Department of Aeronautical and Aviation Engineering 航空及民航工程學系

THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學

UrbanNav

An Open-Sourced Multisensory Dataset for Benchmarking Positioning Algorithms Designed for Urban Areas

Hong Kong Team

Li-Ta Hsu[1], Weisong Wen[1], Wu Chen[1], Zhizhao Liu[1],

[1] The Hong Kong Polytechnic University, Hong Kong

Japan Team

Nobuaki Kubo[2], Taro Suzuki[3] and Junichi Meguro[4]

[2] Tokyo University of Marine Science &Technology

[3] Chiba Institute of Technology, Japan

[4] Meijo University, Japan

34th International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+ 2021), September 20-24, 2021

https://doi.org/10.33012/2021.17895

ION/IAG WG4.1.5 Initiative

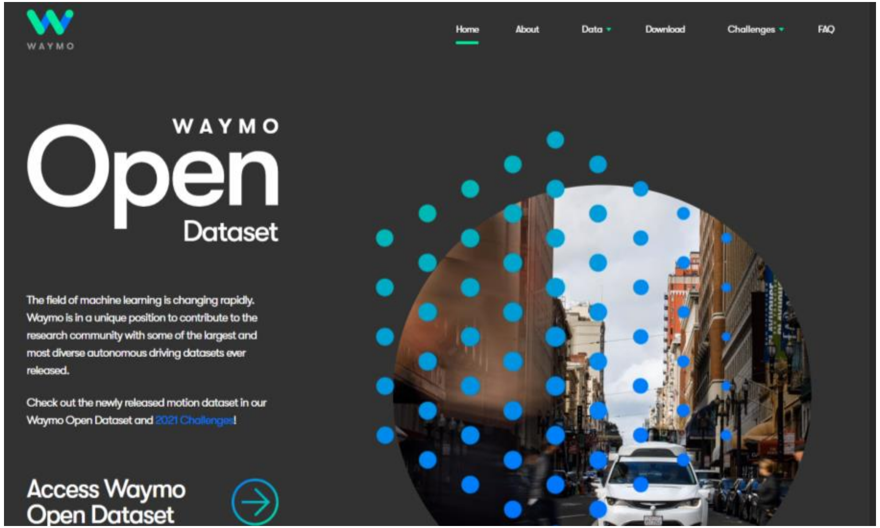
Objectives

- **Open-sourcing multi-sensors positioning data collected for in Asian urban canyons (UrbanNav)**
- Raising the **awareness** of the urgent **navigation requirement in highly-urbanized areas**, especially in Asian-Pacific regions
- **Benchmarking positioning algorithms** based on the open-sourcing data

Benchmarks are important to foster the research and development

http://www.cvlibs.net/datasets/kitti/

https://waymo.com/open/



The dataset are for autonomous driving research (not exclusive to navigation and positioning)

Most Economic Activities are in Urbanized Cities.
Positioning and Navigation are Fundamental for Many Applications

Smartphone Apps

Intelligent Vehicles

Autonomous driving

Sensors and their challenges in urban areas

>GNSS

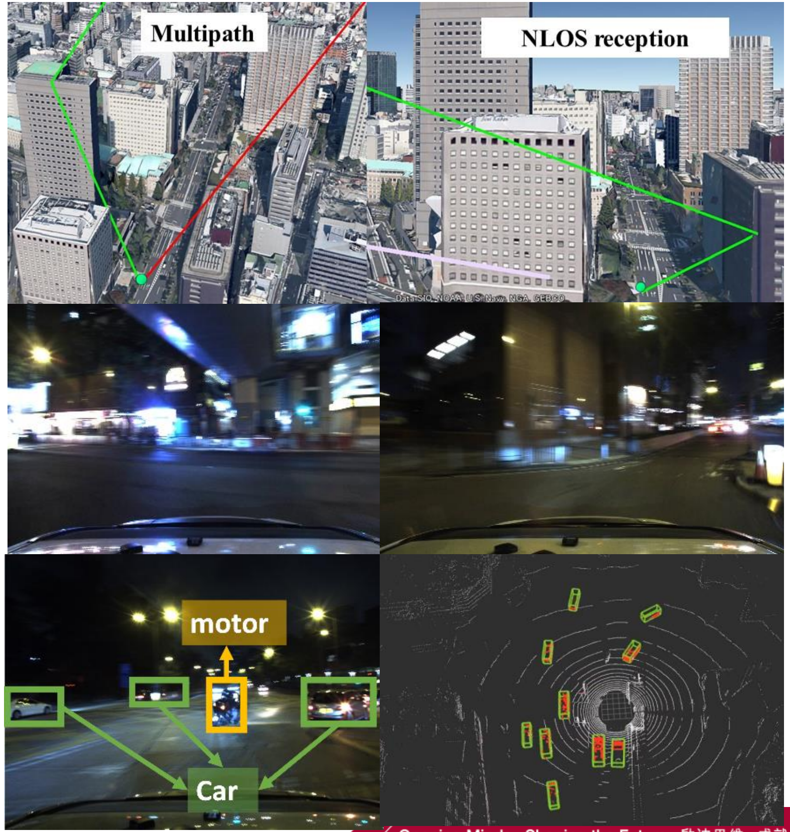
- Multipath and NLOS

>Visual sensor

- Image blur (various),
- high dynamics
- dynamic objects

>LiDAR

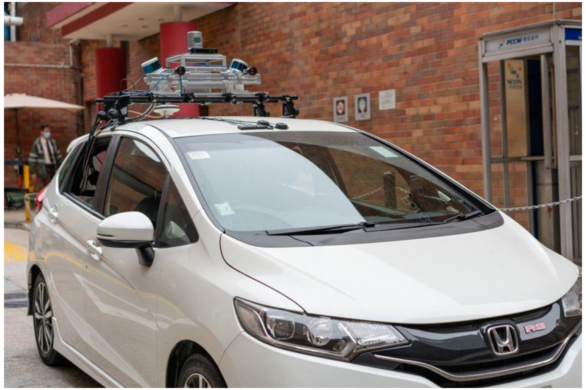
- high dynamics
- dynamic objects

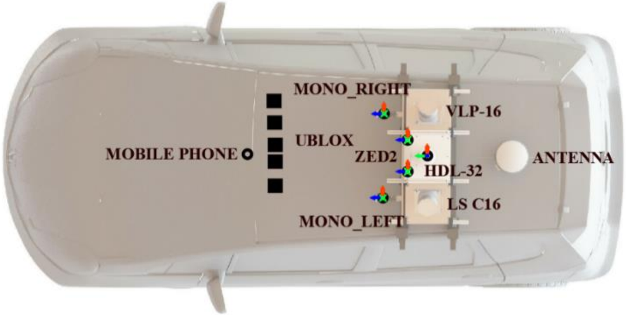


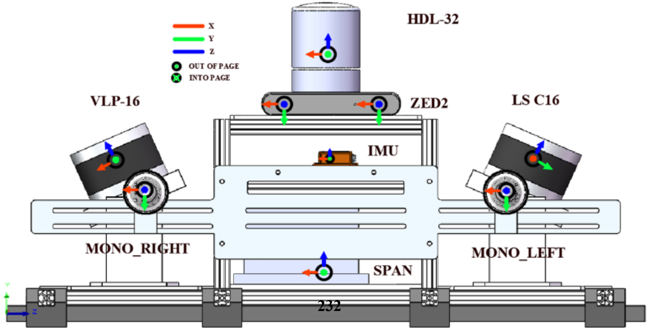
230

Current UrbanNav Dataset

The Hong Kong Data Collection Platform







- **Ground truth:** NovAtel SPANCPT+ Inertial Explorer® (we also compare the result with image data to make sure the GT is trustworthy)
- **GNSS:** u-blox & NovAtel
- **LiDAR:** Velodyne
- **IMU:** Xsens

- Intrinsic and extrinsic parameters are available.
- Time synchronization is done by NMEA PPS from GPS receiver.

Time synchronization between on-onboard ROS computer and GPS time

> We use Chrony [1] + GPSd [2] to receive the NMEA+PPS signal from Ublox M8T to synchronize ROS computer with GPS time.

> **The ROS computer is synchronized to GPS reference clock provided by u-blox.**

> *The wire latencies between sensors (LiDAR, Camera and IMU) and ROS computer are not considered in this dataset.*

NMEA + PPS source from ublox M8T to onboard ROS computer

https://github.com/IPNL-POLYU/UrbanNavDataset/blob/master/docs/GETTING_STARTED.md#time-synchronization-between-gps-time-and-ros-time

Sensors for L4 Autonomous Driving Localization Research

Sensors	Grade	Sensors model	Data format	Ros topic	Freq	Time standard	Remarks
GNSS x 2	commercial	u-blox ZED-F9P	RINEX3.02 NMEA	Nil	1 Hz	GPS time	**GPS (L1, L2)**; **GLONASS (G1, G2)**; **GALILEO (E1, E5b)**; **BeiDou (B1, B2)**; **QZSS (L1, L2)** 2 receivers will be used (1 connect to geodetic grade antenna; 1 connect to patch antenna)
GNSS	Geodetic	NovAtel FlexPak6	RINEX3.02 NMEA	Nil	1 Hz	GPS time	**GPS** (**L1**, **L2**, L2C, L5); **GLONASS** (**L1**, **L2**, L2C); **BeiDou** (**B1**, **B2**); Galileo (E1, E5a, E5b);QZSS
LiDAR	Navigation	Velodyne 32E	sensor_msgs/PointCloud2	/velodyne_points	10 Hz	GPS time in unix t	https://github.com/ros-drivers/velodyne/tree/1.6.1
LiDAR (right)	Navigation	Velodyne VLP16	sensor_msgs/PointCloud2	/right/velodyne_points	10 Hz	GPS time in unix t	https://github.com/ros-drivers/velodyne/tree/1.6.1
LiDAR (left)	Navigation	Lslidar C16	sensor_msgs/PointCloud2	/left/lslidar_point_cloud	10 Hz	GPS time in unix t	http://wiki.ros.org/lslidar_c16
Stereo Camera	commercial	ZED2	sensor_msgs/Image	/zed2/camera/left/image_raw /zed2/camera/right/image_raw	15 Hz	GPS time in unix t	https://github.com/willdzeng/zed_cpu_ros (for CPU only desktop)
IMU	MEMS commercial	Xsens-MTI-30	sensor_msgs/Imu	/imu/data 234	400 Hz	GPS time in unix t	

Commercial level GNSS/INS

Sensors	Grade	Sensors model	Data format	Freq	Time format	Remarks
GNSS	commercial	u-blox EVK-M8T	RINEX3.02 NMEA	1 Hz	GPS time	**GPS (L1)**; **Beidou (B1);** GLONASS (G1); GALILEO (E1);
GNSS	commercial	u-blox ZED-F9P	RINEX3.02 NMEA	1 Hz	GPS time	**GPS (L1, L2)**; **GLONASS (G1, G2)**; **GALILEO (E1, E5b)**; **BeiDou (B1, B2)**; **QZSS (L1, L2)** 2 receivers will be used (1 connect to geodetic grade antenna; 1 connect to patch antenna)
GNSS	Geodetic	NovAtel FlexPak6	RINEX3.02 NMEA	1 Hz	GPS time	**GPS** (**L1, L2**, L2C, L5); **GLONASS** (**L1, L2**, L2C); **BeiDou** (**B1, B2**); Galileo (E1, E5a, E5b); QZSS
IMU	MEMS commercial	Xsens-MTI-30	/sensor_msgs/Imu	400 Hz	GPS time in unix t	

Smartphone level Sensors

Sensors	Grade	Sensors model	Data format	Ros Topic	Freq	Time format	Remarks
GNSS	Smartphone	Xiaomi 8	RINEX3.02 NMEA		1 Hz	GPS time	**GPS** (**L1, L5**); **GLONASS** (**L1**); GALILEO (E1, E5a); Beidou (B1); **QZSS** (**L1, L5**)
Monocular Camera	Smartphone Onboard camera	Xiaomi 8	sensor_msgs/CompressedImage	/android/image_raw/compressed	15 Hz	GPS time in unix t	Smartphone needs connect to ROS using an open-source apk: https://github.com/huaibovip/android_ros_sensors
IMU	MEMS Smartphone Onboard IMU	Xiaomi 8	sensor_msgs/Imu	/android/imu	239 Hz	GPS time in unix t	smartphone need connect to ROS using the open-source apk.

https://github.com/IPNL-POLYU/UrbanNavDataset/blob/master/docs/GETTING_STARTED.md#time-synchronization-between-gps-time-and-ros-time

https://github.com/IPNL-POLYU/UrbanNavDataset/blob/master/docs/GETTING_STARTED.md#time-synchronization-between-gps-time-and-ros-time

Time Synchronization between GPS time and ROS time

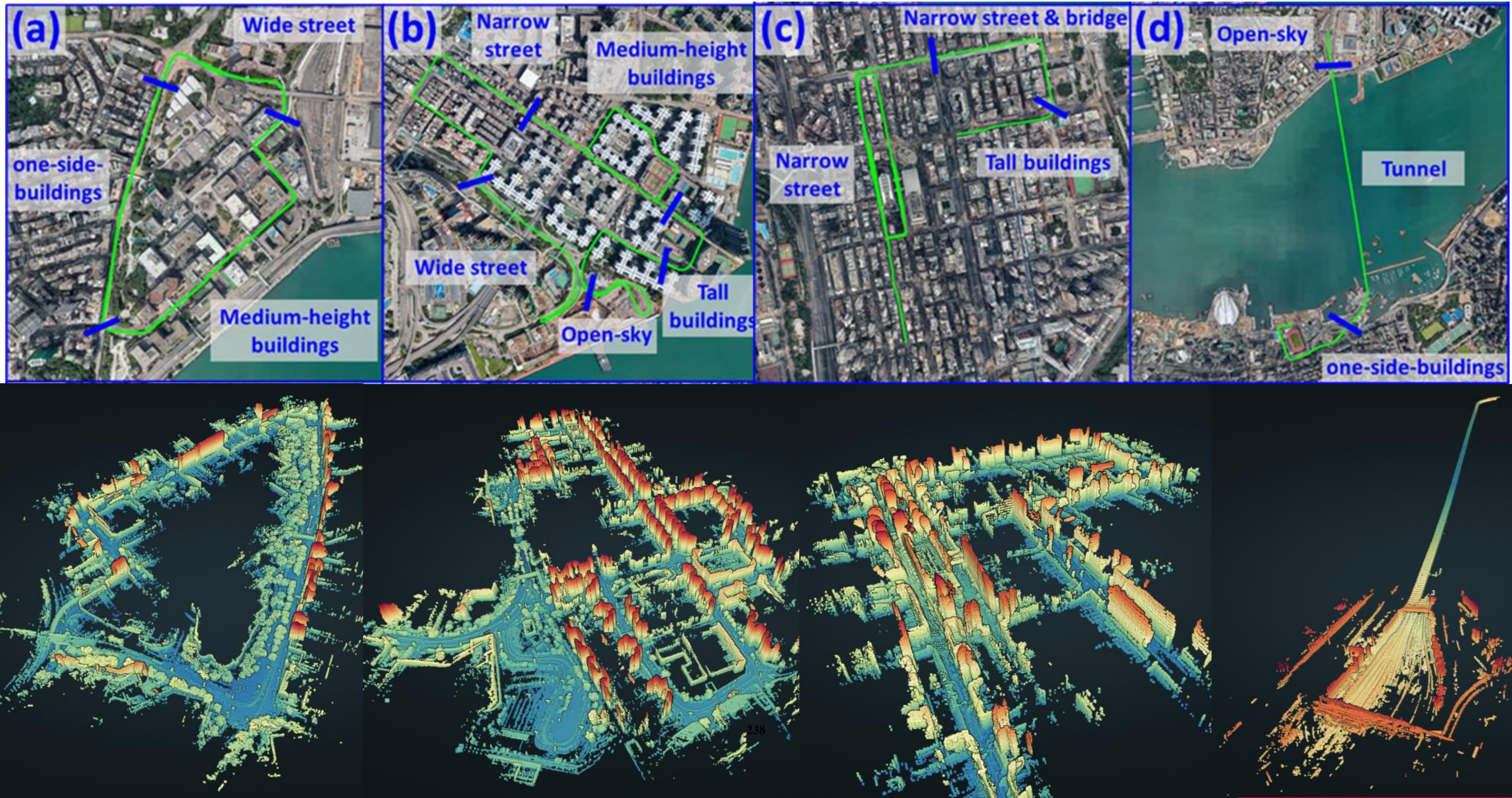
We use Chrony+GPSd to receive the NMEA+PPS signal from Ublox M8T to synchronize ROS computer with GPS time. GPS time: It consists of a count of weeks and seconds of the week since 0 hours (midnight) Sunday 6 January 1980. ROS time: unix epoch time. The Unix epoch is 00:00:00 UTC on 1 January 1970

GPS-UTC offset is 18 leap seconds for data collected in May 2021. Let's use an example to convert the GPS time to ROS time. Assuming the GPS Time is week: 2158 and seconds: 95593, the total seconds is 2158 * 604800(seconds_in_week) + 95593 = 1305253993, then we add 315964800 seconds offset between the origin of GPS time and ROS time. Finally we can get the corresponding UTC time 1621218775 (1305253993 + 315964800 -18 = 1621218775) considering 18 leap seconds.

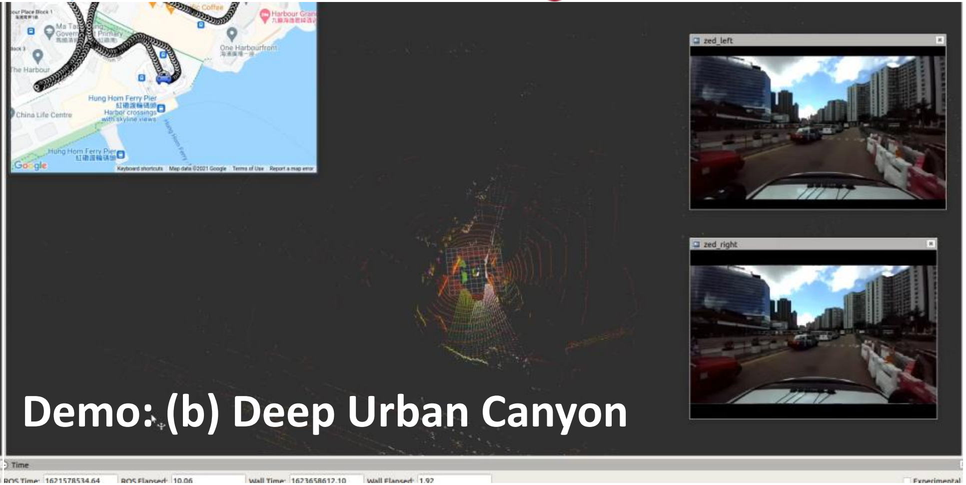
An example of matlab code to convert gps time to utc time is provided as below,

```
function utctime = gps2utc(gps_week, gps_seconds)
    SECONDS_IN_GPS_WEEK = 604800.0;
    utctime = (gps_week * SECONDS_IN_GPS_WEEK + gps_seconds-18) + 315964800  ; % 18 leap se
end
```

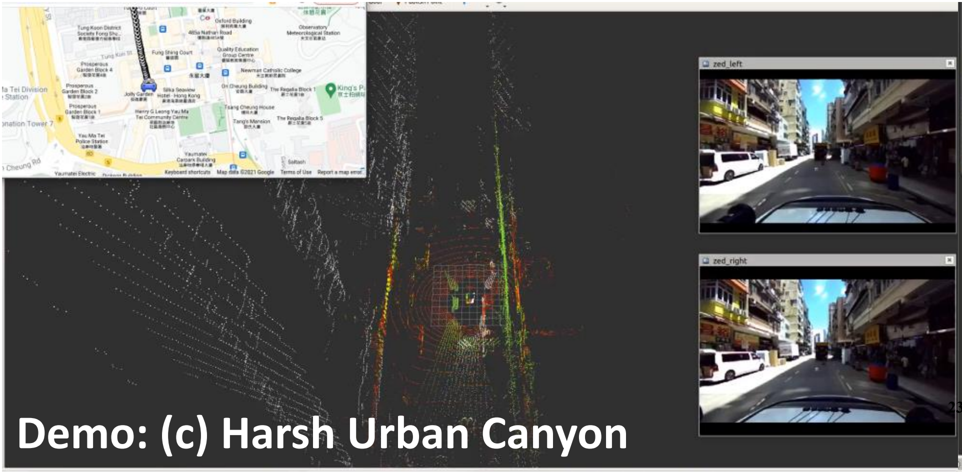
(a) Medium Urban canyon (b) Deep Urban canyon (c) Harsh Urban canyon (d) Tunnel



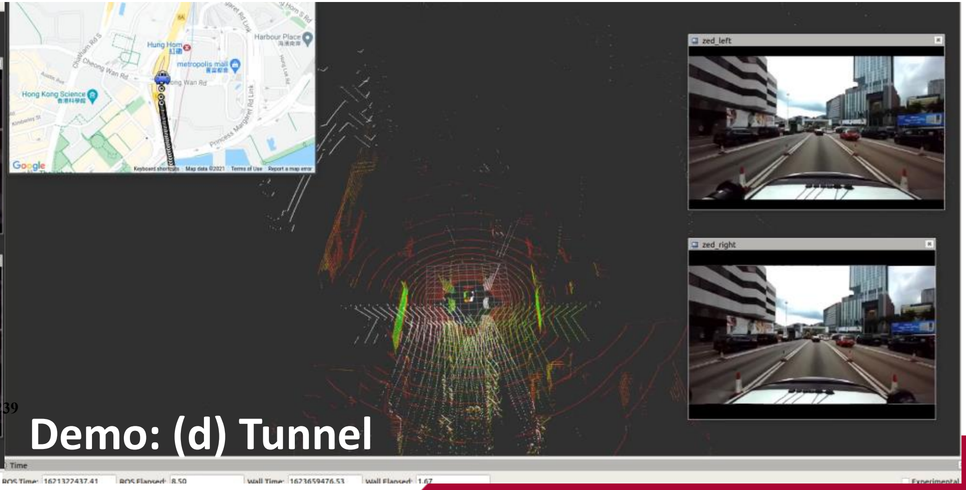
Demo: (a) Medium Urban Canyon



Demo: (b) Deep Urban Canyon



Demo: (c) Harsh Urban Canyon



Demo: (d) Tunnel

https://github.com/IPNL-POLYU/UrbanNavDataset

Details of the Scenarios

DataSets

	Total Size	Path length	Sensors	Urban Canyon	Download	3D PointCloud
UrbanNav-HK-Medium-Urban-1	33.7 GB (785s)	3.64 Km	LiDARs/Stereo Camera/IMU/GNSS	Medium	ROS, GNSS, IMU, Ground Truth	Medium Urban Map
UrbanNav-HK-Deep-Urban-1	63.9 GB (1536s)	4.51 Km	LiDARs/Stereo Camera/IMU/GNSS	Deep	ROS, GNSS, IMU, Ground Truth	Deep Urban Map
UrbanNav-HK-Harsh-Urban-1	147 GB (3367s)	4.86 Km	LiDARs/Stereo Camera/IMU/GNSS	Harsh	ROS, GNSS, IMU, Ground Truth	Harsh Urban Map
UrbanNav-HK-Tunnel-1	17 GB (398s)	3.15 Km	LiDARs/Stereo Camera/IMU/GNSS	N/A	ROS, GNSS, IMU, Ground Truth	Tunnel map
(Pilot data) UrbanNav-HK-Data20190428	42.9 GB (487s)	2.01 Km	LiDAR/Camera/IMU/GNSS	Medium	ROS, GNSS	N/A
(Pilot data) UrbanNav-HK-Data20200314	27.0 GB (300s)	1.21 Km	LiDAR/Camera/IMU/GNSS[240]	Light	ROS, GNSS	N/A

The 3D map visualization

LiDARs/Stereo Camera/IMU are recorded under **ROS**
GNSS measurements are stored in **RINEX3.02 and NMEA**

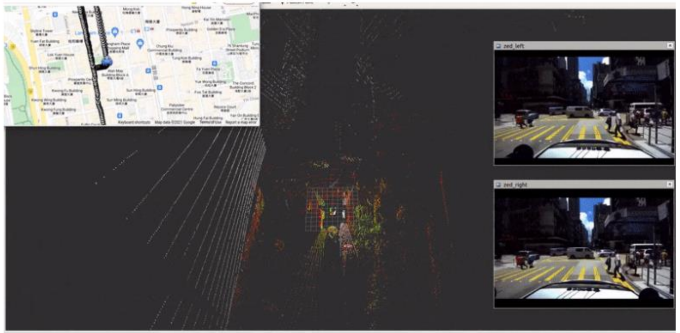
Example:
https://github.com/IPNL-POLYU/UrbanNavDataset#urbannav-hk-harsh-urban-1

README.md

UrbanNav-HK-Harsh-Urban-1

Dataset UrbanNav-HK-Harsh-Urban-1 is collected in an ultra-dense urban canyon of Hong Kong which involves dense vehicles, pedestrians and loops. The coordinates transformation between multiple sensors, and intrinsic measurements of camera can be found via Extrinsic Parameters, IMU Nosie and Intrinsic Parameters of Camera.

- Demo video
- ROS
  - ROSBAG file which includes:
    - 3D LiDAR point clouds (sensor_msgs/PointCloud2): `/velodyne_points`
    - Slant lidars (sensor_msgs/PointCloud2): `/left/lslidar_point_cloud` `/right/velodyne_points`
    - Stereo Camera (sensor_msgs/Image): `/zed2/camera/left/image_raw` `/zed2/camera/right/image_raw`
    - IMU (sensor_msgs/Imu): `/imu/data`
    - Time Reference between latest NMEA and ROS time (sensor_msgs/TimeReference): `/time_reference`
- GNSS (RINEX v3.02)
  - GNSS RINEX files, to use it, we suggest to use the RTKLIB
- IMU, Xsens MTi 10, 400Hz; Phone IMU, Xiaomi 8, 239Hz
- Ground Truth : NovAtel SPAN-CPT + IE, 1Hz



Latitude and longitude on Google map

```
%YAML:1.0

# extrinsic parameters for Dataset UrbanNav-HK-Mongkok-20210518. Be noted that the body is fixed at the IMU frame

################## Extrinsic parameter between IMU and Camera##################
################## camera is ZED2, a stereo camera##################
LEFT_CAMERA_T_IMU:!!opencv-matrix
 rows: 4
   cols: 4
   dt: d
   data:   [0.99958975976322017672, 0.017170804625958683,
              -0.022923255549840760448, -0.0851835233537896739,
               0.0231465893493554992, -0.01292276982900426,
             0.99964855695461152696, 0.1257734831824673213,
            0.016868538110887141801, -0.99976905607667321087,
           -0.013314913952324877203, 0.075888549707280005484,0.0, 0.0, 0.0, 1.0]
```

```
path:        UrbanNav-HK_TST-20210517_sensors.bag
version:     2.0
duration:    13:05s (785s)
start:       May 17 2021 10:32:55.55 (1621218775.55)
end:         May 17 2021 10:46:01.00 (1621219561.00)
size:        32.8 GB
messages:    386309
compression: none [25462/25462 chunks]
types:       novatel_msgs/INSPVAX       [b5d66747957184042a6cca9b7368742f]
             sensor_msgs/CameraInfo     [c9a58c1b0b154e0e6da7578cb991d214]
             sensor_msgs/Image          [060021388200f6f0f447d0fcd9c64743]
             sensor_msgs/Imu            [6a62c6daae103f4ff57a132d6f95cec2]
             sensor_msgs/PointCloud2    [1158d486dd51d683ce2f1be655c3c181]
             sensor_msgs/TimeReference  [fded64a0265108ba86c3d38fb11c0c16]
topics:      /imu/data                        314194 msgs    : sensor_msgs/Imu
             /left/lslidar_point_cloud          7856 msgs    : sensor_msgs/PointCloud2
             /novatel_data/inspvax               786 msgs    : novatel_msgs/INSPVAX
             /right/velodyne_points             7788 msgs    : sensor_msgs/PointCloud2
             /time_reference                     785 msgs    : sensor_msgs/TimeReference
             /velodyne_points                   7848 msgs    : sensor_msgs/PointCloud2
             /zed2/camera/left/camera_info     11763 msgs    : sensor_msgs/CameraInfo
             /zed2/camera/left/image_raw       11763 msgs    : sensor_msgs/Image
             /zed2/camera/right/camera_info    11763 msgs    : sensor_msgs/CameraInfo
             /zed2/camera/right/image_raw      11763 msgs    : sensor_msgs/Image
```

241

Example:

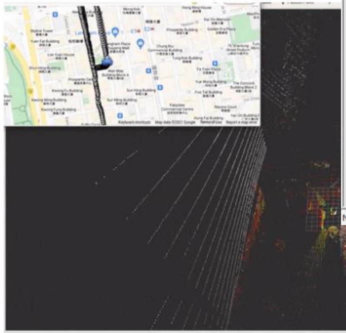
https://github.com/IPNL-POLYU/UrbanNavDataset#urbannav-hk-harsh-urban-1

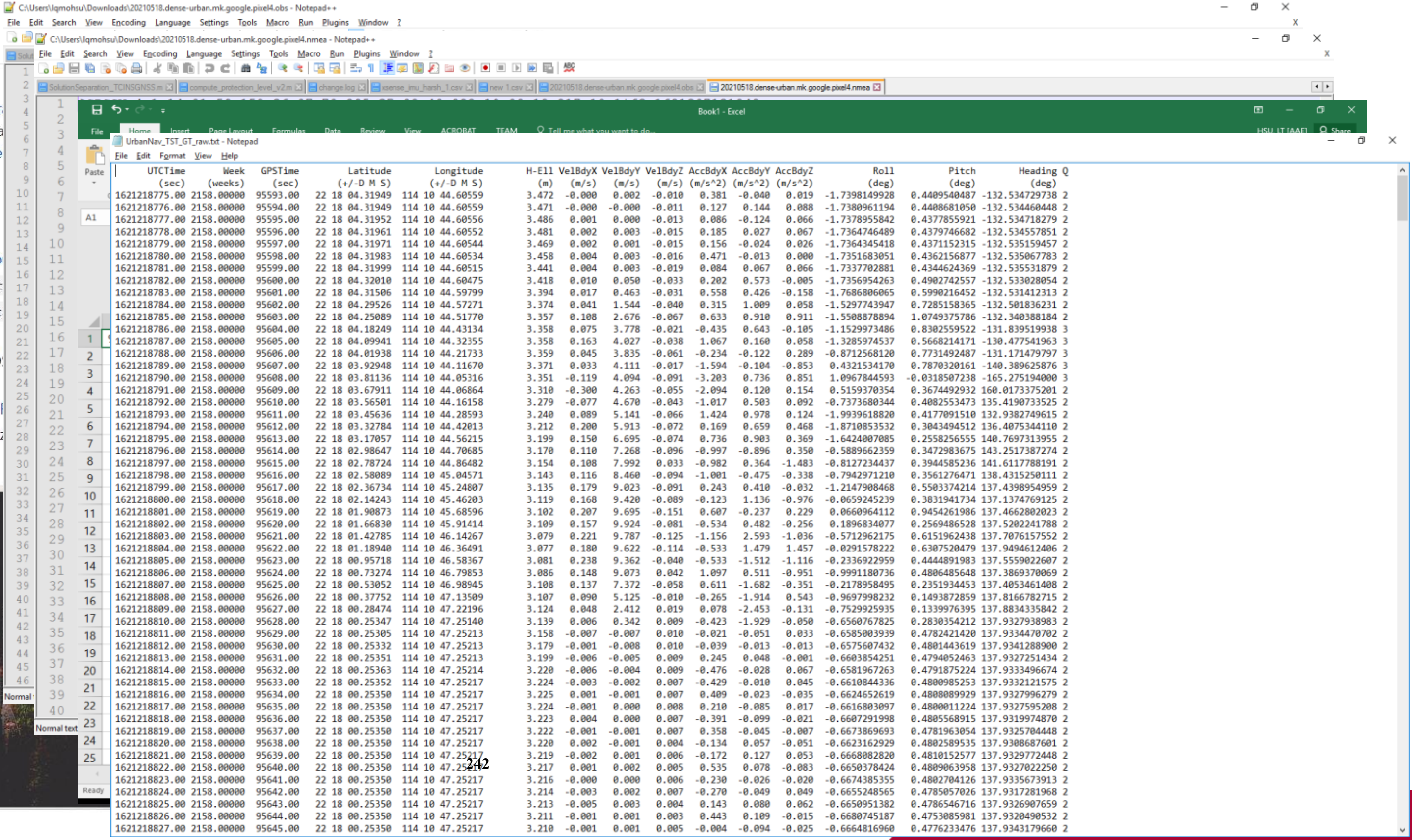
README.md

UrbanNav-HK-Harsh-Urban-1

Dataset UrbanNav-HK-Harsh-Urban-1 is collected in an ultr
vehicles, pedestrians and loops. The coordinates transforma
of camera can be found via Extrinsic Parameters, IMU Nosie

- Demo video
- ROS
  - ROSBAG file which includes:
    - 3D LiDAR point clouds (sensor_msgs/PointClo
    - Slant lidars (sensor_msgs/PointCloud2): `/left`
    - Stereo Camera (sensor_msgs/Image): `/zed2/c`
    - IMU (sensor_msgs/Imu): `/imu/data`
    - Time Reference between latest NMEA and RO
- GNSS (RINEX v3.02)
  - GNSS RINEX files, to use it, we suggest to use the
- IMU, Xsens MTi 10, 400Hz; Phone IMU, Xiaomi 8, 239Hz
- Ground Truth : NovAtel SPAN-CPT + IE, 1Hz





UTCTime (sec)	Week (weeks)	GPSTime (sec)	Latitude (+/-D M S)	Longitude (+/-D M S)	H-Ell (m)	VelBdyX (m/s)	VelBdyY (m/s)	VelBdyZ (m/s)	AccBdyX (m/s^2)	AccBdyY (m/s^2)	AccBdyZ (m/s^2)	Roll (deg)	Pitch (deg)	Heading (deg)	Q
1621218775.00	2158.00000	95593.00	22 18 04.31949	114 10 44.60559	3.472	-0.000	0.002	-0.010	0.381	-0.040	0.019	-1.7398149928	0.4409540487	-132.534729738	2
1621218776.00	2158.00000	95594.00	22 18 04.31949	114 10 44.60559	3.471	-0.000	-0.000	-0.011	0.127	0.144	0.088	-1.7380961194	0.4408681050	-132.534460448	2
1621218777.00	2158.00000	95595.00	22 18 04.31952	114 10 44.60556	3.486	0.001	0.000	-0.013	0.086	-0.124	0.066	-1.7378955842	0.4377855921	-132.534718279	2
1621218778.00	2158.00000	95596.00	22 18 04.31961	114 10 44.60552	3.481	0.002	0.003	-0.015	0.185	0.027	0.067	-1.7364746489	0.4379746682	-132.534557851	2
1621218779.00	2158.00000	95597.00	22 18 04.31971	114 10 44.60544	3.469	0.002	0.001	-0.015	0.156	-0.024	0.026	-1.7364345418	0.4371152315	-132.535159457	2
1621218780.00	2158.00000	95598.00	22 18 04.31983	114 10 44.60534	3.458	0.004	0.003	-0.016	0.471	-0.013	0.000	-1.7351683051	0.4362156877	-132.535067783	2
1621218781.00	2158.00000	95599.00	22 18 04.31999	114 10 44.60515	3.441	0.004	0.003	-0.019	0.084	0.067	0.066	-1.7337702881	0.4344624369	-132.535531879	2
1621218782.00	2158.00000	95600.00	22 18 04.32010	114 10 44.60475	3.418	0.010	0.050	-0.033	0.202	0.573	-0.005	-1.7356954263	0.4902742557	-132.533028054	2
1621218783.00	2158.00000	95601.00	22 18 04.31506	114 10 44.59799	3.394	0.017	0.463	-0.031	0.558	0.426	-0.158	-1.7686806065	0.5990216452	-132.531412313	2
1621218784.00	2158.00000	95602.00	22 18 04.29526	114 10 44.57271	3.374	0.041	1.544	-0.040	0.315	1.009	0.058	-1.5297743947	0.7285158365	-132.501836231	2
1621218785.00	2158.00000	95603.00	22 18 04.25089	114 10 44.51770	3.357	0.108	2.676	-0.067	0.633	0.910	0.911	-1.5508878894	1.0749375786	-132.340388184	2
1621218786.00	2158.00000	95604.00	22 18 04.18249	114 10 44.43134	3.358	0.075	3.778	-0.021	-0.435	0.643	-0.105	-1.1529973486	0.8302559522	-131.839519938	3
1621218787.00	2158.00000	95605.00	22 18 04.09941	114 10 44.32355	3.358	0.163	4.027	-0.038	1.067	0.160	0.058	-1.3285974537	0.5668214171	-130.477541963	3
1621218788.00	2158.00000	95606.00	22 18 04.01938	114 10 44.21733	3.359	0.045	3.835	-0.061	-0.234	-0.122	0.289	-0.8712568120	0.7731492487	-131.171479797	3
1621218789.00	2158.00000	95607.00	22 18 03.92948	114 10 44.11670	3.371	0.033	4.111	-0.017	-1.594	-0.104	-0.853	0.4321534170	0.7870320161	-140.389625876	3
1621218790.00	2158.00000	95608.00	22 18 03.81136	114 10 44.05316	3.351	-0.119	4.094	-0.091	-3.203	0.736	0.851	1.0967844593	-0.0318507238	-165.275194000	3
1621218791.00	2158.00000	95609.00	22 18 03.67911	114 10 44.06864	3.310	-0.300	4.263	-0.055	-2.094	0.120	0.154	0.5159370354	0.3674492932	160.0173375201	2
1621218792.00	2158.00000	95610.00	22 18 03.56501	114 10 44.16158	3.279	-0.077	4.670	-0.043	-1.017	0.503	0.092	-0.7373680344	0.4082553473	135.4190733525	2
1621218793.00	2158.00000	95611.00	22 18 03.45636	114 10 44.28593	3.240	0.089	5.141	-0.066	1.424	0.978	0.124	-1.9939618820	0.4177091510	132.9382749615	2
1621218794.00	2158.00000	95612.00	22 18 03.32784	114 10 44.42013	3.212	0.200	5.913	-0.072	0.169	0.659	0.468	-1.8710853532	0.3043494512	136.4075344110	2
1621218795.00	2158.00000	95613.00	22 18 03.17057	114 10 44.56215	3.199	0.150	6.695	-0.074	0.736	0.903	0.369	-1.6424007085	0.2558256555	140.7697313955	2
1621218796.00	2158.00000	95614.00	22 18 02.98647	114 10 44.70685	3.170	0.110	7.268	-0.096	-0.997	-0.896	0.350	-0.5889662359	0.3472983675	143.2517387274	2
1621218797.00	2158.00000	95615.00	22 18 02.78724	114 10 44.86482	3.154	0.108	7.992	0.033	-0.982	0.364	-1.483	-0.8127234437	0.3944585236	141.6117788191	2
1621218798.00	2158.00000	95616.00	22 18 02.58089	114 10 45.04571	3.143	0.116	8.460	-0.094	-1.001	-0.475	-0.338	-0.7942971210	0.3561276471	138.4315250111	2
1621218799.00	2158.00000	95617.00	22 18 02.36734	114 10 45.24807	3.135	0.179	9.023	-0.091	0.243	0.410	-0.032	-1.2147908468	0.5503374214	137.4398954959	2
1621218800.00	2158.00000	95618.00	22 18 02.14243	114 10 45.46203	3.119	0.168	9.420	-0.089	-0.123	1.136	-0.976	-0.0659245239	0.3831941734	137.1374769125	2
1621218801.00	2158.00000	95619.00	22 18 01.90873	114 10 45.68596	3.102	0.207	9.695	-0.151	0.607	-0.237	0.229	0.0660964112	0.9454261986	137.4662802023	2
1621218802.00	2158.00000	95620.00	22 18 01.66830	114 10 45.91414	3.109	0.157	9.924	-0.081	-0.534	0.482	-0.256	0.1896834077	0.2569486528	137.5202241788	2
1621218803.00	2158.00000	95621.00	22 18 01.42785	114 10 46.14267	3.079	0.221	9.787	-0.125	-1.156	2.593	-1.036	-0.5712962175	0.6151962438	137.7076157552	2
1621218804.00	2158.00000	95622.00	22 18 01.18940	114 10 46.36491	3.077	0.180	9.622	-0.114	-0.533	1.479	1.457	-0.0291578222	0.6307520479	137.9494612406	2
1621218805.00	2158.00000	95623.00	22 18 00.95718	114 10 46.58367	3.081	0.238	9.362	-0.040	-0.533	-1.512	-1.116	-0.2336922959	0.4444891983	137.5559022607	2
1621218806.00	2158.00000	95624.00	22 18 00.73274	114 10 46.79853	3.086	0.148	9.073	0.042	1.097	0.511	-0.951	-0.9991180736	0.4806485648	137.3869370069	2
1621218807.00	2158.00000	95625.00	22 18 00.53052	114 10 46.98945	3.108	0.137	7.372	-0.058	0.611	-1.682	-0.351	-0.2178958495	0.2351934453	137.4053461408	2
1621218808.00	2158.00000	95626.00	22 18 00.37752	114 10 47.13509	3.107	0.090	5.125	-0.010	-0.265	-1.914	0.543	-0.9697998232	0.1493872859	137.8166782715	2
1621218809.00	2158.00000	95627.00	22 18 00.28474	114 10 47.22196	3.124	0.048	2.412	0.019	0.078	-2.453	-0.131	-0.7529925935	0.1339976395	137.8834335842	2
1621218810.00	2158.00000	95628.00	22 18 00.25347	114 10 47.25140	3.139	0.006	0.342	0.009	-0.423	-1.929	-0.050	-0.6560767825	0.2830354212	137.9327938983	2
1621218811.00	2158.00000	95629.00	22 18 00.25305	114 10 47.25213	3.158	-0.007	-0.007	0.010	-0.021	-0.051	0.033	-0.6585003939	0.4782421420	137.9334470702	2
1621218812.00	2158.00000	95630.00	22 18 00.25332	114 10 47.25213	3.179	-0.001	-0.008	0.010	-0.039	-0.013	-0.013	-0.6575607432	0.4801443619	137.9341288900	2
1621218813.00	2158.00000	95631.00	22 18 00.25351	114 10 47.25213	3.199	-0.006	-0.005	0.009	0.245	0.048	-0.001	-0.6603854251	0.4794052463	137.9327251434	2
1621218814.00	2158.00000	95632.00	22 18 00.25363	114 10 47.25214	3.220	-0.006	-0.004	0.009	-0.476	-0.028	0.067	-0.6581967263	0.4791875224	137.9333496674	2
1621218815.00	2158.00000	95633.00	22 18 00.25352	114 10 47.25217	3.224	-0.003	-0.002	0.007	-0.429	-0.010	0.045	-0.6610844336	0.4800985253	137.9332121575	2
1621218816.00	2158.00000	95634.00	22 18 00.25350	114 10 47.25217	3.225	0.001	-0.001	0.007	0.409	-0.023	-0.035	-0.6624652619	0.4808089929	137.9327996279	2
1621218817.00	2158.00000	95635.00	22 18 00.25350	114 10 47.25217	3.224	-0.001	0.000	0.008	0.210	-0.085	0.017	-0.6616803097	0.4800011224	137.9327595208	2
1621218818.00	2158.00000	95636.00	22 18 00.25350	114 10 47.25217	3.223	0.004	0.000	0.007	-0.391	-0.099	-0.021	-0.6607291998	0.4805568915	137.9319974870	2
1621218819.00	2158.00000	95637.00	22 18 00.25350	114 10 47.25217	3.222	-0.001	-0.001	0.007	0.358	-0.045	-0.007	-0.6673869693	0.4781963054	137.9325704448	2
1621218820.00	2158.00000	95638.00	22 18 00.25350	114 10 47.25217	3.220	0.002	-0.001	0.004	-0.134	0.057	-0.051	-0.6623162929	0.4802589535	137.9308687601	2
1621218821.00	2158.00000	95639.00	22 18 00.25350	114 10 47.25217	3.219	-0.002	0.001	0.006	-0.172	0.127	0.053	-0.6668082820	0.4810152577	137.9329772448	2
1621218822.00	2158.00000	95640.00	22 18 00.25350	114 10 47.25[illegible]	3.217	0.001	0.002	0.005	0.535	0.078	-0.083	-0.6650378424	0.4809063958	137.9327022250	2
1621218823.00	2158.00000	95641.00	22 18 00.25350	114 10 47.25217	3.216	-0.000	0.000	0.006	-0.230	-0.026	-0.020	-0.6674385355	0.4802704126	137.9335673913	2
1621218824.00	2158.00000	95642.00	22 18 00.25350	114 10 47.25217	3.214	-0.003	0.002	0.007	-0.270	-0.049	0.049	-0.6655248565	0.4785057026	137.9317281968	2
1621218825.00	2158.00000	95643.00	22 18 00.25350	114 10 47.25217	3.213	-0.005	0.003	0.004	0.143	0.080	0.062	-0.6650951382	0.4786546716	137.9326907659	2
1621218826.00	2158.00000	95644.00	22 18 00.25350	114 10 47.25217	3.211	-0.001	0.001	0.003	0.443	0.109	-0.015	-0.6680745187	0.4753085981	137.9320490532	2
1621218827.00	2158.00000	95645.00	22 18 00.25350	114 10 47.25217	3.210	-0.001	0.001	0.005	-0.004	-0.094	-0.025	-0.6664816960	0.4776233476	137.9343179660	2

Get Started – GNSS/VIO/LIO

Using RTKLIB [1] to run UrbanNav GNSS data
https://www.youtube.com/watch?v=b1-lKmUttzc

Using VINS-Fusion [2] to run UrbanNav Images and IMU data
https://www.youtube.com/watch?v=b1-lKmUttzc

Using LIO-SAM [3] to run UrbanNav LiDAR and IMU data
https://www.youtube.com/watch?v=HurGAq0DKeo

[1] T. Takasu, TUMSAT
http://www.rtklib.com/

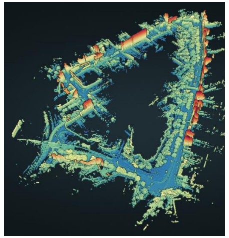
[2] T. Qin, P. Li and S. Shen, "VINS-Mono: A Robust and Versatile Monocular Visual-Inertial State Estimator," in *IEEE Transactions on Robotics*, vol. 34, no. 4, pp. 1004-1020, Aug. 2018, doi: 10.1109/TRO.2018.2853729
https://github.com/HKUST-Aerial-Robotics/VINS-Fusion

[3] T. Shan, B. Englot, D. Meyers, W. Wang, C. Ratti and D. Rus, "LIO-SAM: Tightly-coupled Lidar Inertial Odometry via Smoothing and Mapping," 2020 IEEE IROS, 2020, pp. 5135-5142, doi: 10.1109/IROS45743.2020.9341176.
https://github.com/TixiaoShan/LIO-SAM

Evaluation – RTKLIB [1]

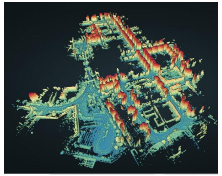
RKTLIB 2.4.3 b34 settings, GPS+GLO+GAL+BDS+QZS, El mask: 15 deg, SNR mask: 15dBHz

Receiver	Availability (%)	Mean (m)	STD (m)
Novatel Flexpak 6	45.36	4.41	9.72
Ublox F9P	41.42	6.48	5.17
Ublox M8T	61.88	12.60	15.10
Xiaomi Mi 8	72.05	25.14	38.86



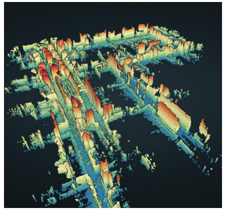
Medium Urban Canyon

Receiver	Availability (%)	Mean (m)	STD (m)
Novatel Flexpak 6	85.45	5.47	19.82
Ublox F9P	56.86	7.62	8.94
Ublox M8T	66.41	11.13	12.98
Xiaomi Mi 8	59.58	36.97	96.01



Deep Urban Canyon

Receiver	Availability (%)	Mean (m)	STD (m)
Novatel Flexpak 6	69.03	13.42	72.75
Ublox F9P	25.17	18.35	22.70
Ublox M8T	47.49	27.21	63.42
Xiaomi Mi 8	67.04	53.69	250.67



Harsh Urban Canyon

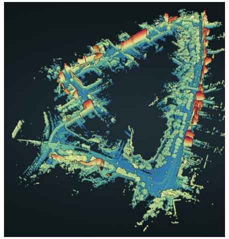
244

[1] http://www.rtklib.com/ , https://github.com/tomojitakasu/RTKLIB

Evaluation – RTKLIB (Kinematic)

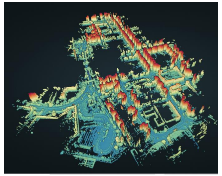
RKTLIB 2.4.3 b34
settings, GPS+GLO+GAL+BDS+QZS,
AR: Fix and hold, combined
El mask: 15 deg,
SNR mask: 15dBHz

Receiver	Availability (%)	Fix rate (%)
Novatel Flexpak 6	5.84	12.89
Ublox F9P	4.96	25.32
Ublox M8T	3.30	9.81
Xiaomi Mi 8	2.16	26.15



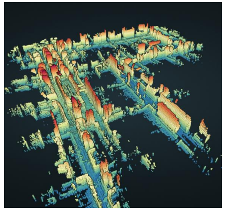
Medium Urban Canyon

Receiver	Availability (%)	Fix rate (%)
Novatel Flexpak 6	5.91	6.92
Ublox F9P	4.87	11.56
Ublox M8T	7.28	14.16
Xiaomi Mi 8	3.83	26.70



Deep Urban Canyon

Receiver	Availability (%)	Fix rate (%)
Novatel Flexpak 6	3.63	5.26
Ublox F9P	0.56	4.22
Ublox M8T	3.76	19.86
Xiaomi Mi 8	4.28	24.81



Harsh Urban Canyon

Availability:

$$\frac{Fix\ sol}{Total\ epochs}$$

Fix rate:

$$\frac{Fix\ sol}{RTK\ sol\ (fix\ \&\ float)}$$

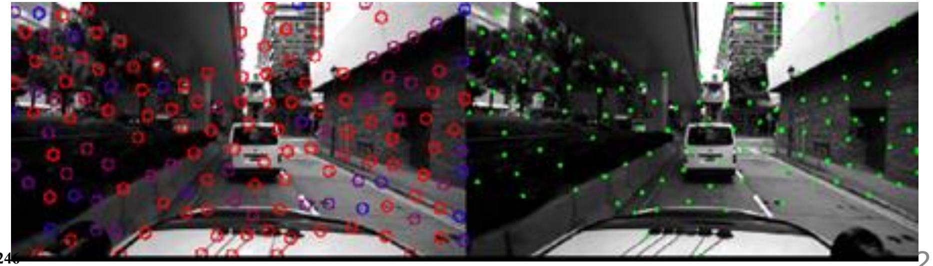
[1] http://www.rtklib.com/ , https://github.com/tomojitakasu/RTKLIB

Evaluation - Visual Inertial Odometry via VINS-Fusion [2]

The mean error is defined by the relative pose error (RPE) in the EVO [3], which is widely used in SLAM field. We look at the translation (displacement between two epochs).

Scenario (1Hz)	Mean	RMSE	Max	Min
Middle	0.560m	0.875m	6.069m	0.001m
Deep	Fail	Fail	Fail	Fail
Harsh	0.667m	1.882m	14.243m	0.001m
Tunnel	Fail	Fail	Fail	Fail

[2] T. Qin, P. Li and S. Shen, "VINS-Mono: A Robust and Versatile Monocular Visual-Inertial State Estimator," in *IEEE Transactions on Robotics*, vol. 34, no. 4, pp. 1004-1020, Aug. 2018, doi: 10.1109/TRO.2018.2853729
https://github.com/HKUST-Aerial-Robotics/VINS-Fusion
[3] https://github.com/MichaelGrupp/evo

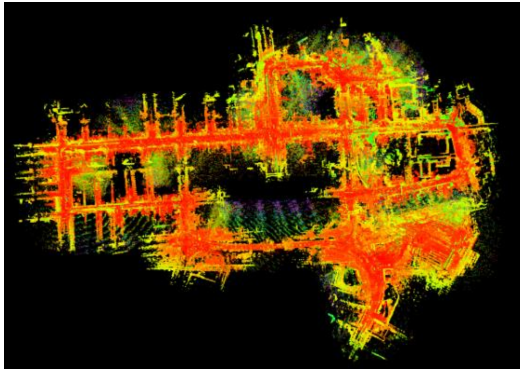


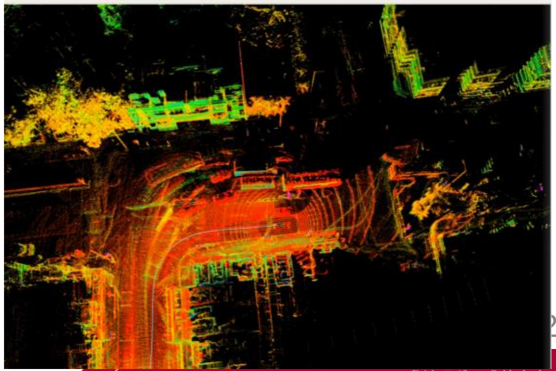
Evaluation - LiDAR Inertial Odometry – LIO-SAM [4]

The mean error is defined by the relative pose error (RPE) in the EVO [3], which is widely used in SLAM field. We look at the translation (displacement between two epochs).

Scenario (1Hz)	Mean	RMSE	Max	Min
Middle	0.250m	0.369m	2.323m	0.017m
Deep	0.127m	0.297m	7.410m	0.005m
Harsh	0.178m	0.302m	4.004m	0.010m
Tunnel	Fail	Fail	Fail	Fail

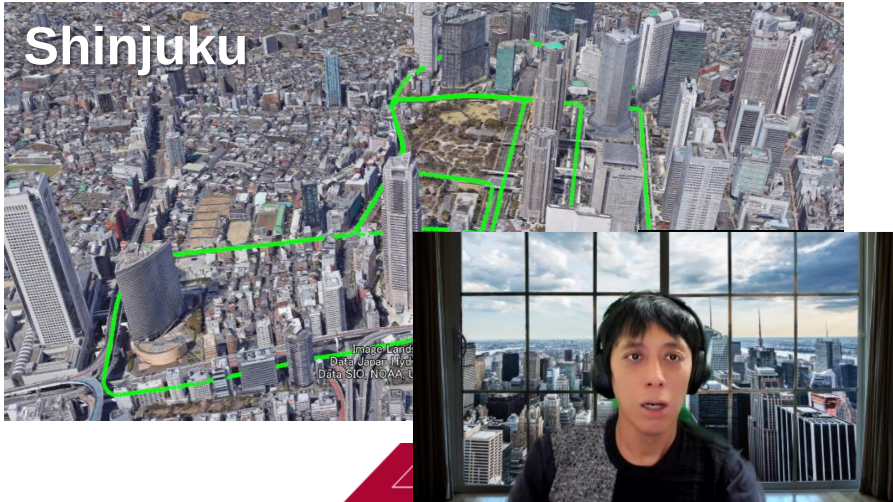
[4] T. Shan, B. Englot, D. Meyers, W. Wang, C. Ratti and D. Rus, "LIO-SAM: Tightly-coupled Lidar Inertial Odometry via Smoothing and Mapping," 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2020, pp. 5135-5142, doi: 10.1109/IROS45743.2020.9341176. https://github.com/TixiaoShan/LIO-SAM
[3] https://github.com/MichaelGrupp/evo





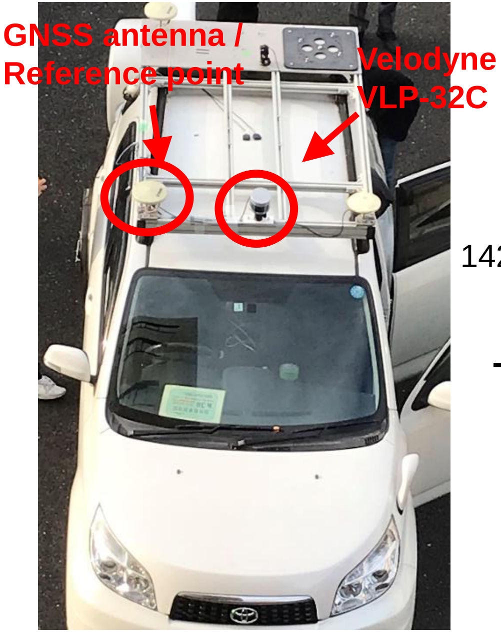
Tokyo Dataset

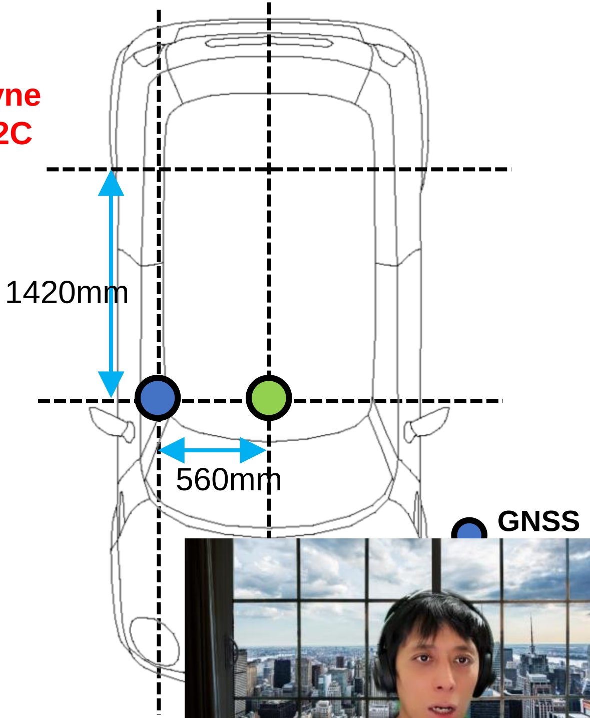
Tokyo Dataset



The Tokyo Data Collection Platform

- **Ground truth:**
  Applanix POS LV 620
- **GNSS:** u-blox & Trimble
- **LiDAR:** Velodyne VLP-32C
- **IMU:** Tamagawa TAG264



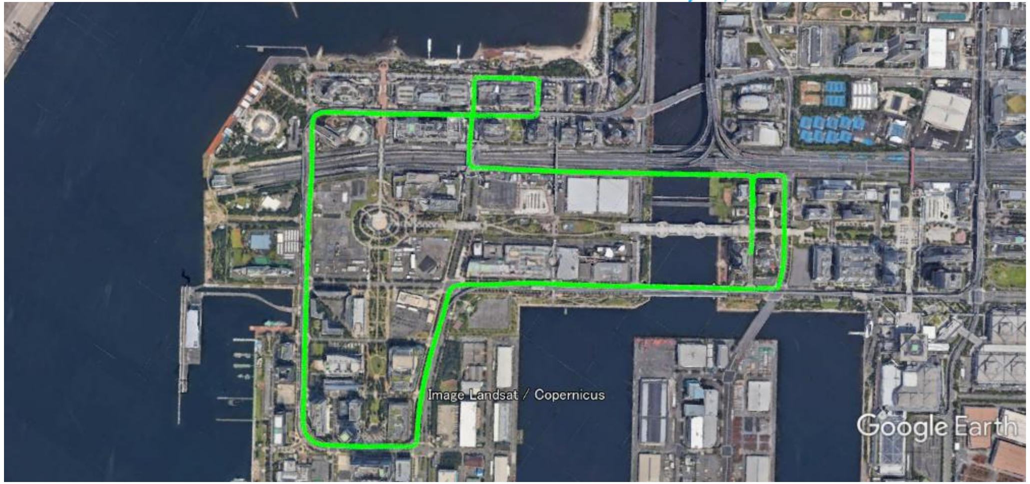


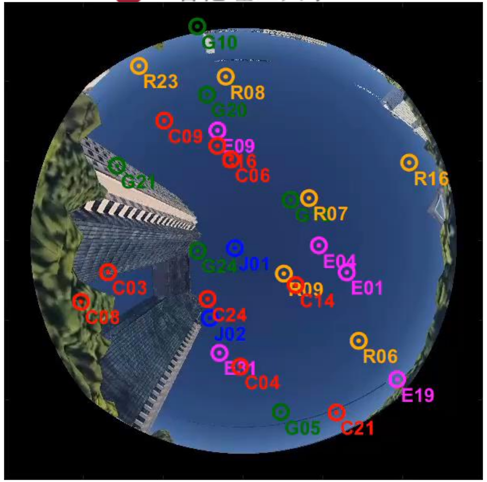
Sensors

Sensors	Grade	Sensors model	Data format	ROS topic	Freq	Time Standard	Remarks
GNSS	commercial	u-blox ZED-F9P	RINEX3.02	Nil	5 Hz	GPS time	GPS (L1, L2); GLONASS (L1, L2); GALILEO (E1, E5b); BeiDou (B1, B2); QZSS (L1, L2)
GNSS	Geodetic	Trimble NetR9	RINEX3.02	Nil	10 Hz	GPS time	GPS (L1, L2, L2C, L5); GLONASS (L1, L2, L2C); Galileo (E1, E5a, E5b); BeiDou (B1, B2); QZSS
GNSS (Base)	Geodetic	Trimble NetR9	RINEX3.02	Nil	1 Hz	GPS time	GPS (L1, L2, L2C, L5); GLONASS (L1, L2, L2C); Galileo (E1, E5a, E5b); BeiDou (B1, B2); QZSS
LiDAR	Navigation	Velodyne VLP-32C	velodyne_msgs/VelodyneScan	/velodyne_packets	10 Hz	ROS time	https://github.com/ros-dr
IMU	MEMS commercial	Tamagawa TAG264	CSV	Nil	50 Hz	GPS time	Synch

Odaiba

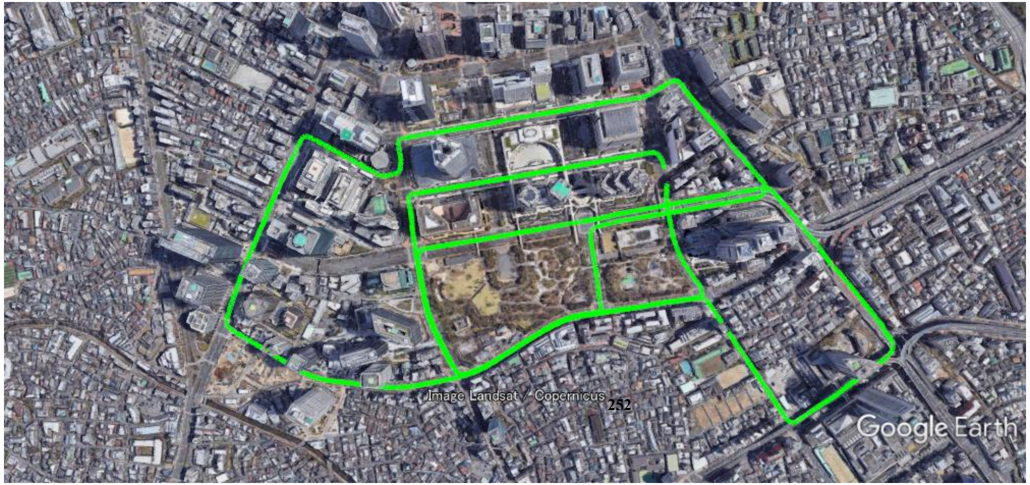
- Medium Urban
- Elevated railway





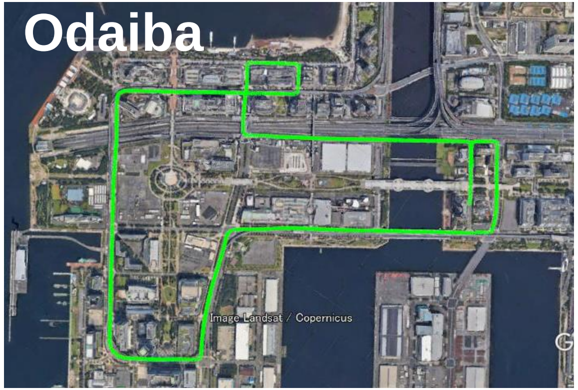
Shinjuku

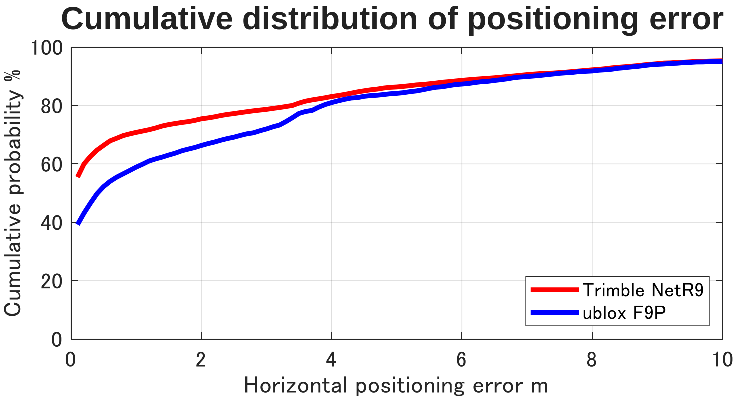
- Deep Urban Canyon
- Over 200m buildings



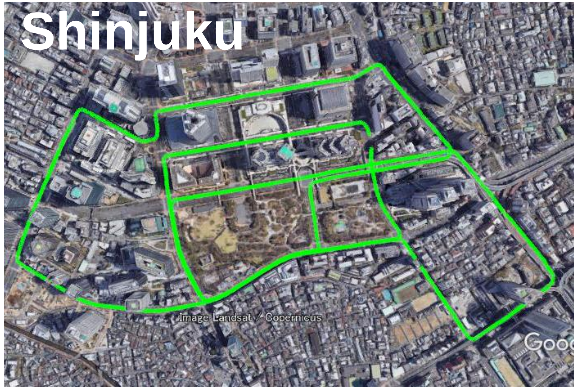
Evaluation - GNSS PPK by RTKLIB

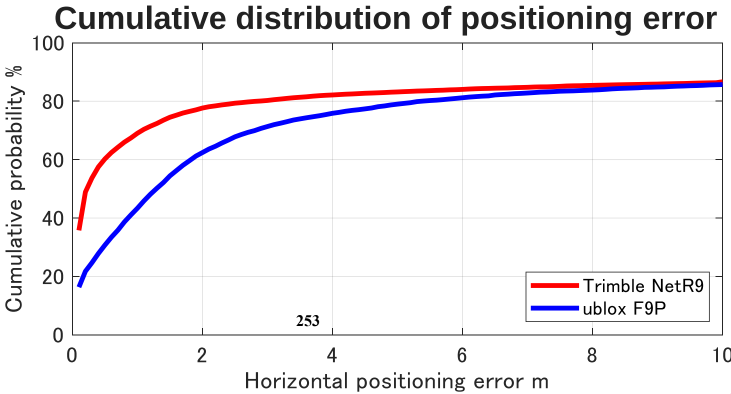
* RTKLIB settings, GPS+GLO+GAL+BDS+QZS, AR: Instantaneous, El mask: 30 deg, SNR mask: 35 dB-Hz





Receiver	FIX rate (%)
Trimble NetR9	53.9
Ublox F9P	43.9





Receiver	FIX rate (%)
Trimble	

Conclusion

- **UrbanNav** **(from HK and Tokyo Now)**
- **Open-Source Multi-Sensory Dataset in Urban Canyons**
  - LiDAR, Camera, GNSS and INS are included.
  - Middle-, Deep- and Harsh Urban Canyons, and Tunnel

Future work:

- Building a website to let the researchers upload their paper and result that evaluated based on the open-source data
- Reporting the performance of the state-of-the-art positioning and integration algorithms using **UrbanNav** in every 2 years.

Students contributed to the dataset

Mr Feng Huang

Mr Hoi-Fung Ng

Mr Guohao Zhang

Miss Xiwei Bai

Mr Yihan Zhong

Miss Jiachen Zhang

Thank you for your attention!

Questions, Comments and Collaboration are welcome.

Dr Li-Ta Hsu (許立達)
lt.hsu@polyu.edu.hk

Limin Endowed Young Scholar in Aerospace Navigation,

Associate Professor and Associate Head,

Department of Aeronautical and Aviation Engineering,

The Hong Kong Polytechnic University.

Google: UrbanNavDataset

https://github.com/IPNL-POLYU/UrbanNavDataset