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Machine Learning-Based Vehicle/Human Motion Detection of Low-Cost IMU for Two-Wheeler DR Navigation

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AIROHA (Company of MediaTek Group)

Agenda

- Introduction
- Motivation
- Methodology
- Experiment Setting
- Results
- Conclusion

AIROHA Overview

MEDIATEK GROUP

- **Fabless IC Design Company with a focus on Wired and Wireless Communication Technologies**
  - 2021/4 : merger of Airoha and Econet
  - 940+ employees, 85% in R&D and 70% with MS or PhD degree
  - A subsidiary of MediaTek

- **Diversified Product portfolio and customer base**
  - Wireless Communications: Bluetooth, GNSS/M2M
  - Fixed-line Networking: Broadband, Ethernet

- **Worldwide Offices**
  - Hsinchu, Taiwan (HQs/R&D)
  - Taipei, Taiwan (Sales/R&D)
  - Chengdu, China (R&D)
  - Suzhou, China (R&D)
  - Nanjing, China (R&D)
  - Shenzhen, China (Sales/FAE)
  - Shanghai, China (Sales/FAE)

Positioning Communications Product (PCP)

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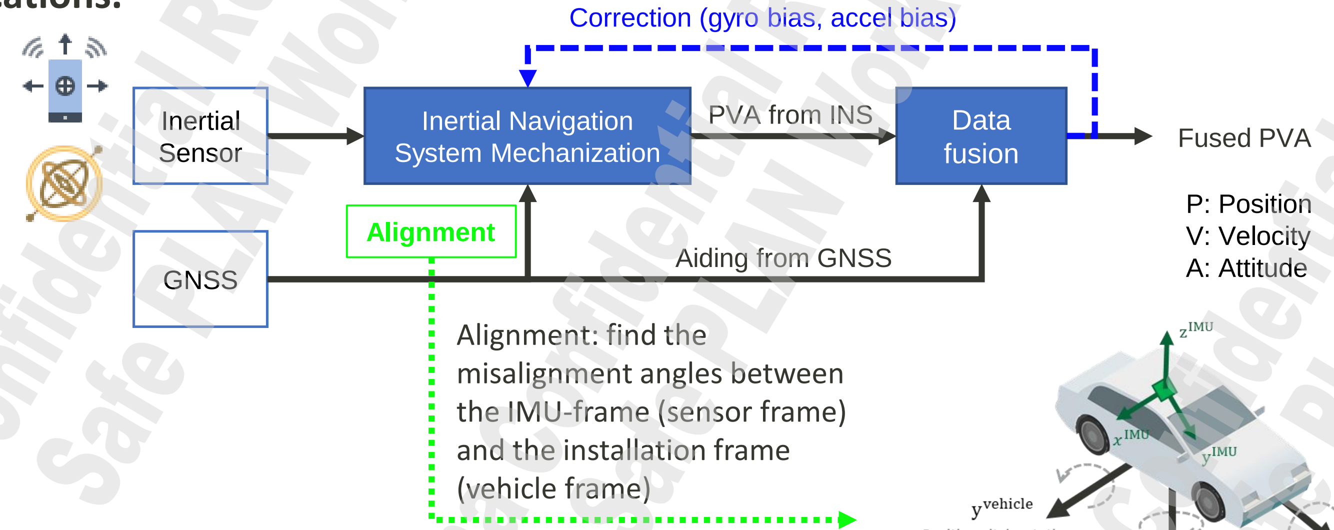
Introduction – DR

- **Dead Reckoning (DR) is a positioning technique which combines inertial sensor and GNSS data to achieve seamless navigation and better positioning performance for automotive applications.**

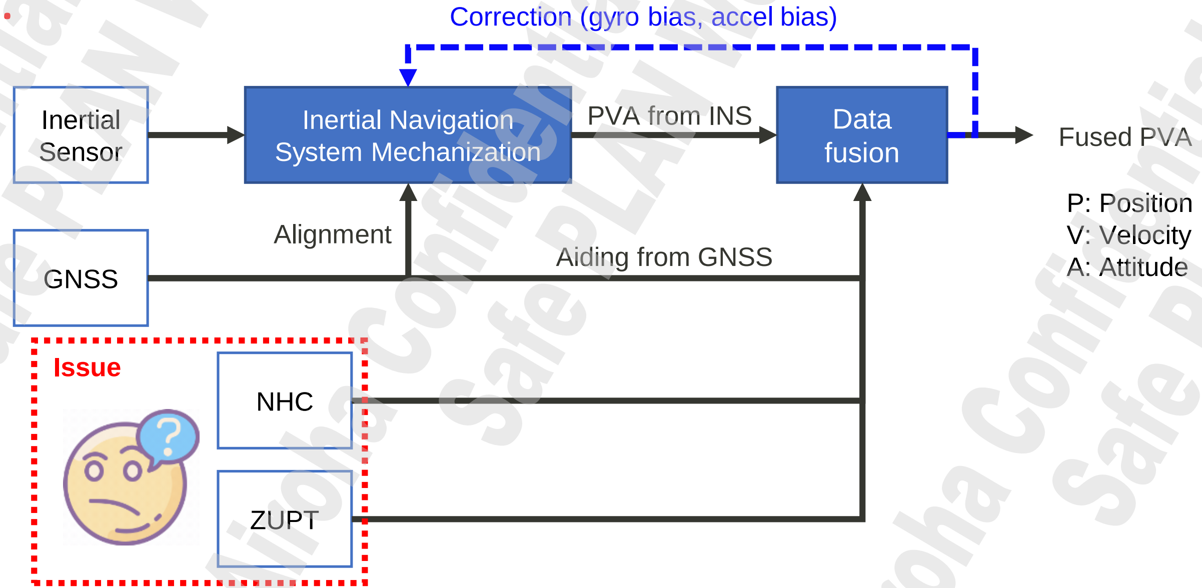


IMU frame
- Origin: the center of the IMU;
- x-axis, y-axis and z-axis are based on the manufacturer's defintion.

Vehicle frame
- Origin: the same as the IMU frame;
- x-axis: the front of the vehicle;
- y-axis: the right of the vehicle;
- z-axis: pointing down.

Introduction – Conventional Two-Wheeler DR (2WDR)

- **Non-Holonomic Constraints (NHC): constraint the lateral and vertical velocity while driving.**
- **Zero Velocity Update (ZUPT): constraint the velocity to zero when detect vehicle is static.**
- **Issue: when non-linear motion happens, they are not the correct assumptions for 2WDR (kick scooter).**



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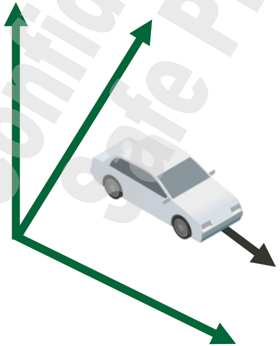
Motivation – Why Detect Non-Linear Motions

- **Conventional DR algorithm is based on the linear and vehicle motion to derive the navigation information. If the motion severely violates these assumptions, the performance might degrade quickly.**
- **Hence, to maintain the DR performance, it is important to detect these non-linear motions especially for the case that vehicle's motion with a lot of human intervention, such as riding kick scooter.**

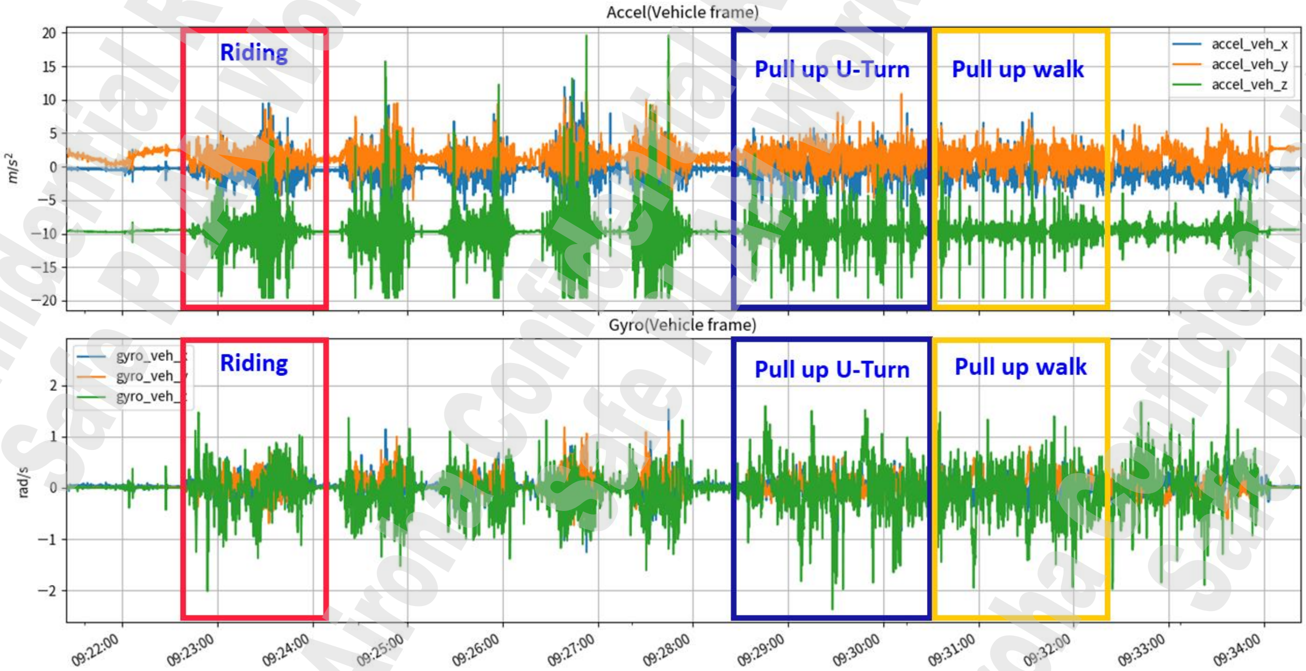


Nonlinear Motion: Pull-up U-Turn

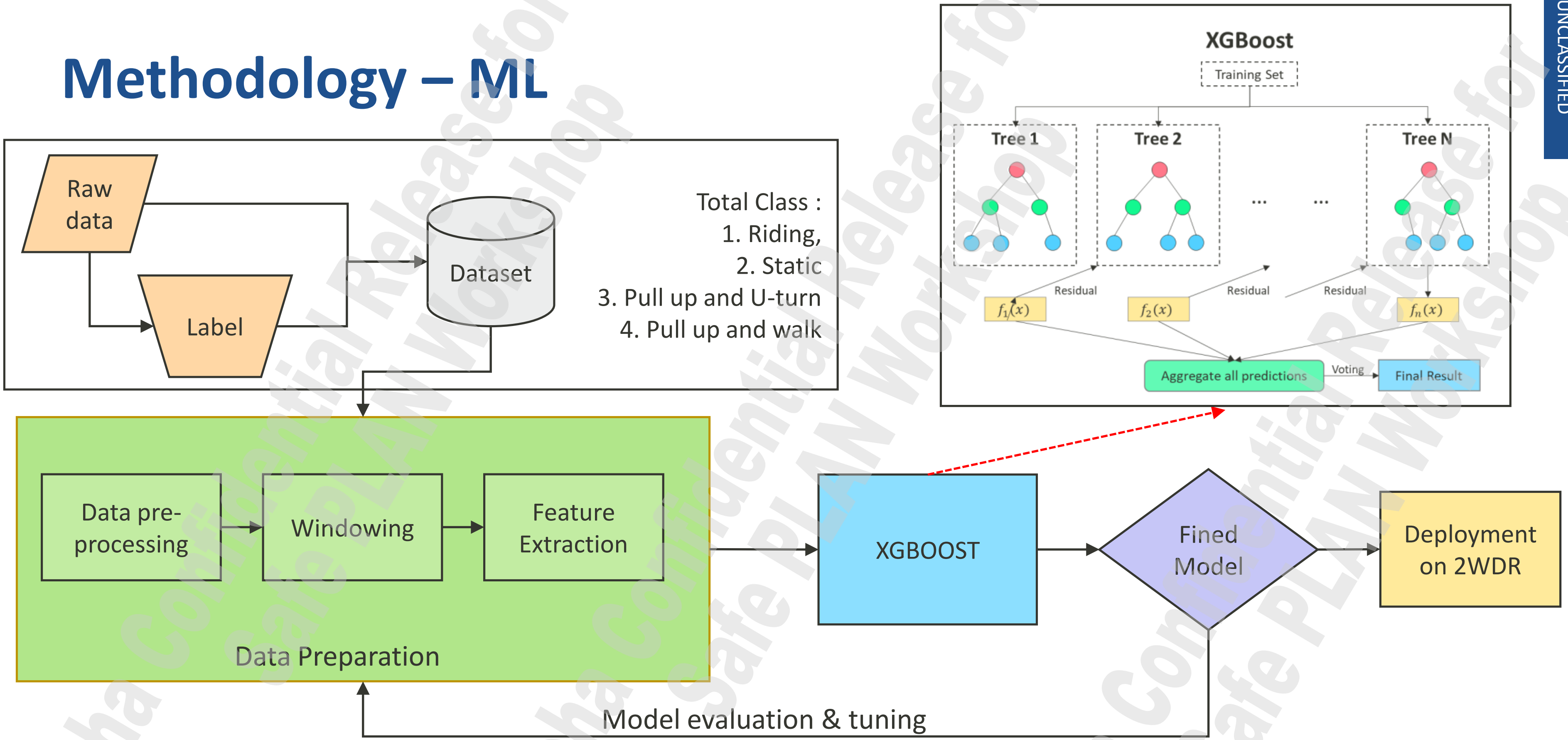
Nonlinear Motion: Pull-up Walk

Motivation – Why Use ML to Detect

- **Complex data signal makes it more difficult to classify.**
- **Empirical threshold is not applicable for different users.**

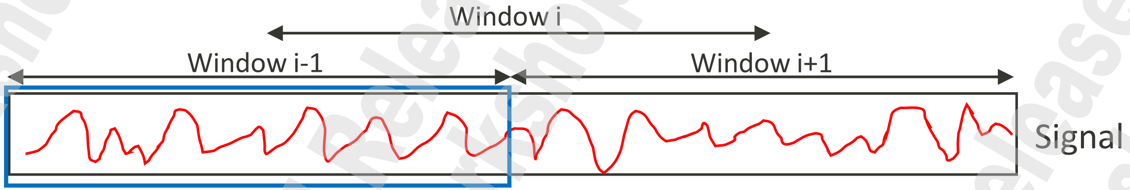


Methodology – ML



Methodology – ML Data Preparation

- **Windowing:**
  - **1.5 sec sliding window**



- **Feature Extraction**
  - **Time domain**
  - **Hjorth parameters**

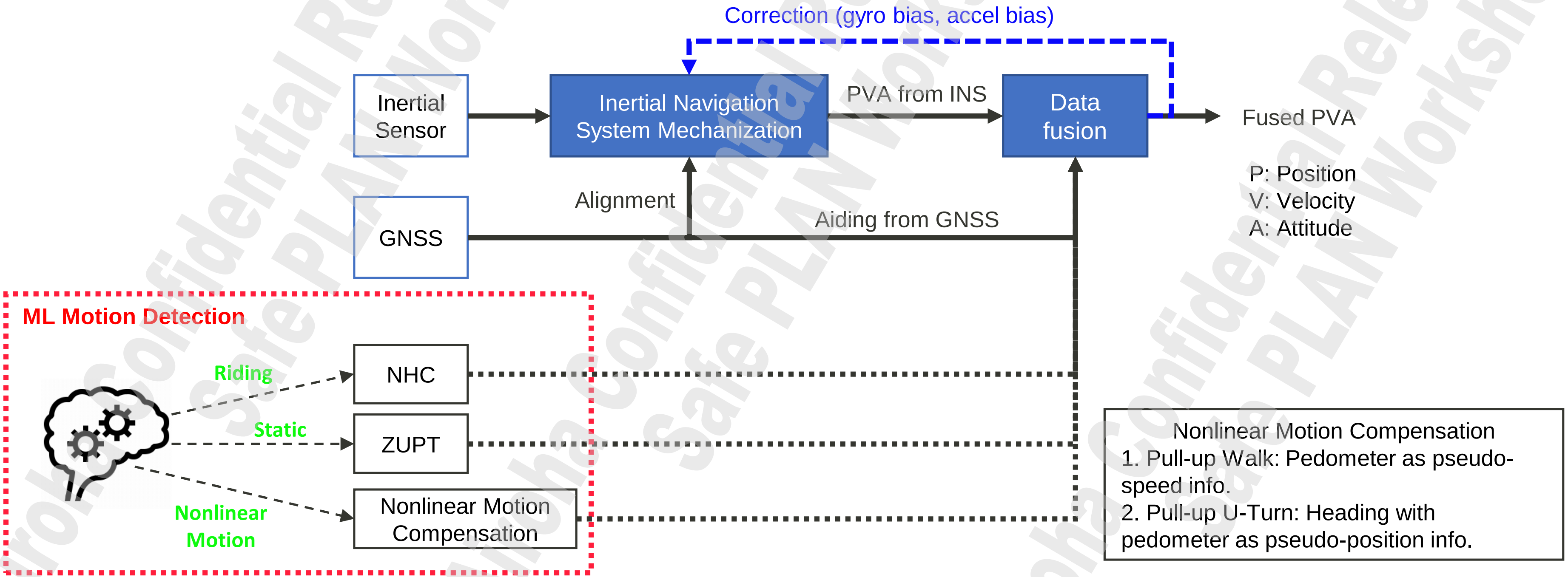
Type	Features	Definition	Applied Components
Time-domain	σ	Standard Deviation	$a_x, a_y, a_z, a_{norm}, gyro_x, gyro_y, gyro_z, gyro_{norm}$
	µ	Mean	
	MS	Mean squared	
	WMAX	Window max	
	WMIN	Window min	
	RANGE	WMAX-WMIN	
	PAR	Peak to average ratio	
Hjorth parameters	A	Activity	
	M	Mobility	
	C	Complexity	

- **Deal With Unbalance Data:**
  - **Add weight for the objecti**

$$W_i = \frac{m_{all}}{n_{cls} * m_{(i|all)}}$$

Methodology – 2WDR + ML

- **Using ML motion detection to identify the corresponding motions and assumptions (models) to control the sensor drifting.**



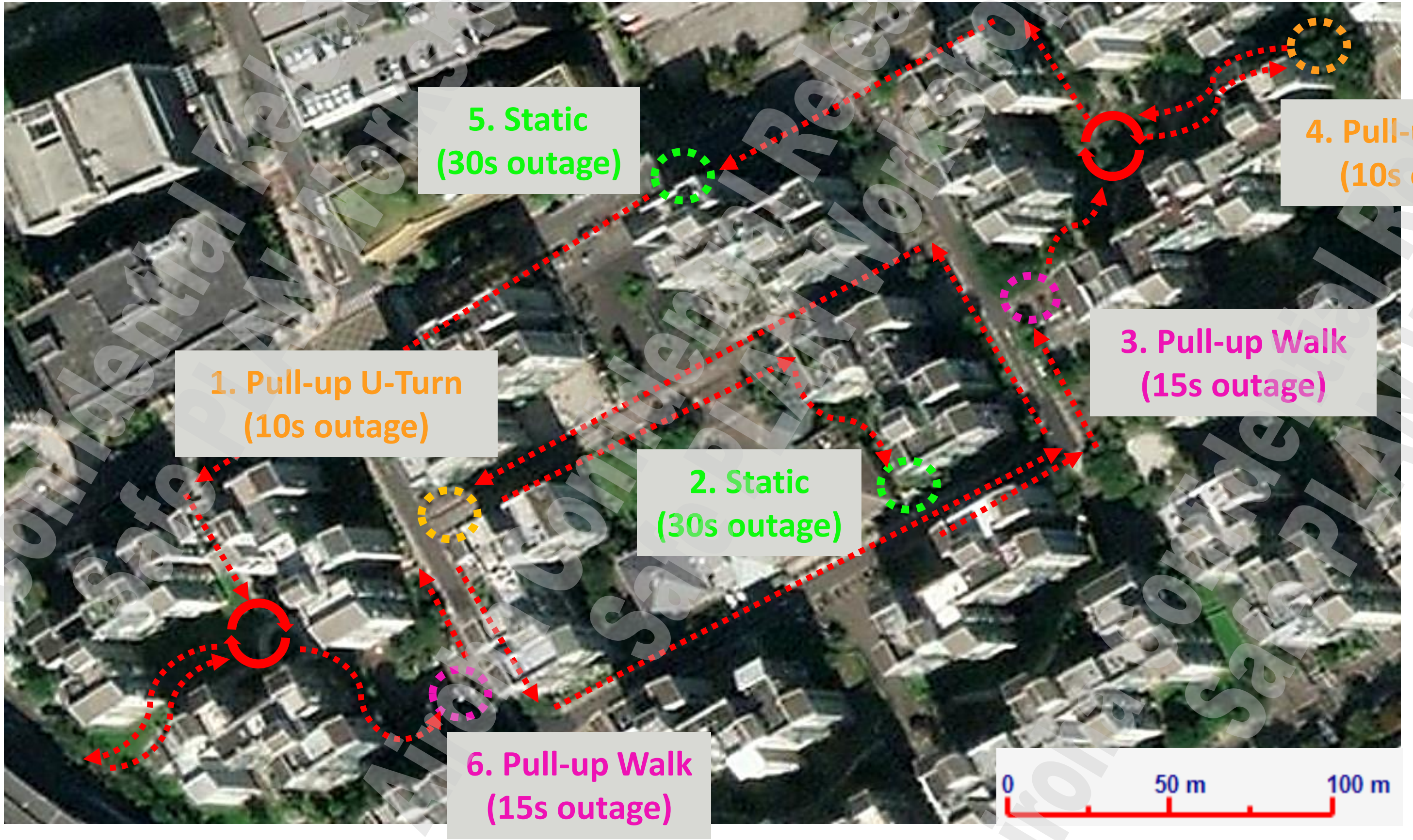
Experiment Setting

- **Configuration for AG3335AD**
  - **IMU: ICM-42607-T**
  - **Dual frequency GNSS with multi-constellation**

	Gyroscope		Acceleration	
Sensor Serial Number	ZRO Variation vs. Temperature (± º/s/ºC)	RMS Noise º/s /√Hz	Zero-G Level Change vs. Temperature (± mg/ºC)	RMS Noise (µg/√Hz, 4g)
ICM-42607-T	0.015	0.007	0.15	100

Airoha AG3335AD	L1+L5
Process	12nm
Constellation	L1 G3B L5 : G2B+ NavIC
Power(mW) (L1 GPS / L1 G3B)	4.8/18(L1+L5)
Accuracy	1m
TTFF(-130dBm) W/O Aiding	24s (CTTFF) 1s (HTTFF)
Sensitivity (cold/TRK)	-148dBm / -167dBm
Package Size Ball/Pin	3.8x4.2x0.86 BGA73
Flash (KB)	4096
RAM (KB)	4096(PSRAM)+664(SYSRAM)
CPU(MHz)	530 (Max.)

Experiment Scenarios - 2WDR + ML



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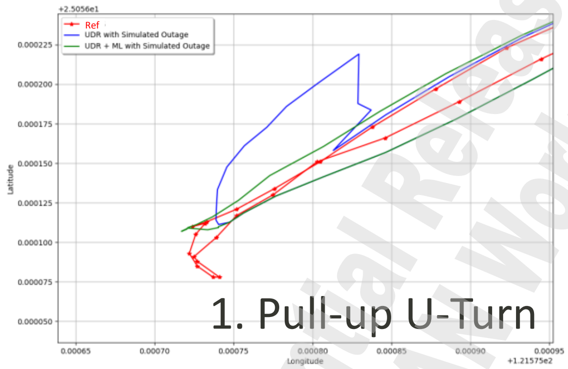
Results: ML Motion Detection

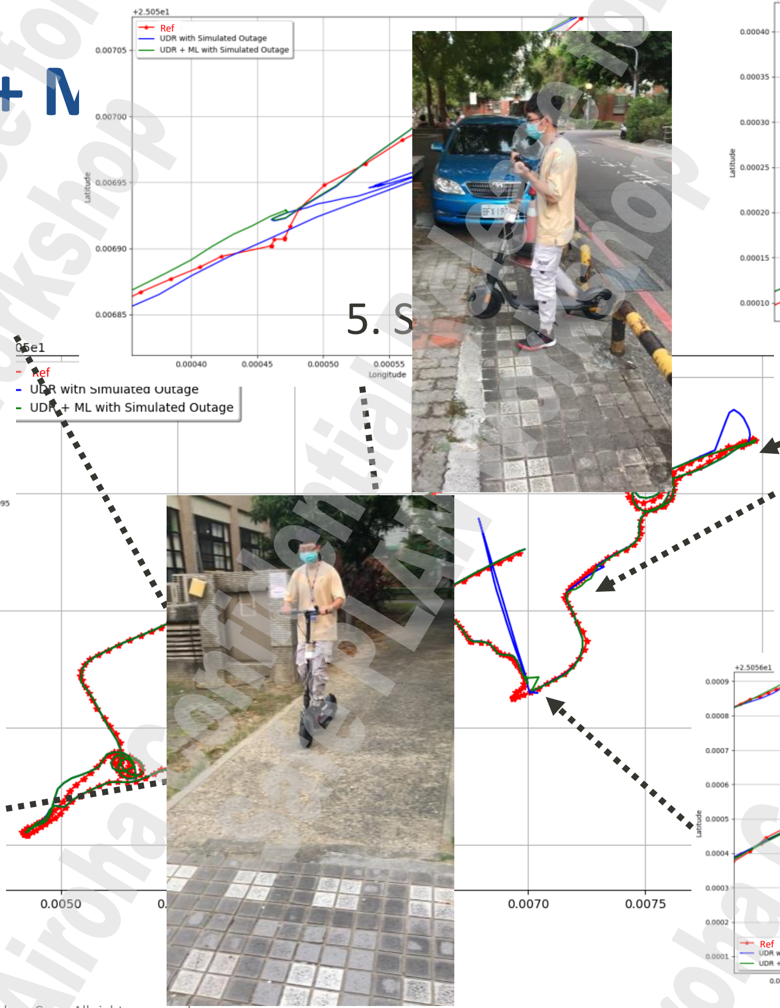
Motion Detection on the Map

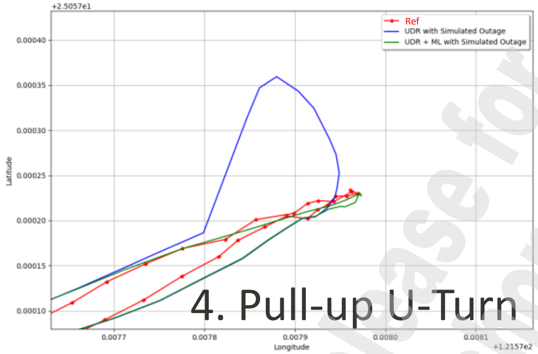
Motion Detection Performance Table

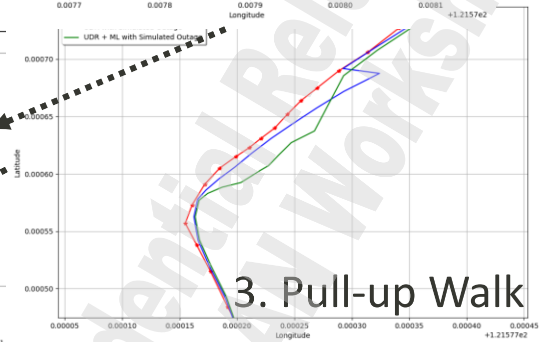
	Precision	Recall	F1-score
0, Riding	0.99	0.99	0.99
1, Static	0.98	1.00	0.99
2, Pull up U-Turn	1.00	0.95	0.98
3, Pull up walk	0.97	0.88	0.92

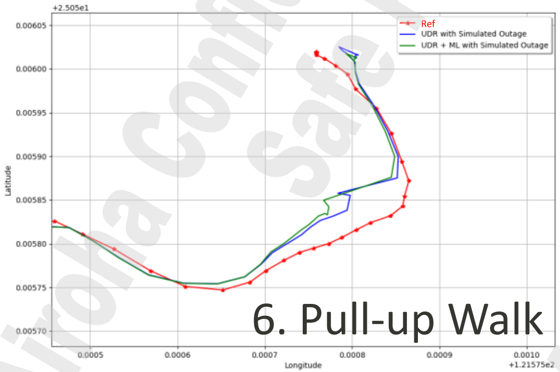
Results 2WUDR + M

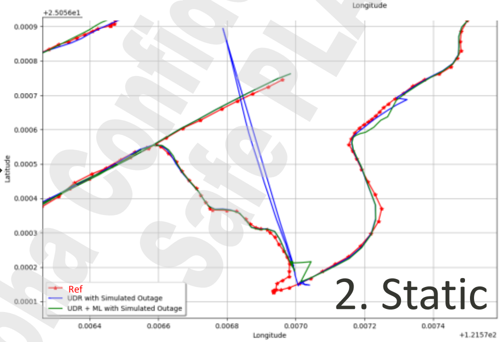












Conclusion

- This research proposed the 2WDR with ML's assistant to enhance the performance of pure 2WDR.
- The designed data preparation process successfully prevents the over estimation and data unbalance issues.
- The designed nonlinear motion compensation and DR algorithm cooperate with ML's detection to make whole trajectory more stable and more accurate.
- Airoha AG3335 series GNSS chipset is able to perform UDR/ADR for 2W/4W platforms with ML.
- Future work
  - Airoha AG3335 series GNSS chipset is going to support Fitness/Wearable DR application with ML.
  - The ongoing Fitness/Wearable DR application will enhance the trajectory as well as achieve the power saving for different scenarios.

Reference

- [1] Shin, E. H. (2005). Estimation techniques for low-cost inertial navigation. UCGE report, 20219.
- [2] Chang, H. W. (2014). Enhanced Portable Navigation for Cycling Applications.
- [3] Asperti, M., Vignati, M., & Braghin, F. (2021). Modelling of the Vertical Dynamics of an Electric Kick Scooter. IEEE Transactions on Intelligent Transportation Systems.
- [4] Ushijima, H., Helinyi, P., Aoki, S., Nishiyama, Y., & Sezaki, K. (2021, September). An Unsupervised Learning-based Approach for User Mobility Analysis of E-Scooter Sharing Systems. In 2021 IEEE International Intelligent Transportation Systems Conference (ITSC) (pp. 1425-1430). IEEE.
- [5] Lu, D. N., Nguyen, D. N., Nguyen, T. H., & Nguyen, H. N. (2018). Vehicle mode and driving activity detection based on analyzing sensor data of smartphones. Sensors, 18(4), 1036.

Thank you

Questions and Discussions

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