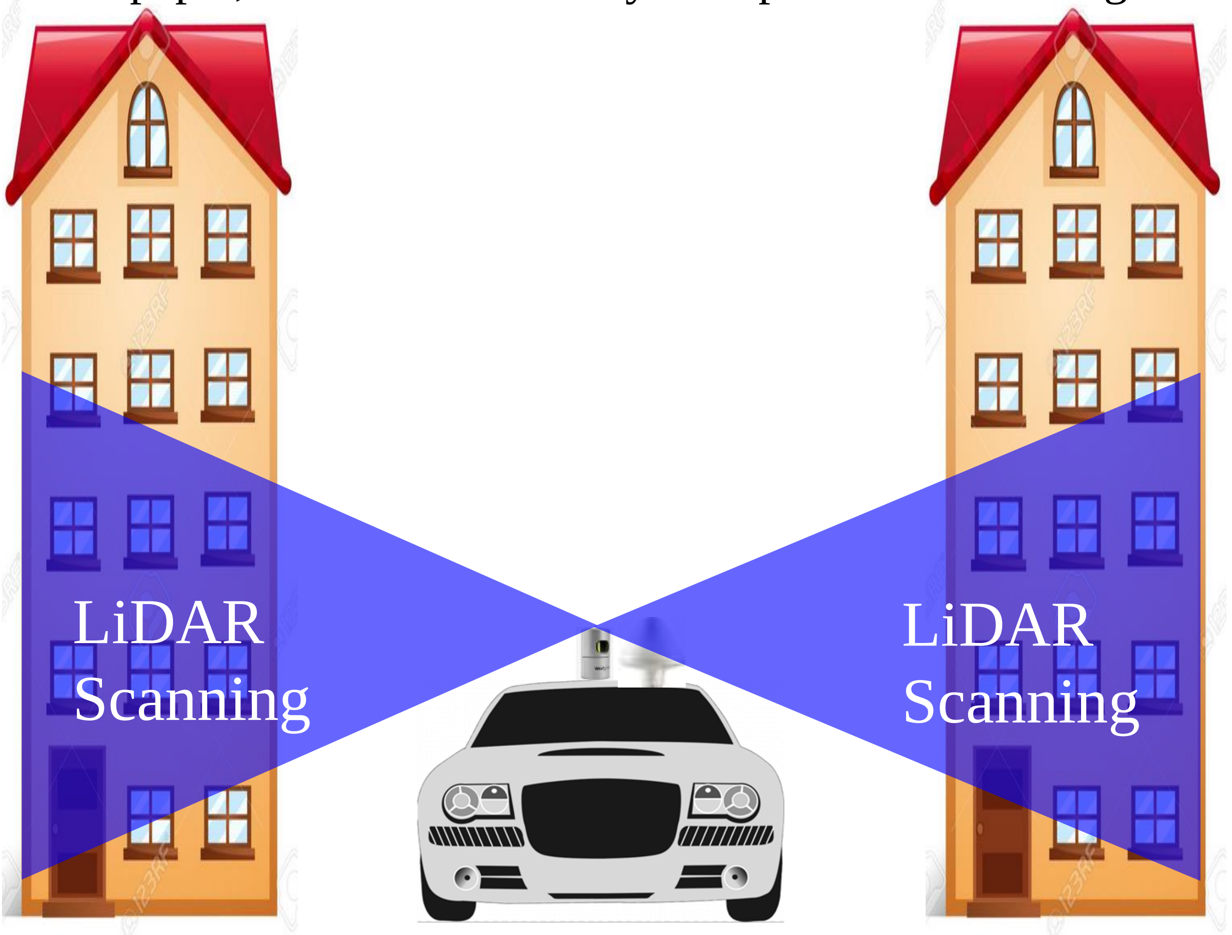
Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

Proposed idea in this paper

Satellite

Due to the limited field of view (FOV), for example +10° to -30° vertical FOV used this paper, the LiDAR can only scan part of the building.



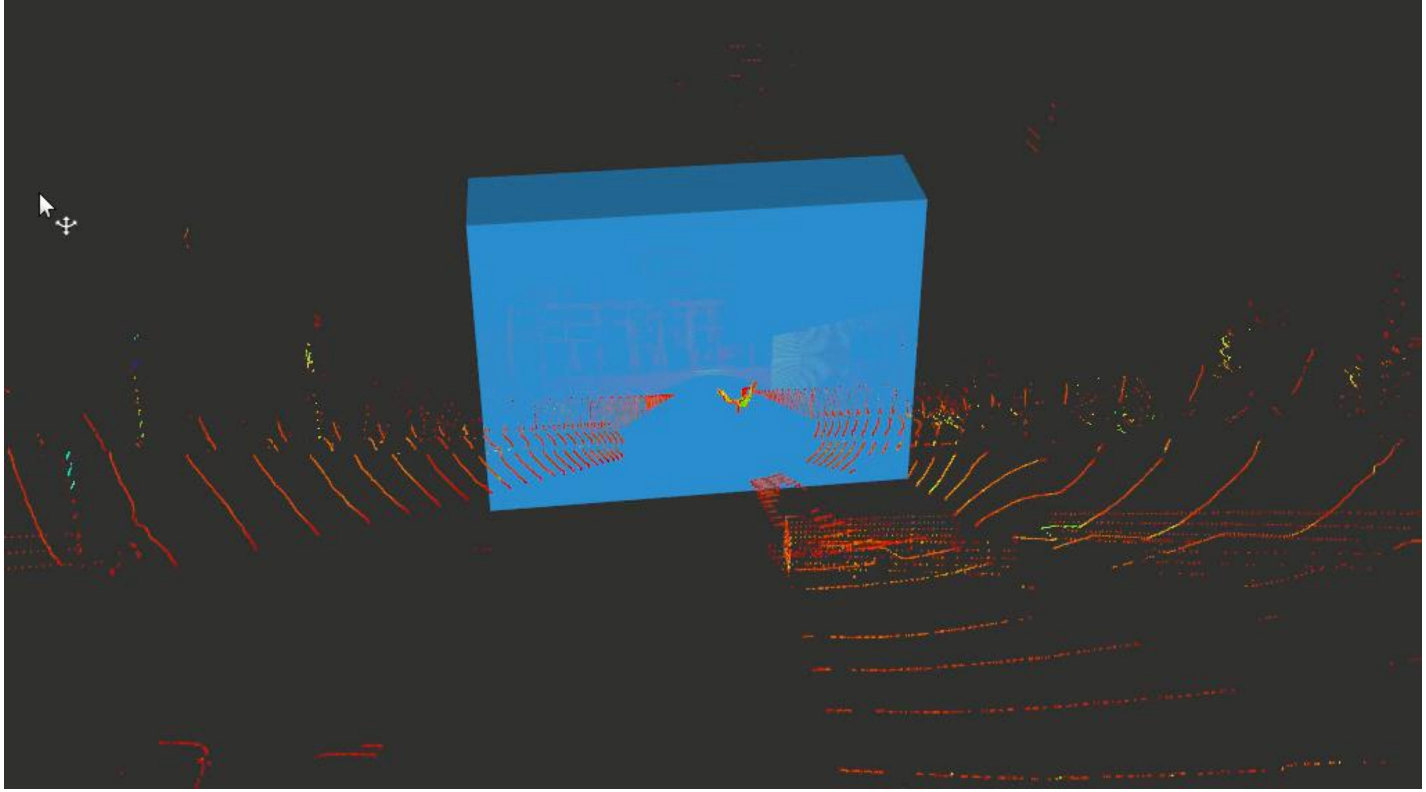
Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

Proposed Idea

Identify the building and get the **height** from the list.

Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

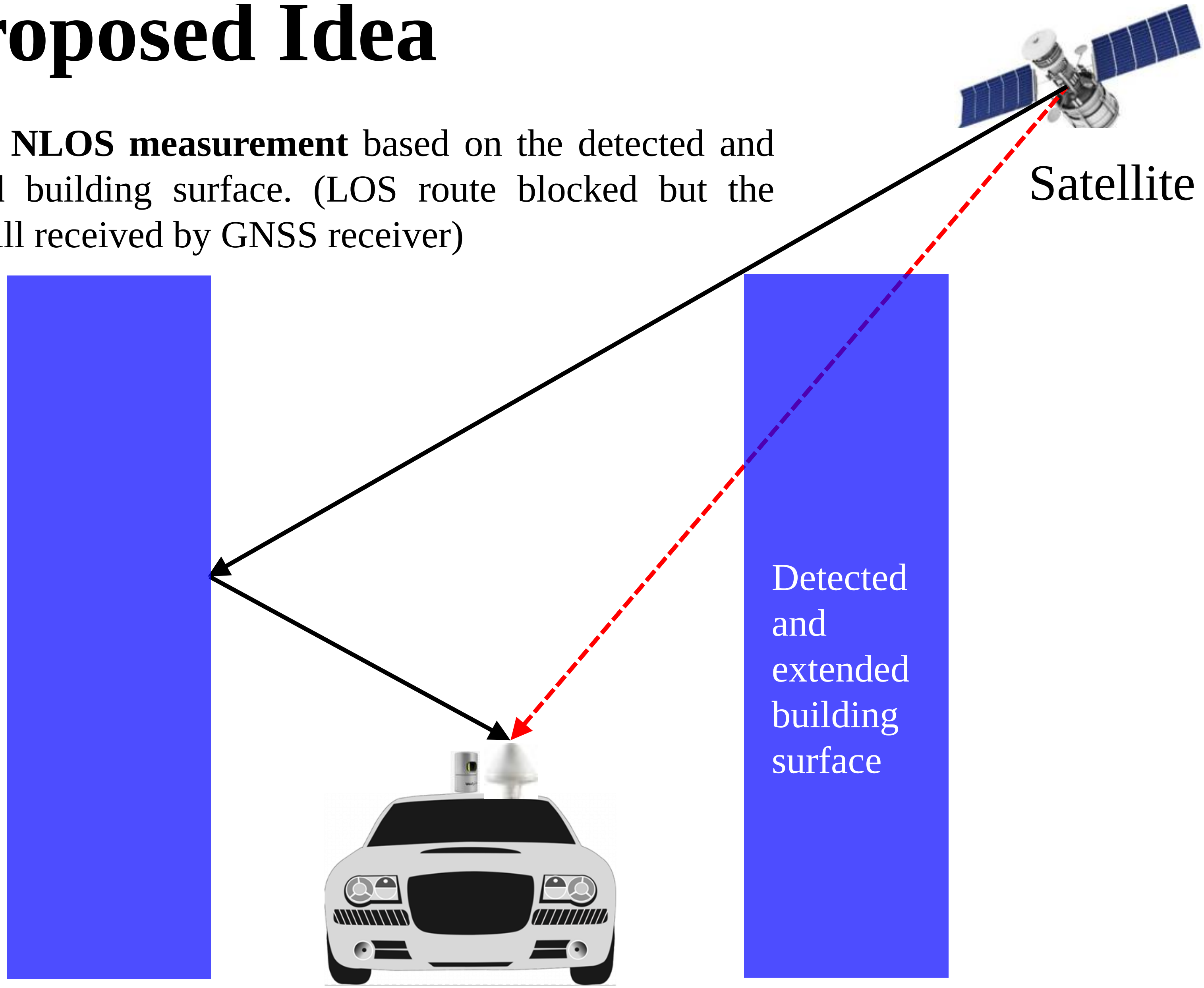
- Demo of detecting the buildings based on LiDAR point clouds.
- The height is extended from the list.



Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

Proposed Idea

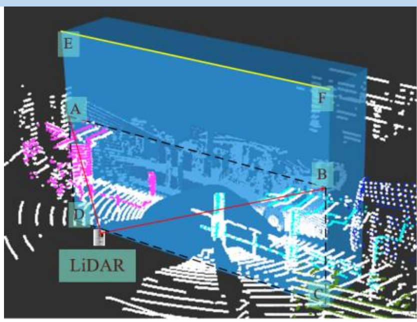
Identify NLOS measurement based on the detected and extended building surface. (LOS route blocked but the signal still received by GNSS receiver)



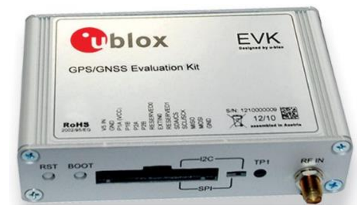
Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

Projection of the detected building boundaries to Skyplot

Building boundary in LiDAR coordinate system



GNSS Receiver



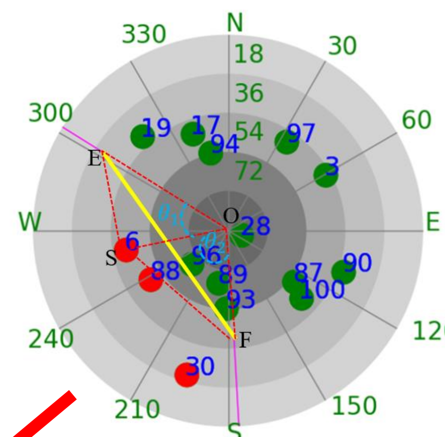
Bounding box descriptor

GNSS measurements

Coordinate transformation

Inertial navigation system/Attitude and heading reference system

Heading

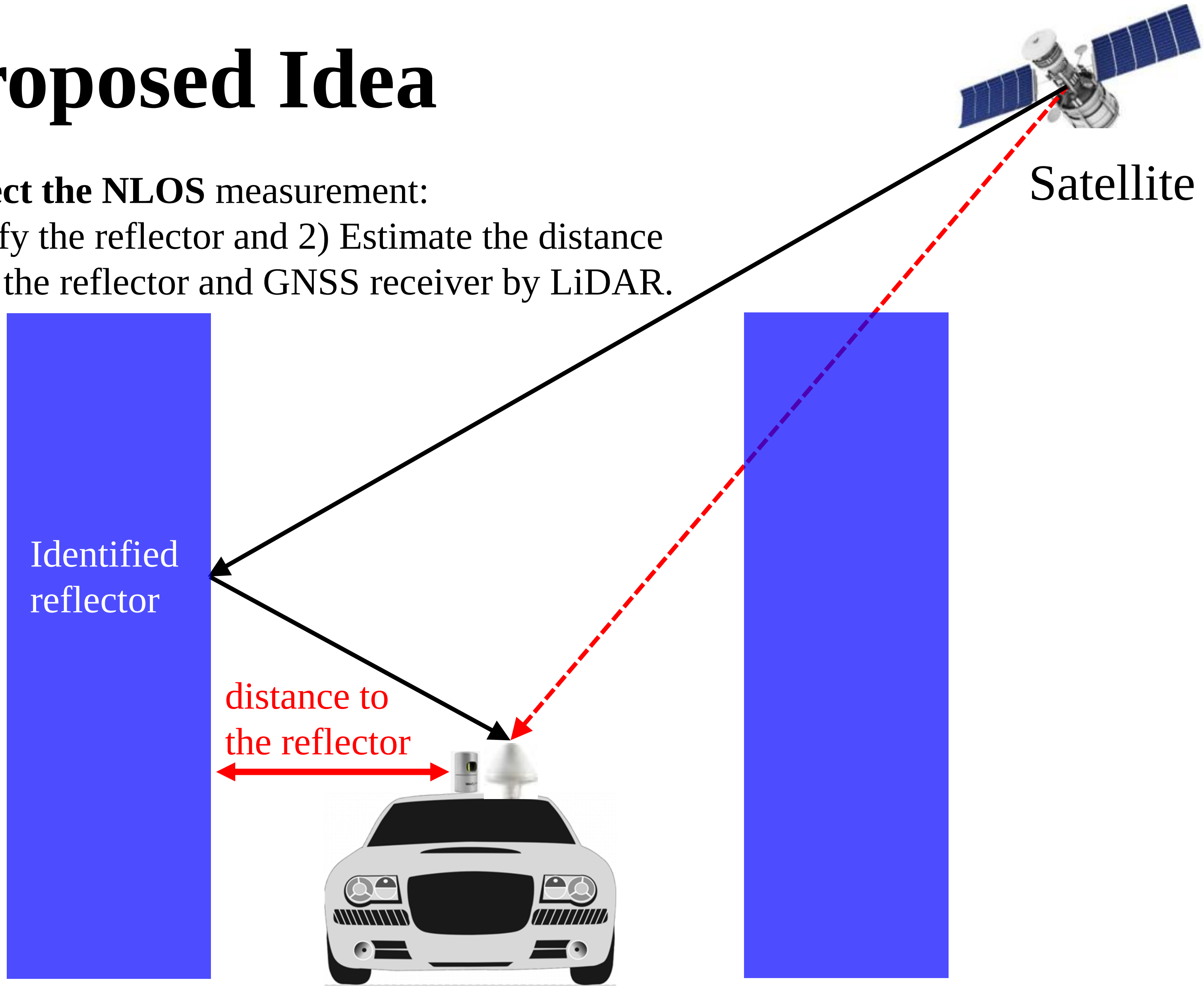


Identify Satellites 6, 88 and 30

Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

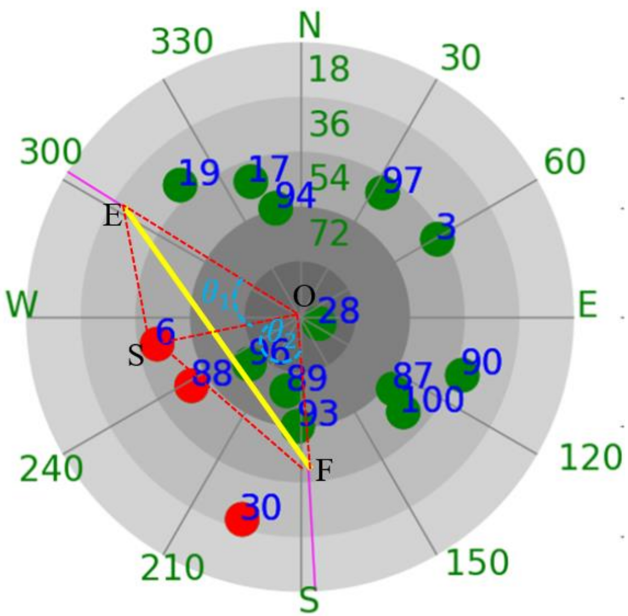
Proposed Idea

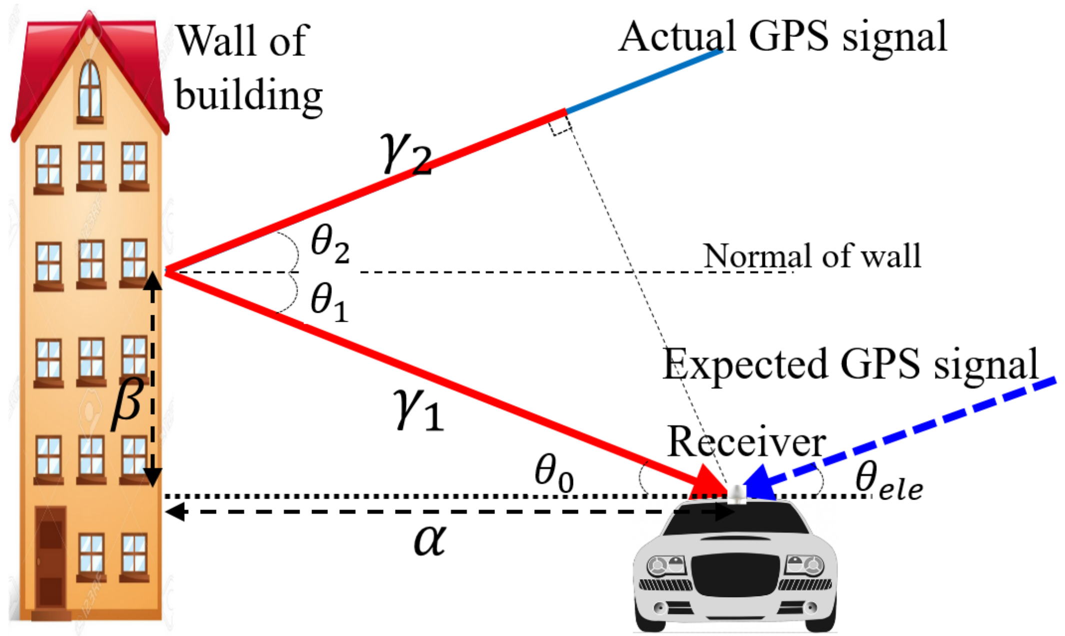
To **correct the NLOS** measurement:
1) Identify the reflector and 2) Estimate the distance between the reflector and GNSS receiver by LiDAR.



Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

NLOS Correction





To correct the measurements of satellites 6, 88 and 30, we use the elevation based model.

- $\gamma = \gamma_1 + \gamma_2$
- $\gamma_1 = \alpha sec\theta_{ele}$
- $\gamma_2 = \gamma_1 \cos(\theta_1 + \theta_2)$
- $\gamma = \alpha(sec\,\theta_{ele}\,(1 + cos\,2\theta_{ele}))$

Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

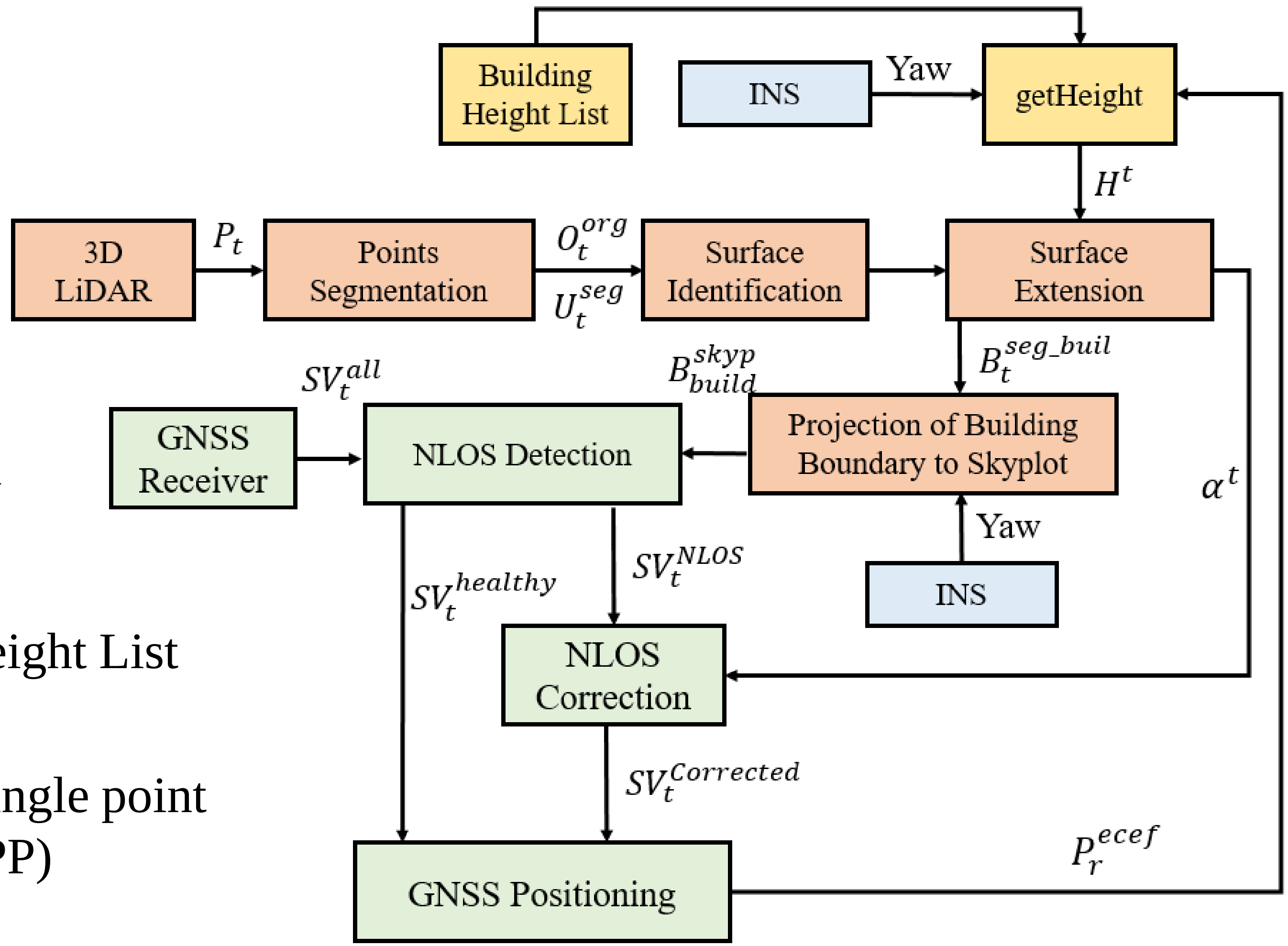
Flowchart of the proposed method

Input:

- Point Cloud
- GNSS data
- INS data
- Building Height List

Output:

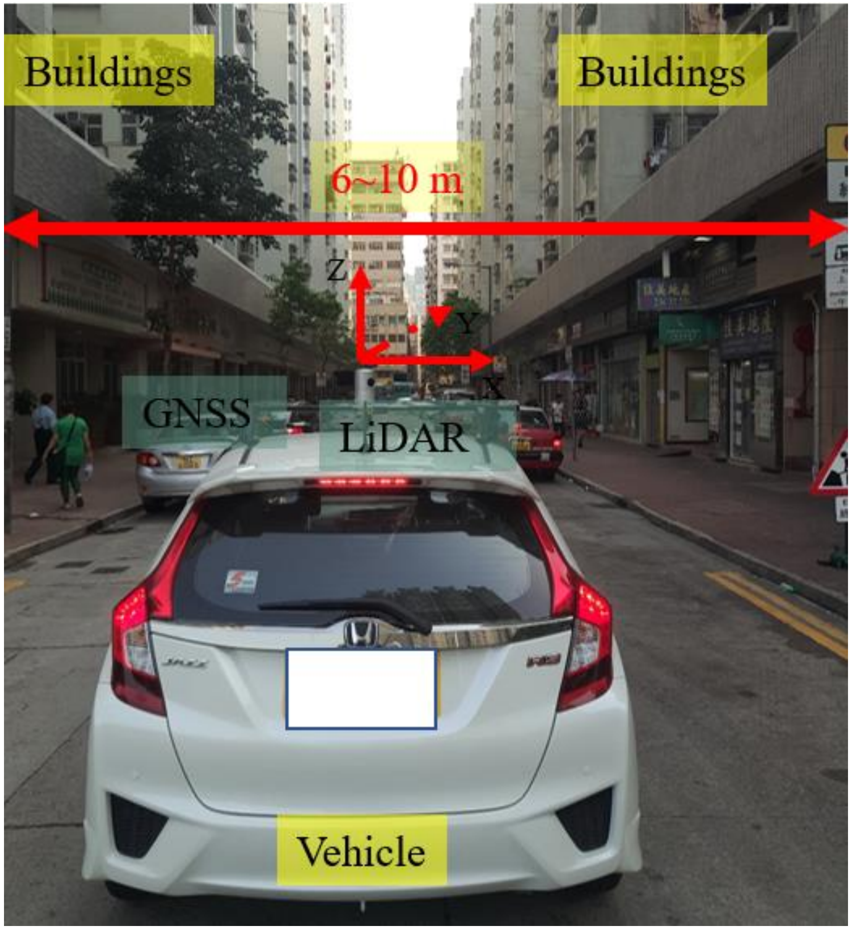
- Improved single point position (SPP)



THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Experimental Setup

The ublox M8T receiver is used to collect raw GPS and Beidou measurements. 3D LiDAR sensor, Velodyne 32, is employed to provide the real-time point cloud



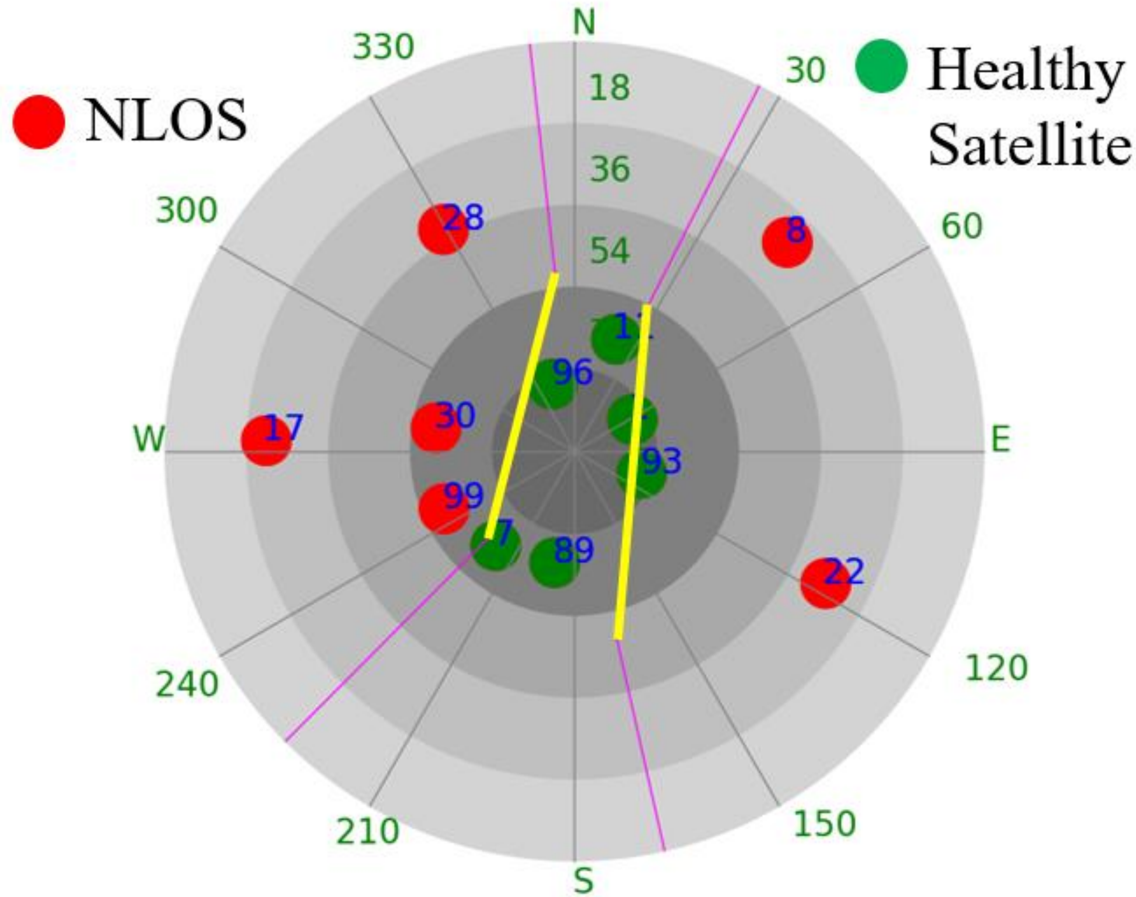
32 Channels
20Hz

GPS,BeiDou
1Hz

SPAN-CPT
(GNSS/INS)
1 Hz

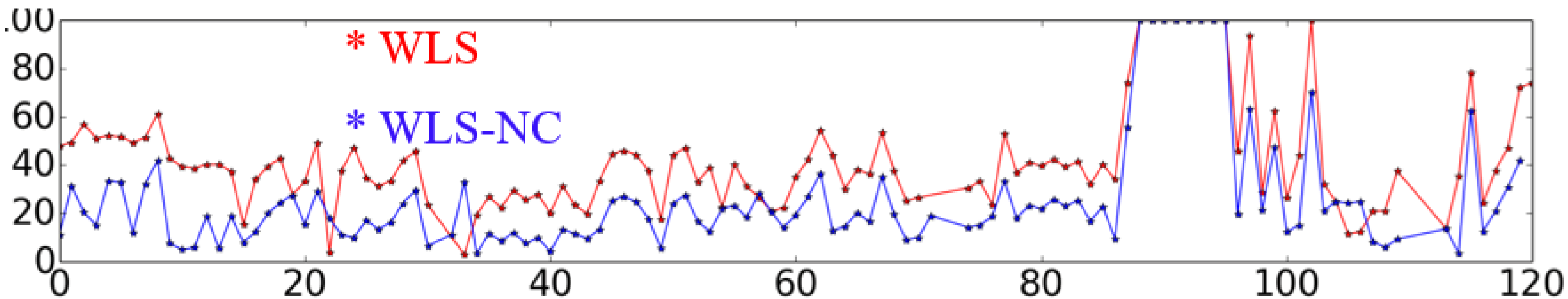
Satellites Distribution

Only 12 satellites are received, due to the blockage from the tall buildings. Almost 6 of 12 satellites are NLOS.



Experiment Result

(1) LS positioning (LS)
(2) WLS positioning (WLS)
(3) WLS positioning + NLOS exclusion (WLS-NE)
(4) WLS positioning + NLOS correction (WLS-NC)



All data	LS	WLS	WLS-NE	WLS-NC
Mean error	81.53	42.15	394.05	26.7
Std	114.38	21.29	241.01	24.32
Percentage (>40 meters)	59.29%	27.68%	98.23%	13.39%

Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

Experiment Result

Positioning Performance of **WLS-NC** with manual satellite selection (in the unit of meter)

All data	Elevation (18°~36°)	Elevation (36°~54°)	Elevation (54°~72°)
Mean error	29.93	41.95	42.01
Std	24.62	21.80	21.81
Percentage (<15 meters)	51.32%	7.96%	8.03%
Improvement	12.22	0.2	0.14
Satellites PRN	8,17,22,28	88	30,99

Wen W., Zhang G., Hsu, L.T.* (2019) Correcting NLOS by 3D LiDAR and Building Height to improve GNSS Single Point Positioning, NAVIGATION, Journal of the Institute of Navigation, (Accepted).

Conclusions

WLS vs. **WLS-NC**

Mean: 42.15 → 26.70 meters

Std: 21.29 → 24.32 meters

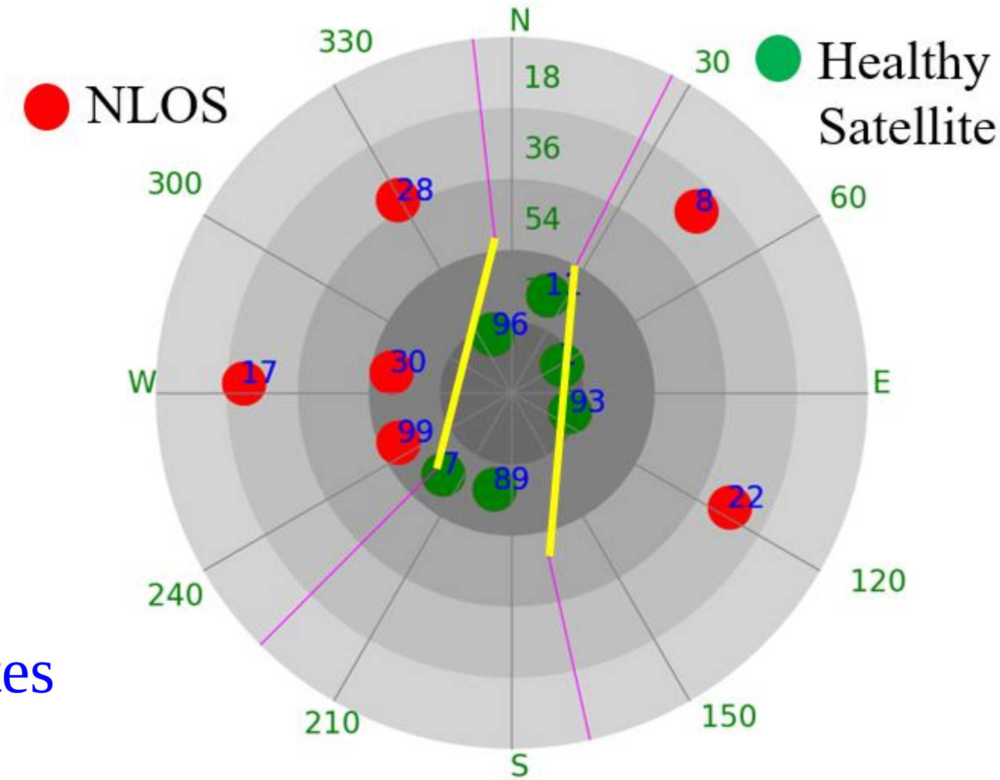
Satellite Excluded: no

WLS vs. **WLS-NE**

Mean: 42.15 → 394.05 meters

Std: 21.29 → 241.01 meters

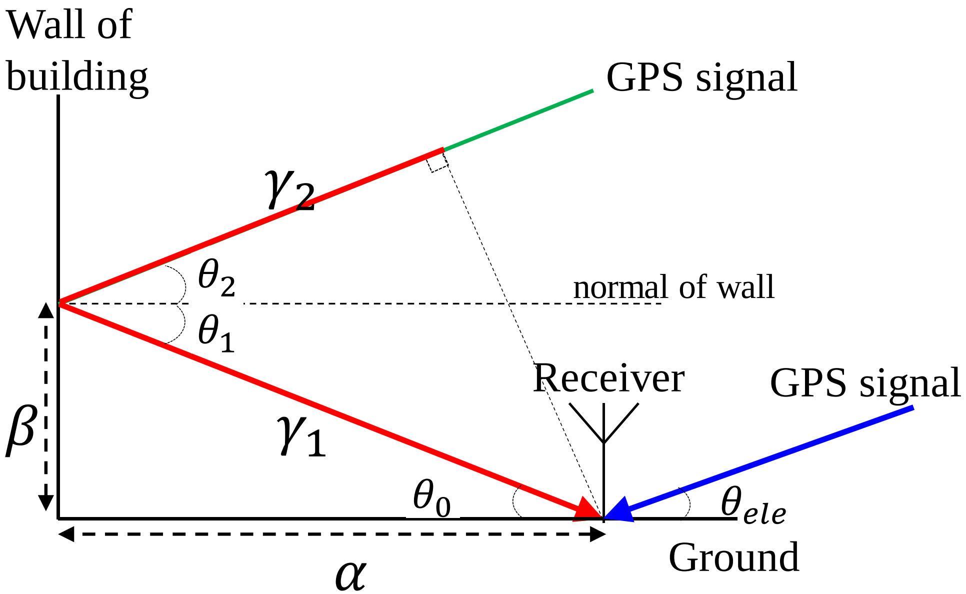
Satellite Excluded: 3~8 Satellites



- The NLOS receptions are severe in highly urbanized areas. Half of the measurements are NLOS.
- Exclusion of NLOS measurement can distort the GNSS DOP, obtaining even worse positioning result.

Conclusions

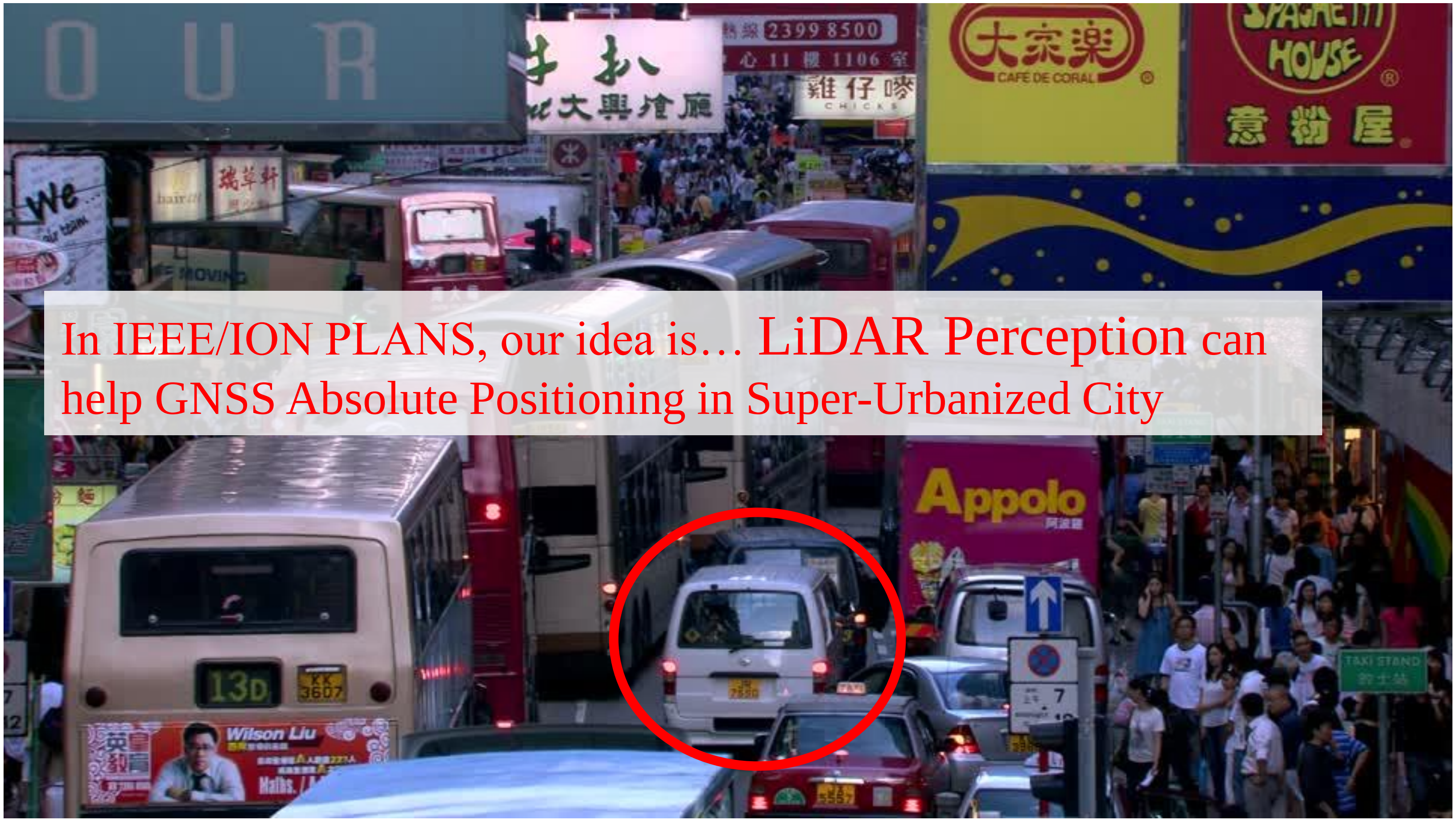
- NLOS measurements with lower elevation angles has larger NLOS delay in pseudorange domain.
- NLOS Correction based on the following model is very promising.
- $d_{NLOS} = \alpha\left(sec\,\theta_{ele}\,(1 + cos\,2\theta_{ele}) + sec\,\theta_{azm}\,(1 + cos\,2\theta_{azm})\right)$



α: distance between reflector and receiver

L.-T. Hsu, "Analysis and modeling GPS NLOS effect in highly urbanized area," *GPS Solutions*, 22(1):1-7, 2018

The Bus can block GNSS signal as well!



In IEEE/ION PLANS, our idea is… LiDAR Perception can help GNSS Absolute Positioning in Super-Urbanized City

Wen, W., Zhang, G., Hsu, Li-Ta, Exclusion of GNSS NLOS Receptions Caused by Dynamic Objects in Heavy Traffic Urban Scenarios Using Real-Time 3D Point Cloud: An Approach without 3D Maps, *IEEE/ION PLANS, 2018*, California, USA.