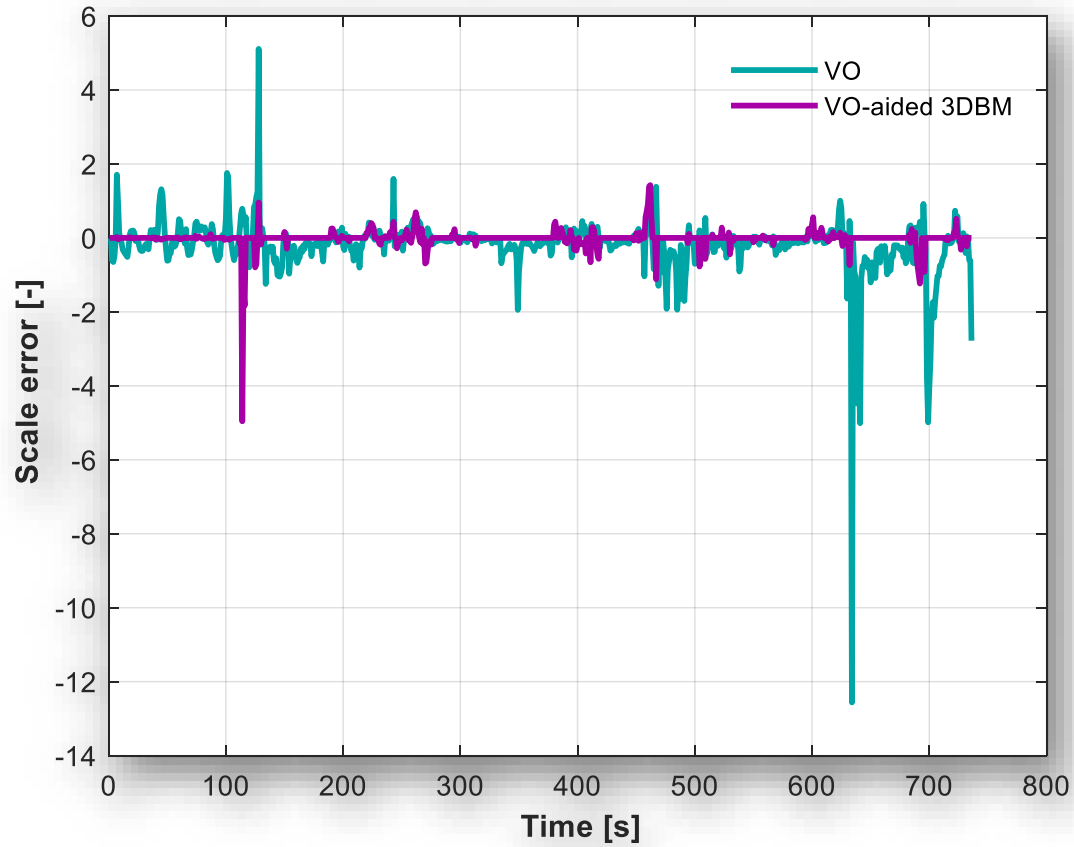


(a) Test vehicle with the rigidly attached equipment on the top

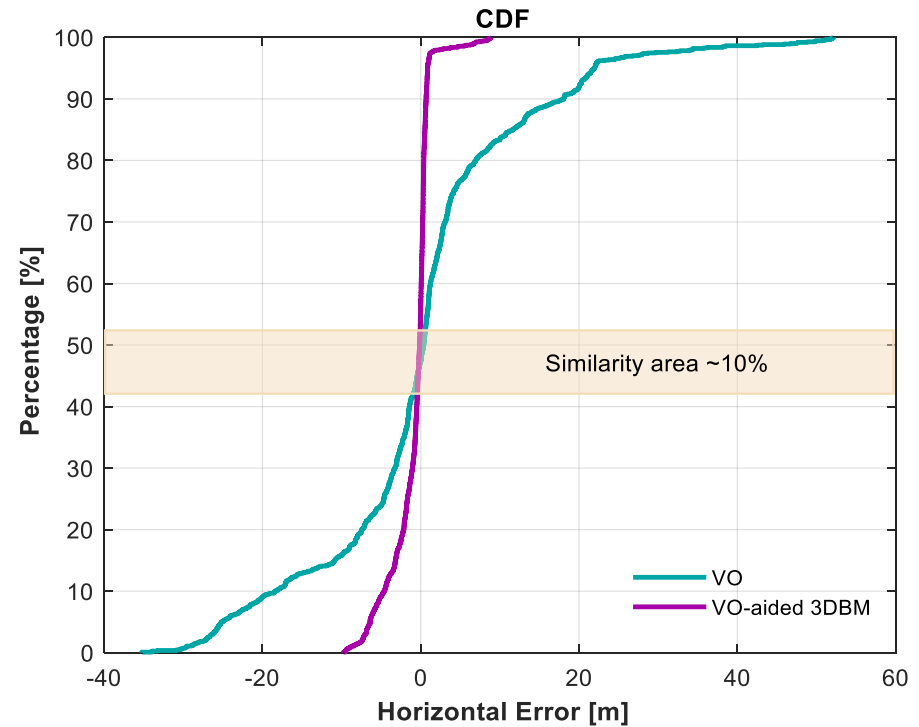
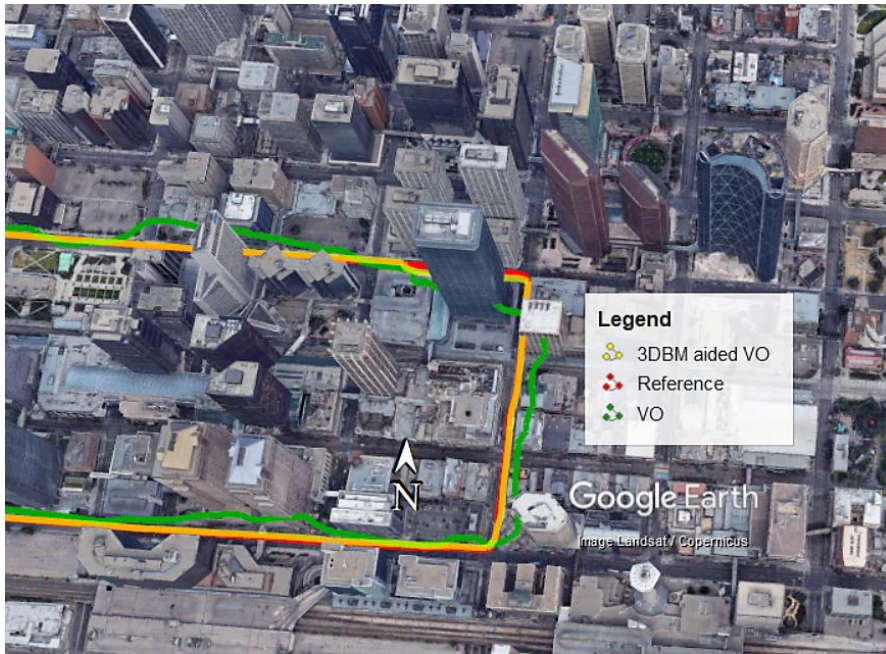


(b) Top view of the vehicle

Experiment and Results – 2/3



Experiment and Results – 3/3



Conclusions

- **Scale factor recovery for monocular visual odometry was presented**
 - **skyline-based positioning using a narrow FOV visual spectrum camera**
 - **Slant distance obtained from a 3DBM used to recover the SF and aid the VO**
- **Results showed the effectiveness of the proposed method**
 - **90% of the time improvement compare to VO-only**

THANK YOU!



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